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The Mammals

Eight federally threatened or endangered mammals occur in South Florida. Most of these mammals occur only in South Florida and are concentrated in areas like the Florida Keys (which supports five of the eight threatened or endangered mammals). Other species, like the West Indian manatee, occur in South Florida but also occur elsewhere in the southeastern U.S. The final mammal species category includes the Florida panther, which was once widely distributed throughout the southeastern U.S. but finds its last refuge in South Florida.

This section of the Multi-Species Recovery Plan contains accounts of the threatened and endangered mammal species of South Florida. These accounts detail the biology, ecology, status and trends, and management for each of these mammals. Each account is followed by the recovery needs of the species which consist of the recovery objective, criteria that will be used to determine when the objective has been achieved (called recovery criteria), and the tasks that will be necessary to achieve the objective (called recovery actions). The recovery tasks are divided into species-level recovery actions that address species-specific conservation and biology, and habitat-level recovery actions that address habitat management, conservation, and restoration needs for the species. The habitat-level recovery actions form the basis for the multi-species/community-level restoration actions that are provided in the community accounts. For species that have distributions outside of South Florida, there are two sections to the recovery objective: the first is the recovery objective for the species throughout its range; the second section identifies how South Florida will contribute to the species' recovery throughout its range.

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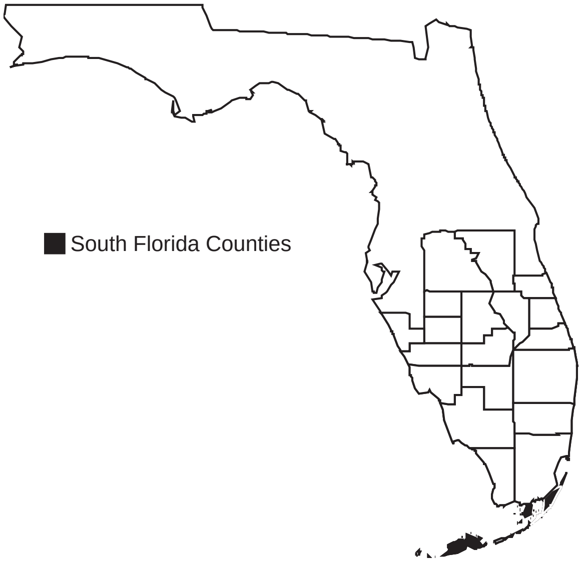
Key Deer

Odocoileus virginianus clavium

Federal Status:	**Endangered (March 11, 1967)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. Distribution of the Key deer; this species is endemic only to the Florida Keys.



By the late 1940s, over-hunting and killing by Keys residents and visitors had nearly driven the Key deer to extinction. By the early 1950s only 25 deer remained. Efforts to enforce hunting bans and to protect the deer from human disturbance allowed the Key deer population to increase slowly. The Key deer remains federally listed due to the continued loss of its habitat and because of high, human-related mortalities and disturbances.

This account represents a revision of the existing recovery plan for the Key deer (FWS 1985).

Description

The Key deer is the smallest subspecies of the North American white-tailed deer. Adult males average 36 kg and adult females 28 kg. Fawns weigh about 1.5 kg at birth. Height at the shoulder averages 69 cm for adult bucks and 65 cm for adult does (Hardin *et al.* 1984).

The body appears stockier than that of other deer (Klimstra *et al.* 1978a); the legs are shorter, and the skull is shorter and relatively wider (Klimstra *et al.* 1991). Pelage varies from deep reddish-brown to grizzled gray, and a distinct black cross or mask is often present between the eyes and across the brow (Klimstra 1992). Antler size and number of points for male Key deer are less than those of other white-tail deer (Folk and Klimstra 1991a). Bucks typically grow spikes until their second year, when forked antlers are produced; they attain eight points usually by the fourth year.

In addition to their size, a number of other characteristics distinguish Key deer from other white-tailed deer; these include high saltwater tolerance (Jacobson 1974), low birth rates, low productivity (Folk and Klimstra 1991b), more solitary habits, and weak family bonds (Hardin 1974). According to Ellsworth *et al.* (1994), the Key deer population is the most genetically divergent deer population in the southeastern United States.

Taxonomy

The Key deer is a member of the Cervidae family of the order Artiodactyla, class Mammalia. It was first recognized as a subspecies distinct from the races of *O. v. osceola* and *O. v. virginianus* when it was described by Barbour and Allen (1922).

Distribution

The Key deer's historical range probably extended from Key Vaca to Key West (Klimstra *et al.* 1978a). The current range includes approximately 26 islands (330 km^2) from Big Pine Key to Sugarloaf Key (Folk 1991) (Figure 1). The National Key Deer Refuge and Great White Heron NWR encompass much of this territory and are managed for the Key deer and other imperiled species. Big Pine Key, the largest of the Lower Keys (2,500 ha), is the center of the Key deer's range and supports about two-thirds of the entire population (Klimstra *et al.* 1974).

The principal factor influencing the distribution and movement of Key deer in the Keys is the location and availability of fresh, surface water. Key deer swim easily between keys and use all islands during the wet season (May to October), but during the dry season (November to April), suitable water is available on only 13 islands (Folk 1991). Big Pine Key and No Name Key provide the most fresh water and support the majority of the Key deer population.

Habitat

Key deer utilize all habitat types within their range, including pine flatwoods, pine rocklands, hardwood hammocks, buttonwood wetlands, mangrove wetlands, and freshwater wetlands. They may use these habitats year-round or seasonally for foraging, cover, shelter, fawning, and bedding. Pine rocklands, in particular, are very important to Key deer because they contain permanent freshwater sources that are critical to the long-term survival of the species. Only five of the 26 islands, Big Pine, Little Pine, Sugarloaf, Cudjoe, and No Name keys, support extensive pine rocklands. Key deer forage on mangroves in tidal wetlands and use open areas for foraging and resting. Key deer also use residential and commercial areas extensively where they feed on ornamental plants and grasses and where they can seek refuge from biting insects.

Behavior

Key deer have well-defined patterns of activity and habitat use (Klimstra *et al.* 1974). Established trails, worn deep into the marl soil from years of daily use, are clearly visible in many of the Key deer's movement corridors. Bedding and feeding areas are used regularly by individuals, and hot spot road crossings are

Key deer.
Original photograph courtesy of U.S. Fish and Wildlife Service.

clearly apparent from roadkill data (Klimstra 1992).

The social structure of the Key deer varies throughout the year with the reproductive cycle. Their behavior is more solitary than northern white-tail deer (Klimstra *et al.* 1978a), although feeding by people has resulted in aggregations on the human-inhabited islands (Folk and Klimstra 1991a). Bucks associate with females only during the breeding season and will tolerate other males when feeding and bedding only during the nonbreeding season. Does may form loose matriarchal groups consisting of an adult female with several generations of her female offspring, but these associations are not stable (Hardin *et al.* 1976).

Home ranges vary seasonally and with age and also may be affected by the degree of urbanization. Average monthly home range size for adult males is about 120 ha and for adult females is about 52 ha, while yearly ranges are larger with an average of 320 ha for males and 175 ha for females. Males tend to disperse from their natal range as fawns or yearlings. Adult males range over much larger areas during the breeding season (Silvy 1975) and may shift to an entirely new area (Drummond 1989). Territorial behavior is limited to a buck's defense of a receptive doe from other bucks and is not used to defend a specific territory size or area (Klimstra *et al.* 1974). Aggressive male behaviors, such as fighting between rutting males, may be more serious in Key deer populations than in other white-tailed deer populations.

The sociobiology of many Key deer on Big Pine Key appears to have changed in recent years as a result of increasing contact and influence by humans (Folk and Klimstra 1991a). Increase in group size, reduction in movements, and change in behavior from the early 1970s (Hardin 1974) to the early 1990s (Folk and Klimstra 1991a) in several subdivisions on Big Pine Key indicate increasing domestication of the deer and urbanization of its habitat.

Reproduction

On average, Key deer produce fewer young than any other free ranging white-tailed deer population in North America (Folk and Klimstra 1991b). This may be a result of a nutrient deficiency (possibly phosphorus) or an adaptation to a restricted, insular environment. Either way, fecundity (number of fetuses/female) and rate of reproductive activity (percent of females reproducing) are low, and fetal sex ratio (males to females) and mean age of first breeding are high, resulting in reproductive potential that is lower than any other North American deer population (Folk and Klimstra 1991b). The sex ratio is skewed towards male offspring; with a 1.75:1 fetal ratio and 2:1 fawn ratio. The tendency for male offspring may be caused by inbreeding, high population densities, or a decrease in nutrition (Seal and Lacy 1990).

The breeding season for Key deer begins in September, peaks in October, and declines through December and January (Hardin 1974). Younger animals apparently breed later in the season, if at all (Klimstra *et al.* 1978b). Male fawns do not breed and female fawns rarely do so. Most yearling males do not breed; however, many females will breed as yearlings. Even adults may fail to breed, especially young bucks that are excluded from breeding by older, more aggressive males (Klimstra 1992).

Parturition occurs about 204 days after breeding and peaks in April and May, although spotted fawns have been observed in every month of the year (Hardin 1974). The coincidence of fawning with the rainy season ensures an ample food supply for lactating females. Open hammocks and pinelands are preferred fawning habitats (Silvy 1975). Twinning is infrequent, and triplets have been documented once.

Foraging

The Key deer's diet varies seasonally with availability of specific plants and changes in nutritional requirements (Carlson *et al.* 1989, Klimstra and Dooley 1990). Seasonal availability of special foods [e.g., black mangrove (*Avicennia germinans),* palm (*Thrinax morrisii*, *Coccothrinax argentata)*, and dilly fruits (*Manilkara bahamensis*)] influences Key deer movements. Key deer forage on more than 160 other species to meet nutritional requirements (Klimstra and Dooley 1990), especially red mangroves (*Rhizophora mangle*), blackbead (*Pithecellobium keyense*), grasses, acacia (*Acacia pinetorum*), Indian mulberry (*Morinda royoc*), and pencil flower (*Stylosanthes hamata*). Red and black mangroves constitute 24 percent by volume of the diet of the Key deer (Klimstra and Dooley 1990).

Many of the important food plants occur in pine rocklands and are stimulated by fire, which arrests succession, reduces the canopy, promotes understory growth, decreases invasion by woody species, increases plant palatability, and reduces ground litter (Carlson *et al*. 1989). Gross energy values of most Key deer foods are comparable to commercial feeds (Morthland 1972), but may be high in calcium and sodium and low in phosphorus

(Widowski 1977). Although Key deer have been observed drinking water half as saline as seawater (15 ppt), Key deer may not be able to survive for long periods without fresh (<5 ppt) water (Folk *et al.* 1991).

Relationship to Other Species

The complex relationships that occur between the endemic species of the Lower Florida Keys and their habitats depend upon the integrity of the entire ecosystem. If a link in that relationship is removed, the whole system is disrupted. The Key deer uses a variety of habitats in the Lower Keys for foraging, resting, and reproduction. The deer's dependence on these habitats is also shared by several other endangered species such as the Key tree-cactus (*Pilosocereus robinii*), Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*) and silver rice rat (*Oryzomys argentatus*).

Key deer frequently use cactus hammock (the sole location for the Key tree-cactus) for foraging and resting, and as a travel corridor. Foraging behaviors of the Key deer may play an important role in windthrow or dispersal of the Key tree-cactus in this area (Hennessey and Habeck 1994). Deer, marsh rabbits, and silver rice rats use similar vegetation in salt marshes (*e.g.*, *Sporobolus virginicus*), transitional areas (*e.g.*, *Conocarpus erectus*), and freshwater marshes (*e.g.*, *Cladium jamaicense*). Deer and silver rice rats both rely on mangrove swamps. Coastal berm areas on Long Beach and Sugarloaf Beach on Big Pine Key are used by marsh rabbits, as well as by Key deer who use these same areas for bedding and birthing (Folk *et al.* 1990). Sugarloaf Beach is also used by nesting Atlantic loggerhead (*Caretta caretta*) and green sea turtles (*Chelonia mydas mydas*).

Status and Trends

Prior to Anglo settlement in the Keys in the early 18th century, the Key deer probably was exposed to very few natural competitors or predators. The population dynamics of the Key deer had evolved to withstand natural phenomena such as drought, hurricanes, fire, *etc*. Behavioral responses (*e.g*. migration) and physiological adaptations (*e.g*. low reproductive output) were a result of conditions as they existed before human influence (Hardin 1974, Klimstra *et al.* 1974, Silvy 1975).

Since the widespread settlement of humans in the Keys, Key deer have been exposed to influences they had not evolved to overcome, which almost led to their extinction between 1940-1950 and is the cause of their endangerment today. A Federal refuge was established in the 1950s, and the Key deer was officially listed as federally endangered on March 11, 1967 (32 FR 4001). The Key deer was listed as an endangered species because of the loss of its habitat to residential and commercial construction and because of high, human-related mortality and human disturbances.

Historically, the maximum population of Key deer was probably between 600 to 700 individuals occupying about 7,695 ha of habitat in the historical range (Seal *et al.* 1990). A 1998 survey indicates the Key deer population is between 579 to 678 individuals which is a 250 percent increase on Big Pine Key and a 379 percent increase on No Name Key from 1970 levels (Lopez and Silvy 1999). Due to continued urbanization of Key deer habitat, there is little opportunity to increase the carrying capacity of the Keys, although habitat enhancement on outlying islands may afford some opportunities.

In addition to habitat loss, the persistence of the Key deer is highly vulnerable to natural events such as hurricanes and sea-level rise. A population viability assessment (PVA) completed in 1990, when population estimates were 250 to 300 individuals, assessed the risk of extinction, predicted the impacts of management options, and set targets for recovery (Seal *et al*. 1990). The PVA predicted that a Key deer population of 250 animals, under existing conditions, had a 74 percent probability of going extinct within 67 years. Road mortality continues to increase, as does habitat fragmentation and loss. As long as such threats exist, the status of the Key deer will continue to be in question.

Threats

Key deer were threatened by over-hunting until it was prohibited in the early 1950s. Since that time, other human-caused threats are placing pressures on the abundance and distribution of the Key deer, including habitat loss, vehicular traffic, habitat degradation, and illegal feeding. In recent years, the most intensive threat to the continued existence of the Key deer is the loss or alteration of habitat. Residential and commercial construction activities have destroyed essential components of Key deer habitat including vegetation and freshwater resources. Fencing has resulted in a loss of habitat and interference with migration routes. In addition, other human-induced actions adversely affect the Key deer. Vehicular traffic is responsible for the most mortalities. Illegal feeding of Key deer may result in an alteration of habitat use patterns, spread of parasites and disease at feeding sites, and aggregations of deer in residential areas. Key deer are also negatively affected by illegal dumping, contaminants, open pit mining, and feral and domestic dogs. All of these threats are altering the Key deer's distribution, damaging essential habitat, and disturbing behavioral activities, such as foraging, and reproduction.

Loss of habitat, particularly on Big Pine Key, is the major threat to the future of the Key deer (Klimstra *et al.* 1974). Nearly half of the islands in the range of the deer are currently inhabited by people, and eight have large subdivisions and commercial areas (Folk 1991). In 1990, the human population of Big Pine Key was estimated at 4,208 permanent residents, a 77 percent increase since 1980; an additional 2,154 seasonal residents spend winters on Big Pine Key (Monroe County Growth Management Division 1992).

Habitat degradation and fragmentation has reduced the Key deer's distribution and affected behavior. Habitat fragmentation from fencing and development restricts deer movements, creating bottlenecks that interfere with their ability to reach permanent water and feeding areas and often forcing them to cross roads in areas of heavy traffic. Exotic plant species such as Australian pine (*Casuarina* spp.), Brazilian pepper (*Schinus terebinthifolia*), and leatherleaf fern (*Colubrina asiatica*) are invading disturbed areas and outcompeting native vegetation, reducing Key deer foods and habitat. Fire suppression is responsible for deterioration of important pine rockland communities in the Keys (Klimstra 1986, Carlson *et al.* 1989), and the ability of land managers to use prescribed fire is hampered by increasing urbanization. The availability of fresh water is affected by filling, ditching, draining, pollution (septic tanks), illegal dumping, and pumpage from private wells (Folk 1991).

Human-related mortality, primarily roadkills, is the greatest known source of deer deaths. In 1998, road mortality accounted for 67 percent of all known deaths (Wilmers 1998). The total number of roadkills was 90 that year, the highest in the history of the refuge. Since 1985, more than 90 percent of all deer roadkills have occurred on Big Pine Key, mainly on U.S. Highway 1 and Key Deer Boulevard. Other sources of mortality include poaching, drowning in ditches and canals, running by dogs, entanglement in fences, sparring between bucks, and foreign debris in the digestive tract from feeding in trash containers (Klimstra 1992).

Illegal feeding has been reported to cause the deer to become more sedentary and to lose natural alarm and flight responses (Folk and Klimstra 1991c). This may lead to nutritional imbalances, increased chance of disease and parasite transmission, dependence on humans, density-related problems, and loss of genetic interchange (inbreeding). Increased harassment of deer by people, automobiles, and dogs may also stress the deer, and may result in higher mortality and lower reproduction.

The Key deer is more susceptible to a loss of genetic diversity because of its island environment and the population bottlenecks it has already experienced (Seal and Lacy 1990). Possible adverse genetic consequences include loss of heterozygosity, adaptability and reproductive potential resulting from genetic drift and inbreeding depression (Seal and Lacy 1990). The small population is also at greater risk from the effects of a natural catastrophe (*e.g.*, hurricane) or disease outbreak.

Management

The National Key Deer Refuge was established in 1957 for the purpose of protecting and maintaining the remaining 1,643 ha of habitat for the Key Deer and actively managing the Key deer population. To date, the FWS has acquired over 3,238 ha to be managed as part of the National Key Deer Refuge and Great White Heron NWR. Acquisition of these lands is the most significant recovery action to protect the Key deer.

Management and restoration of habitat is a major conservation effort that involves prescribed burning, mowing of clearings and fire breaks, filling of ditches to prevent fawn drownings and limit influx of saline water, removing exotic vegetation and planting native vegetation, and development and protection of habitat corridors. The FWS also coordinates with the SFWMD to improve water resources by removing cesspools and installing septic tanks, allowing no net increase of pollution. To alleviate road mortality, the FWS is cooperating with DOT and Monroe County to establish and enforce speed zones and maintain warning signs for deer crossings. FWS law enforcement is working to minimize human interactions with Key deer, especially feeding.by the public. Other management activities include guzzler (water tank) maintenance, relocation of nuisance and rehabilitated animals, and coordination of volunteer activities including exotic plant removal, law enforcement, and public education.

Other areas protected within the range of the deer include a 81 ha tract on Big Pine Key managed by SFWMD's Save Our Rivers Program, a 8.1 ha Nature Conservancy tract on Big Pine Key, and an 75 ha Nature Conservancy preserve on Little Torch Key. Several hundred acres of land have been acquired on Big Pine Key for the DEP's Conservation and Recreational Lands Key Deer-Coupon Bight project. The Monroe County Land Authority has also purchased land in the No Name/BigPine/Torch Keys area.

Efforts to inform the public about Key deer are continuing on the refuge. The Key Deer Protection Alliance, a local citizens' group formed in 1988, is also working to increase awareness and public education by providing accurate information, sponsoring direct action projects, and supporting preservation of Key deer habitat.

Literature Cited

Barbour, T. and G.M. Allen. 1922. The white-tailed deer of the eastern United States. Journal of Mammalogy 3(2):65-78.

Carlson, P.C., J.M. Wood, G.W. Tanner, and S.R. Humphrey. 1989. Vegetation management for the Key deer. Final Report. Cooperative Fish and Wildlife Research Unit, University of Florida; Gainesville, Florida.

Drummond, F. 1989. Factors influencing road mortality of Key deer. M.S. Thesis. Southern Illinois University; Carbondale, Illinois.

Ellsworth, D.L., R.L. Honeycutt, N.J. Silvy, M.H. Smith, J.W. Bickham, W.D. Klimstra. 1994. White-tailed deer restoration to the southeastern United States: evaluating genetic variation. Journal of Wildlife Management 58(4):686-697.

Folk, M.J. and W.D. Klimstra. 1991a. Antlers of white-tailed deer (*Odocoileus virginianus*) from insular and mainland Florida. Florida Field Naturalist 19:97-105.

Folk, M.J. and W.D. Klimstra. 1991b. Reproductive performance of female Key deer. Journal of Wildlife Management 55:386-390.

Folk, M.J. and W.D. Klimstra. 1991c. Urbanization and domestication of the Key deer *(Odocoileus virginianus clavium*). Florida Field Naturalist 19:1-9.

Folk, M.L. 1991. Habitat of the Key deer. Ph.D. Dissertation. Southern Illinois University; Carbondale, Illinois.

Folk, M.L., W.D. Klimstra, and C.R. Kruer. 1991. Habitat evaluation: National Key deer range. Final report, under review. Florida Game and Fresh Water Fish Commission Nongame Wildlife Program; Tallahassee, Florida.

Hardin, J.W. 1974. Behavior, socio-biology, and reproductive life history of the Florida Key deer, *Odocoileus virginianus clavium*. Ph.D. Dissertation. Southern Illinois University; Carbondale, Illinois.

Hardin, J.W., W.D. Klimstra, and N.J. Silvy. 1984. Florida Keys. Pages 381-390 *in* L.K. Halls, ed. White-tailed deer: ecology and management. Stackpole Books; Harrisburg, Pennsylvania.

Hardin, J.W., N.J. Silvy, and W.D. Klimstra. 1976. Group size and composition of the Florida Key deer. Journal of Wildlife Management 40:454-463.

Jacobson, B.N. 1974. Effects of drinking water on habitat utilization by Key deer. M.S. research paper. Southern Illinois University; Carbondale, Illinois.

Klimstra, W.D. 1986. Controlled burning in habitat management: some observations, National Key Deer Refuge. Final Report; Big Pine Key, Florida.

Klimstra, W.D. 1992. Key deer. Pages 201-215 *in* S.R. Humphrey, ed. Rare and endangered biota of Florida, volume 1: mammals. University Press of Florida; Gainesville, Florida.

Klimstra, W.D. and A. Dooley. 1990. Foods of the Key deer. Florida Scientist 53:264-273.

Klimstra, W.D., M.J. Folk, and R.W. Ellis. 1991. Skull size of two insular and one mainland subspecies of *Odocoileus virginianus* from the southeast. Transactions Illinois State Academy of Science 84:185-191.

Klimstra, W.D., J.W. Hardin, and N.J. Silvy. 1978a. Endangered Key deer. Pages 15-17 *in* J.N. Layne, ed. Rare and endangered biota of Florida, volume 1: mammals. University Presses of Florida; Gainesville, Florida.

Klimstra, W.D., J.W. Hardin, and N.J. Silvy. 1978b. Population ecology of Key deer. Pages 313-321 *in* P.H. Oehser and J.S. Lea, eds. research reports, 1969. National Geographic Society; Washington, D.C.

Klimstra, W.D., J.W. Hardin, N.J. Silvy, B.N. Jacobson, and V.A. Terpening. 1974. Key deer investigations final report: December 1967-June 1973. U.S. Fish and Wildlife Service; Big Pine Key, Florida.

Klimstra, W.D., N.J. Silvy, and J.W. Hardin. 1982. The Key deer: its status and prospects for the future. Proceedings of the Nongame and Endangered Wildlife Symposium, Georgia Department of Natural Resources Technical Bulletin WL5:137-141.

Lopez, R.R. and N.J. Silvy. 1999. Preliminary report: Population estimates of Florida key deer. Report to the U.S. Fish and Wildlife Service, Florida Keys National Wildlife Refuges, Big Pine Key, Florida.

Monroe County Growth Management Division. 1992. Monroe County year 2010 comprehensive plan. Technical document. Monroe County Planning Department; Key West, Florida.

Morthland, D.E. 1972. Energy values of selected vegetation from Big Pine Key, Florida. M.S. Research Paper. Southern Illinois University; Carbondale, Illinois.

Seal, U.S., R.C. Lacy, and workshop participants. 1990. Florida Key deer population viability assessment. Captive Breeding Specialist Group; Apple Valley, Minnesota.

Silvy, N.J. 1975. Population density, movements, and habitat utilization of Key deer, *Odocoileus virginianus clavium*. Ph.D. Dissertation. Southern Illinois University; Carbondale, Illinois.

U.S. Fish and Wildlife Service [FWS]. 1985. Key deer recovery plan. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Widowski, S. 1977. Calcium and phosphorus in selected vegetation from Big Pine Key, Florida. M.S. research paper. Southern Illinois University; Carbondale, Illinois.

Wilmers, T. 1998. Key deer mortality summary. 1998 annual narrative report. On file at U.S. Fish and Wildlife Service National Key Deer Refuge

Recovery for the Key Deer

Odocoileus virginianus clavium

Recovery Objective: RECLASSIFY to threatened.

Recovery Criteria

The Key deer has a narrow geographic range and low reproductive performance causing it to be susceptible to extinction. Recent information indicates the Key deer has experienced local extirpations and a contraction in range due to the loss, fragmentation, and degradation of its habitat and other anthropogenic factors. Consequently, the objective of this recovery plan is to reclassify the Key deer from *endangered* to *threatened* by protecting, managing, and restoring its habitat in the Lower Keys; increasing the size of its population; and increasing its range. This objective will be achieved when: further loss, fragmentation, or degradation of suitable, occupied habitat in the Lower Keys has been prevented; when native and non-native nuisance species have been reduced by 80 percent; when all suitable, occupied habitat on priority acquisition lists for the Lower Keys is protected either through land acquisition or cooperative agreements; when Key deer habitat is managed, restored, or rehabilitated on protected lands; when stable populations of the Key deer are distributed throughout its historic range; and two, additional, stable populations have been established along the periphery of the historic range of the Key deer. These populations will be considered demographically stable when they exhibit a stable age structure and have a rate of increase (r) equal to or greater than 0.0 as a 7-year running average for 14 years.

Species-level Recovery Actions

S1. **Determine the distribution and status of the Key deer and its habitat.** Survey all appropriate Key deer habitat. Focus surveys on determining the status of the Key deer and the status of its habitat.

S1.1. **Develop a Master Census Plan to determine the status of the Key deer and its habitat.** Revisit the Silvy (1975) study and gather information on sex ratios, population numbers, age structure, group size, interaction of deer, home range size, and minimum area. Include behavioral aspects and how they affect the Key deer's range. Develop the census to address the above issues and be feasible to repeat for future monitoring. Develop the census to include mark/recapture methods and telemetry work.

S1.2. **Survey for the presence/absence of Key deer in suitable habitat.** Identify any additional potential habitat patches and survey for suitability of vegetation and presence/absence of Key deer. Using past studies as a baseline, determine current habitat condition and characterize how deer are using it. Determine why deer are present in some suitable habitat areas, but are absent in other areas (*i.e.*, suitable habitat exists on Sugarloaf, but deer are not permanently established there anymore).

S1.3. Maintain and improve the GIS database for Key deer information. Compile and maintain Key deer distribution information through the FWS Geographic Information System (GIS) database. Produce GIS maps to overlay the status of the Key deer and its habitat. Overlay presence/absence data with habitat status to help develop a reserve design plan for the Key deer.

S2. Protect and enhance existing populations. Human-induced or human-related mortality must be minimized if the deer is to survive.

S2.1. Staff the National Key Deer Refuge with a new biologist. The FWS biologist will coordinate Key deer recovery and implement recovery actions for the Key deer, including reintroductions, surveying and monitoring, protection efforts, research, and habitat management. The biologist will coordinate with Key deer experts on the progress and evaluation of the deer's recovery program and develop an annual progress report on the Key deer recovery program.

S2.2. Conduct Key deer reintroductions from natural wild populations. The sociobiology (*e.g.*, group size, movements, behavior) of the Key deer has changed in recent years due to increasing contact and influence by humans (Folk and Klimstra 1991a). As a result, there has been a contraction in the distribution and range of the Key deer, resulting in an unusually high concentration of deer on Big Pine Key. In order to support a sustainable population of Key deer, the distribution and range must be maintained. Release Key deer into suitable habitat with low or no Key deer presence in order to maintain the Key deer's range and distribution.

S2.2.1. Develop a standard protocol for conducting, monitoring, and evaluating all reintroduction, translocation, and supplementation efforts of Key deer using the IUCN Species Survival Commission's Guidelines for Reintroductions. Develop criteria that determine the type of release to be conducted, evaluate and select release site, identify source and health of release stock, develop and monitor short and long-term success indicators, and develop a policy on intervention. Develop a soft release site to acclimate deer prior to release. Ensure release sites are free of threats prior to any release of Key deer.

S2.2.2. Reintroduce Key deer to suitable public lands. Several areas within National Key Deer Refuge property are appropriate for reintroduction, translocation, or supplementation of Key deer, including Upper and Lower Sugarloaf and Cudjoe keys. Radio collar and monitor all released deer.

S2.2.3. Educate the public on the need for and process of Key deer reintroductions. Public awareness and support is important for reintroductions to be successful.

S2.2.4. Enforce protection of reintroduced or released Key deer. Enforce Federal laws (*i.e.*, speed zones, no feeding, *etc.*) as they relate to released deer. Full Federal protection is necessary to ensure the survival of released deer.

S2.3. Conduct consultations on Federal activities. Determine jeopardy thresholds for the Key deer. Estimate and evaluate the type of Federal activities over the next 20 years that are likely to cause jeopardy and determine threshold levels for the total population. Coordinate with law enforcement to prevent take under section 9. Identify what activities could result in take of Key deer, such as habitat loss, dog predation, and vehicular traffic.

S2.4. Provide information about Key deer to Federal, State, county, and city agencies. Distribute information regarding the presence of Key deer, its protection under the ESA, and ways to minimize impacts. Non-Federal agencies that may influence the Key deer include DEP, DCA, GFC, DACS, Monroe County Mosquito Control, Florida Keys Aqueduct Authority, and Monroe County Government.

S2.5. Reduce mortality of Key deer. Address illegal activities that impact deer. Enforcement of state and federal regulations protecting the Key deer is, and has been, critical to the preservation of the subspecies. Man-induced mortality must be minimized.

S2.5.1. Control poaching. The Key deer population will never be large enough to support hunting. Eliminate poaching.

S2.5.2. Prohibit animal trespass. Dog-related deaths of Key deer are the second most frequent cause of man-induced mortality. Enforce refuge regulations prohibiting illegal animal trespass. The problem with dogs is of growing concern in light of developmental pressures. Coordinate with Monroe County to implement and enforce leash law. Coordinate with the Big Pine Key Animal Shelter in identification of offenders and in periodic round-ups of free-roaming dogs.

S2.5.3. Minimize vehicle collisions with Key deer. Coordinate with Monroe County to identify and prioritize road concerns. Develop management methods to reduce vehicle collisions with deer.

S2.5.3.1. Reduce speed limit on primary and secondary roads. Continued efforts by refuge staff have kept the speed limit of Key Deer Boulevard to 50 kmph (30 mph). Enforce speed limits in posted areas. Identify other areas in need of speed regulations and reduce speed limits.

S2.5.3.2. Continue and increase enforcement of speed zones. Enforcement of speed zones has been effective in reducing deer mortality and increasing deer awareness. Continue, and if necessary, increase enforcement of speed zones.

S2.5.3.3. Identify deer crossings. Determine areas where deer commonly cross US Highway 1 and secondary paved roads. Continue to post in these areas signs, reflectors, flashing lights, etc., in order to warn motorists. Monitor the frequency with which deer utilize the crossings.

S2.5.3.4. Investigate the use of fencing to reduce collisions. Evaluate the potential hazards of fencing, including dogs cornering deer at fences, deer becoming entangled in fences, and deer being channeled to new, hazardous crossing sites. The negative results of fencing might outweigh the benefits. If beneficial, install fencing along selected roadways to protect crossing areas and/or to redirect deer movements.

S2.5.3.5. **Identify roads that could be constructed or upgraded.** Identify areas where roads can be constructed. Continue coordination with FDOT and Monroe County to minimize impacts on deer from road building and widening projects.

S2.5.4. **Minimize the impact of accidental drowning in mosquito ditches.** Mosquito ditches pose a threat to fawns, which may drown in them. Approximately 55 km of ditches occur on refuge lands. Several areas of concern have been identified, surveyed, and mapped. Those ditches have been identified as to ease of filling according to access and level of impact on habitat and wildlife. Identify any additional ditches that may pose a threat to deer and manage appropriately**.**

S2.5.4.1. **Fill mosquito ditches in selected areas of the refuge.** The refuge has been filling mosquito ditches to minimize impacts on Key deer. Continue with mosquito ditch management.

S2.5.4.2. **Monitor effects of filling ditches.** Monitor the impact of filling on wildlife, plants, hydrology, etc. Use monitoring reports to upgrade filling procedures and selection of ditches for filling.

S2.6. **Reduce and eliminate disturbance, interference, and harassment of Key deer**.

S2.6.1. **Control public access and use of the refuge.** The refuge is one of the few protected areas for the Key deer and should be maintained as such. Control public access so as to minimize disturbance of habitat and wildlife. Conduct supervised visitation to selected areas of the refuge (*e.g.*, Watson's and Cactus hammocks) when deemed necessary.

S2.6.1.1. **Eliminate incompatible uses on the refuge.** Beekeeping has been eliminated. Eliminate other incompatible uses such as paintballing activities.

S2.6.1.2. **Continue to limit access to daytime use.**

S2.6.1.3. **Continue to prohibit camping and military maneuvers.**

S2.6.1.4. **Continue to limit all vehicles to paved roads except for refuge and emergency operations.** Vehicle trespass has greatly increased with the advent of all-terrain vehicles and non-motorized dirt bikes. These vehicles destroy habitat and disturb wildlife and must be restricted to paved roads and parking areas. Barricades have been erected at most fire trails and access roads on the refuge. Post signs noting areas that are open to foot traffic only. Enforce regulations prohibiting vehicle use.

S2.6.1.5. **Erect fences around developments when deemed necessary.** Investigate the erection of fences in areas where public access by vehicle, or the feeding of deer adjacent to the refuge boundary, continues despite other protection efforts.

S2.6.2. **Prohibit feedings.** Supplemental feeding, particularly with enriched food, alters the behavior, morphology, and population structure of the herd. In addition, supplemental feeding may cause the deer to frequent roadsides and inhabited areas more often, increasing chances of negative deer/human interactions.

S2.6.2.1. **Post signs.** Maintain signs informing the public of the problems of artificial feeding and warning them of legal consequences of their actions. Install signs at additional locations as necessary.

S2.6.2.2. **Distribute educational brochures.** "No feeding" brochures are available at the refuge and are distributed to the public during routine patrols. Provide the public with additional educational materials.

S2.6.2.3. **Increase enforcement of illegal feedings.** Artificial feeding provides a direct threat to maintenance of the uniqueness and integrity of the subspecies. Increase enforcement of illegal feeding by increasing the staff personnel.

S2.7. **Continue rehabilitation program of Key deer.** Develop rehabilitation protocol and criteria. Coordinate with public outreach groups (*e.g.*, parks, zoos) to develop an adoption program of non-releasable deer.

S2.8. **Investigate captive propagation options.** At this time the Recovery Team does not believe captive propagation is necessary for the Key deer, but agrees that guidelines and protocol should be established prior to any authorized captive propagation. The Recovery Team recommends that any captive propagation efforts should be conducted in the Lower Keys in as similar to natural conditions as possible and all propagation efforts should be strictly monitored and continued only as long as established in the Captive Propagation Protocol. Determine a threshold for when you need to captive breed.

S3. **Conduct population ecology research.** A great deal of information has been collected over the years on the Key deer. Collect additional biological information on this species, including number of individuals, age-class structure, habitat use, reproductive viability, food use and availability, and threats.

S3.3.1. **Determine the finite rate of increase for the Key deer population.** The Key deer population experiences natural cycles where the population may exceed or drop below the stabilized population estimate. The fecundity and rate of reproductive activity are low in the Key deer, suggesting poor reproductive output. Investigate what stable rate of increase is necessary for this species to persist.

S3.3.2. **Determine if the total population size is large enough to prevent functional extinction and genetic extinction.** The PVA predicted that an initial Key deer population of 250, under existing conditions, has a 74 percent probability of going extinct in the next 67 years. Investigate the likelihood of this prediction.

S3.3.3. **Determine the effective population size.** The population was recently estimated as 579 to 678 on Big Pine and No name keys. Investigate the stability of the population and determine if it is stable enough to prevent extinction.

S3.3.4. **Determine the number of subpopulations or breeding herds necessary to maintain a stable or increasing population.** Key deer are located throughout their range but Big Pine Key supports about two-thirds of the entire population. Investigate the number of subpopulations, especially on backcountry islands, and determine what number is necessary to support the Key deer.

S3.3.5. **Determine a stable age structure, sex ratio, and group size for the Key deer.** Investigate the stability of reproductive parameters. Monitor genetic variation in extant and future populations with comparisons made to more fecund white tail deer populations to identify inbreeding depression. Also, link the lack of genetic heterozygosity to physiological traits so that etiology of reproductive success is traceable.

S3.3.6. **Characterize social behavior and compare past behaviors with current trends.** Previously, the Key deer was a fairly solitary species, but today there is evidence of aggregating and ganging behaviors. Investigate why deer are aggregating on Big Pine Key and determine how it affects the species' overall persistence and survival.

S3.3.7. **Continue necropsy of all Key deer mortalities.** Investigate deer mortalities, with added emphasis on reproduction and abomasal parasite counts (APC). Continue skeletal collection for aging.

S3.3.8. **Update and compile all existing roadkill data.** Compile and assess trend analyses from roadkills, total mortalities and road census reports. Utilize this information to develop management guidelines.

S4. **Monitor Key deer populations.** Continue to conduct monthly road census. Develop and/or utilize additional census methods for Big Pine/No Name Key complex and selected outer Keys.

S4.1. **Develop methods to monitor demographic parameters.** Monitor sex ratios, age class structure, survivorship, home range size, age of dispersal, and dispersal distance of the deer.

S4.2. **Conduct long-term monitoring of the status of the deer.** Monitor presence/absence and degree of abundance every year until the deer is recovered.

S5. **Increase public awareness and instill stewardship.** Develop educational materials and host public workshops to increase awareness about Key deer and instill a sense of stewardship for the protection of this endangered species. It is essential that the public be made aware of the Key deer and the efforts of the refuge to protect and maintain the population. The maintenance of a wild population within the confines of a highly developed insular environment is greatly dependent on the awareness, concern, and cooperation of the public.

S5.1. **Provide funding to build and operate a visitor center.** Establish a visitor center on/near the refuge as a site for dissemination of information to the public. A centralized visitor center will provide greater education opportunities and reduce the need for visitors to drive around looking for deer. Investigate the opportunity to combine a visitor center with the deer rehabilitation facility.

S5.2. **Continue volunteer program.** Promote through community organizations, media, etc., the need for volunteers and the role they can play in the Key deer management program. These volunteers can assist in a variety of ways, from posting signs and distributing informational leaflets, to monitoring areas and reporting on problem areas. Current volunteer groups, like AmeriCorps and Youth Conservation Corps have lent a great deal of assistance to the recovery of the Key deer. The Key Deer Protection Alliance, a local citizens' group formed in 1988, is working to increase awareness and public education by providing accurate information, sponsoring direct action projects, and supporting preservation of Key deer habitat. Promote volunteer programs by forming a Key deer "Friends" group to participate and implement recovery actions and assist at a Visitor Center.

S5.3. **Prepare informational material for the general public.** Distribute materials at visitor information centers and local chamber of commerces. Provide public with information on the Key deer recovery program. Conduct programs with schools, community and social groups and other special interest organizations. Conduct teacher workshops addressing the Key deer program. Continue press releases through the media highlighting the status of the recovery program.

S5.4. **Provide public officials, planning agencies, and private developers with information on all phases of Key deer management and about potential threats.** Continue to provide technical assistance to the public.

S5.5. **Inform the public through media as to the problems with feeding.**

S5.6. **Inform the public through media as to the problems with animal trespass.** Radio announcements addressing the problem of free-roaming dogs on Federal property have been issued since early 1984. Numerous newspaper articles and television spots have been produced concerning the effects of dogs on the herd. Continue media efforts.

S6. **Establish reclassification criteria.** Develop measurable reclassification criteria based on factors that result in a stable or increasing population including total population size, number of subpopulations, sex ratio, age structure, habitat condition and availability, and level of threats. Evaluate and monitor the Key deer status in relation to reclassification criteria.

S7. **Conduct multispecies recovery actions.** Develop a Lower Keys multispecies recovery program to combine recovery actions for the Key deer with other listed species' recovery actions including efforts to survey, monitor, manage, research, and educate. Coordinate recovery actions with other agencies and concerned parties to ensure the needs of other protected species are considered. Integrate survey and monitoring of the Key deer with the silver rice rat, Lower Keys marsh rabbit, and Stock Island tree snail. Share research information to benefit other affected species.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Habitat loss is the main reason for the Key deer's decline. Habitat protection and management is paramount to the deer's survival. Habitat degradation or loss can decrease the number of deer an area can support, contributing to the overall chance of extinction. Currently, there are approximately 5,272 ha of Key deer habitat that remain vulnerable to residential and commercial construction.

H1.1. Acquire unprotected Key deer habitat. Loss of habitat has been identified as a major limiting factor in the recovery of the Key deer. Increasing and maintaining available habitat is essential to the survival of the Key deer. A major program objective of the National Key Deer Refuge is to expand its existing holdings to ensure that adequate habitat will be available for the future survival of the Key deer. A Land Protection Plan has been prepared by the FWS to accomplish this objective. Movement corridors in the Land Protection Plan will be ground-truthed this year. Develop a reserve design and acquire habitat.

H1.1.1. Continue Federal acquisition efforts. Continue to acquire habitat adjacent to the National Key Deer Refuge and Great White Heron NWR boundaries.

H1.1.2. Support State acquisition efforts. Continue to support the acquisition of state lands by programs such as Florida's CARL program.

H1.1.3. Support and encourage land acquisition by non-governmental agencies. Habitat not listed for Federal, State, or county acquisition may become available for private purchase and management by such organizations as TNC and Florida Keys Land Trust.

H1.1.4. Purchase and/or trade for lands adjacent to larger tracts of the refuge. Securing large blocks of land (40 ha or more) is preferred. Smaller tracts would be of marginal value to Key deer if surrounding areas were developed in the future. Purchase lands outside of the refuge that lie within the conceivable range of the Key deer (*e.g.*, Sugarloaf Key). Improve habitat qualities and simplify management and enforcement of widely dispersed refuge land by purchasing, or trading for, small isolated tracts of refuge land adjacent to larger parts of the refuge.

H1.1.5. Purchase easements when necessary on private property important to Key deer. Easements can protect vital Key deer habitat until funds become available for land purchases.

H1.2. Protect and manage habitat. Human disturbances and degradation of habitat are detrimental to Key deer and other wildlife. Evaluate habitat status and assess additional management strategies. Provide long-term maintenance of habitat. Update management strategies in order to provide the best quality habitat possible for Key deer.

H1.2.1. Protect Key deer on private lands. Protect Key deer populations on private land through acquisition, conservation easements or agreements, and education of land owners. Develop agreements or coordinate ESA section 10 permits between the FWS and private landowners to minimize impacts.

H1.2.2. **Protect Key deer on public lands.** Develop a habitat management plan that outlines priority habitat for acquisition and methods to protect, restore, and minimize impacts on deer and their habitat. Acquire and incorporate deer habitat to Federal, State, and county land protection systems. Manage public lands to control exotics, off-road vehicles, dumping, predators, and vehicular traffic. Identify and minimize other causes of deer injury or mortality on public lands.

H1.2.3. **Protect important corridor areas.** Protect these areas by coordinating with the appropriate permitting offices to avoid negative impact on the deer.

H1.2.4. **Eliminate threats from invasive exotic flora and fauna.** Invasive exotic plant species such as Australian pine, Brazilian pepper, and leatherleaf fern reduce Key deer food and habitat. Feral hogs (*Sus scrofa*) and the habitat destruction they cause has become a major threat to Key deer on Little Pine Key and may threaten fawns. Reduce and eliminate threats from exotic species.

H1.2.5. **Implement refuge fire management plan.** Fire suppression is responsible for deterioration of important pineland habitat (Klimstra 1986, Carlson *et al.* 1989). The Refuge Fire Management Plan provides for a prescribed burning program for habitat enhancement and fire safety. Utilization of prescribed burning, to set back successional stages, will become increasingly important as more private lands are allowed to mature in the absence of fire, increasing wildlife hazards.

H1.2.5.1. **Prohibit campfires in the National Key Deer Refuge.**

H1.2.5.2. **Establish and maintain fire breaks and fire trails.** Trails and breaks are critical to both the refuge lands and the adjacent private properties for protection from fire. In addition they provide travel routes for the deer and other wildlife.

H1.2.5.3. **Conduct prescribed burns on the National Key Deer Refuge when necessary.**

H1.2.6. **Fence or barricade areas where off-road vehicle use and/or dumping is a threat.**

H1.2.7. **Address the management and protection of non-refuge lands.** The insular nature of the Key deer's environment requires that all land practices must be considered in light of the effect(s) on Key deer and other wildlife. Management of non-refuge lands is a vital part of the overall habitat protection program for the deer. Aid in the development of a Monroe County land use plan emphasizing preservation of vital Key deer habitat and the reduction of damage to resources by development practices. Continue to participate in all planning aspects such as the Interagency Management Committee and public meetings. Continue consultation with County biologists and planners as to the needs of Key deer.

H1.2.8. **Conduct experimental habitat management on selected outer Keys.** Consider prescribed burning of Little Pine Key and monitor the effects of burn on plants and animals.

H1.2.9. **Maintain and evaluate present deer exclosures on Big Pine Key.** Establish enclosures on selected outer Keys that have the greatest potential for management *(e.g.*, Little Pine, Water Keys, *etc*.).

H2. Restore and create Key deer habitat.

H2.1. Restore natural tidal flow and hydrology by placing culverts or removing fill.

H2.2. Maintain and manage mosquito ditches so they do not impact deer habitat. Manage mosquito ditches on the refuge and in other areas of deer habitat.

H2.3. Improve water quality in freshwater sources and restore freshwater sources. The principal factor influencing distribution and movement of Key deer in the Keys is the location and availability of fresh surface water. Improve water quality in freshwater areas and monitor. Sample and maintain manmade water holes on outer Keys to assure suitability for use by Key deer. Identify other freshwater sources on outer Keys and consider the use of a "guzzler" or other catchment device for fresh water.

H2.4. Enhance Key deer habitat. Re-establish pines and associated plant communities in areas damaged by severe fire.

H2.5. Improve habitat by planting or encouraging native plant species. Plant native vegetation in areas that have been scarified or degraded. Encourage homeowners to plant native tree species.

H2.6. Create habitat by refilling and recreating areas that have been dredged or altered.

H3. Conduct research on Key deer habitat and how it affects the deer's distribution and abundance. The decline of the Key deer is attributed to the loss or degradation of its habitat. Understanding the relationships between the deer and its habitat will allow for better management of this species.

H3.1. Investigate how Key deer use different habitat components for survival (*e.g.*, food, shelter, nesting, traveling). Red and black mangroves are important food sources for the Key deer. Investigate important food plants throughout Key deer range so their production can be incorporated into the management program if necessary.

H3.1.1. Conduct radio telemetry on various subpopulations. Determine how deer use components of their habitat and which components are most limiting, especially back country island deer.

H3.1.2. Investigate the effect of habitat change. Determine how habitat change affects the deer's persistence, investigating factors such as road mortality, habitat degradation, and hydrology.

H3.2. Determine an index of habitat fragmentation. Much of the Key deer habitat is fragmented by roads, housing, and commercial facilities.

H3.2.1. Investigate movement patterns and the spatial use of habitat to identify important core areas and corridors.

H3.2.2. **Determine stable home range and minimum area required.** Yearly ranges for adult males and females average 319.7 ha and 173.6 ha, respectively, with males having even larger ranges during the breeding season. Investigate the effects of habitat loss and fragmentation on home ranges and minimum habitat area requirements.

H3.2.3. **Determine if the amount and configuration of habitat is sufficient to support a stable or increasing population of deer.** The number of Key deer is currently estimated between 579 to 678 individuals. Determine the carrying capacity of the remaining suitable habitat.

H4. Monitor the status of Key deer habitat and examine ecological processes. Conduct yearly monitoring evaluations of the deer's habitat. Overlay habitat quality with GIS mapping of habitat locations, including what patches are being altered or lost each year. Monitor the availability of deer habitat by updating the loss or change of habitat due to residential or commercial construction.

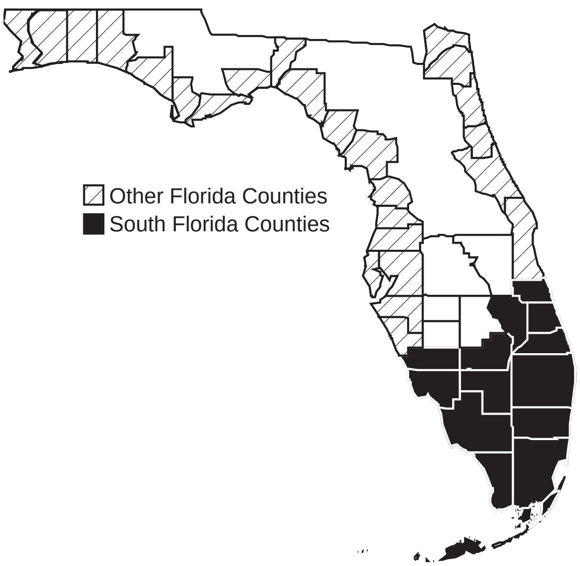
H5. Increase public awareness of Key deer habitat and instill stewardship. Conduct workshops with the public to educate private landowners on appropriate management practices to preserve deer habitat. Encourage private landowners to remove exotics, maintain natural water flow, plant native vegetation, and restore disturbed areas. Prepare literature to provide information regarding the Key deer habitat and ways to protect and conserve it.

West Indian Manatee

Trichechus manatus

Federal Status:	**Endangered (March 11, 1967)**
Critical Habitat:	**Designated (1976)**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. Florida distribution of the West Indian manatee; inland counties include Lake Okeechobee and connecting rivers.



Once mistaken as a mermaid by sailors of the past, the West Indian manatee (*Trichechus manatus*) is one of the largest coastal mammals in North America. This unusual marine mammal with its massive, seal-like body, has been able to adapt well to its marine environment. Manatees migrate seasonally to adapt to changing water temperatures. West Indian manatees roam in fresh, brackish, and marine waters throughout Florida, the Greater Antilles, Central America, and South America. Intensive hunting pressures between the 1500s to 1800s reduced the number of manatees. The West Indian manatee is one of the most endangered marine mammals in coastal waters of the United States. This group includes a separate subspecies called the Florida manatee (*Trichechus manatus latirostris*) that appears to be divided into at least two somewhat isolated subpopulations-one along the Atlantic coast and the other on the Florida Gulf of Mexico coast.

This recovery plan represents South Florida's contribution to the recently published 1996 West Indian Manatee Recovery Plan (FWS 1996).

Description

The West Indian manatee is an aquatic mammal with a robust, fusiform body that is compressed dorsoventrally. Its grey to grey-brown, thick, tough skin is sparsely covered with small, thick hairs (3.0 to 4.5 mm) (Husar 1978) and is sometimes covered with barnacles and algae. The rounded body of the manatee has no hind limbs, but it has paddle-like forelimbs or flippers with three to four nails present on the dorsal surface of each flipper. The body tapers to a spatulate, dorsoventrally flattened tail. Females have a single prominent mamma or teat behind the axilla of each flipper and a relatively short anal-genital distance (Rathbun 1984). The urogenital opening in males is located just behind the navel.

The average adult manatee is 3.5 m long and weighs 1,000 kg. Male and female manatees are similar in size and appearance (Rathbun 1984). Newborn calves are, on average, 1.2 to 1.4 m long and weigh an average of 30 kg (Odell 1981).

Manatees have a dense skeleton. The massive skeletal bones lack marrow cavities in the ribs and forelimbs (Odell 1982). Similar to other marine mammals, manatees have large blubber stores.

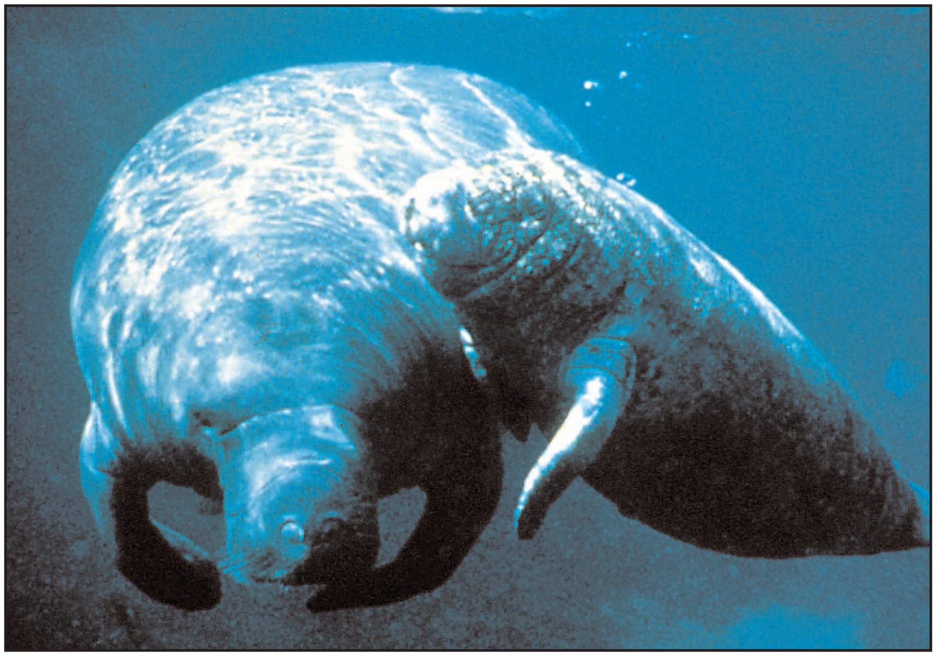
The deeply-set, small eyes have no visible upper or lower lids, but instead have a nictating inner membrane capable of covering the eyeball for protection. Manatees can see for considerable distances, although their depth perception may be limited (Reynolds 1979). Manatees can hear well even though their inconspicuous ears have no external pinnae or earlobe flaps. Manatees communicate through different squeaks, chirps, grunts, and groans, that are within human audible range (Ketten *et al*. 1992). Two nostrils are located on the long upper snout that are capable of opening and closing by muscular valves. Manatees have an enlarged, lobed upper lip with short, stiff bristles and two muscular projections or prehensile pads that aid them in bottom feeding (Odell 1982).

To compensate for the excessive tooth wear caused by the tough vegetative matter they feed upon, manatees replace old, worn-down teeth with new ones. In a manner that is similar to a conveyor belt, their teeth move forward horizontally through their jawbones until worn-down teeth fall out and are replaced by new teeth in the back of their mouths. This replacement process occurs at a rate of about one mm per month. Manatees may use 30 or more molars in a lifetime (Domning and Hayek 1986).

Sea cows (*Protosiren*) first appeared during the Eocene period about 55 million years before the present when flowering plants first evolved. The family Trichechidae appeared in South America in the early Miocene (15 million years before present), about the same time as whales, apes and grazing animals (Domning 1982, Domning *et al.* 1982). During the Pliocene (12 million years before present), the time period when large carnivores evolved, members of Trichechidae first appeared in Atlantic North America (Reinhart 1951, 1959). Pleistocene *Trichechus* fossils have been recovered from the United States' east coast from Florida to Maryland (Simpson 1932).

Taxonomy

The mammalian Order Sirenia has two recent families, three recent genera and five recent species (Rathbun 1984). The two recent families: Dugongidae and Trichechidae have two genera with four living species and one extinct species. The Family Dugongidae contains two genera *Dugong* and *Hydrodamalis* and two species; of which *Dugong dugon* is the only living species of this family. The second species, Steller's sea cow (*Hydrodamalis giga)*, was hunted to extinction by 1768 (Reeves *et al.* 1992). The family Trichechidae was described by Gill in 1872 (Rathbun 1984). The second living genus, *Trichechus,* includes three



West Indian manatee.
Original photograph by Robert Bonde.

allopatric species: the Amazonian manatee (*T. inunguis*), the West African manatee (*T. senegalensis*), and the West Indian manatee (*T. manatus*). The West Indian manatee is represented by two subspecies, the Florida manatee (*T. manatus latirostris*) and the Antillean manatee (*T. manatus manatus*) (Hatt 1934). *T. manatus* was described by Linneaus in 1758, and further distinguished as *T. m. latirostris* in 1924 (Harlan 1924). The four living sirenian species are geographically isolated, and listed as threatened or endangered (32 FR 4001, 35 FR 8495, 44 FR 42911). The closest, living terrestrial mammalian relative to the manatee is the elephant.

Distribution

The global distribution of sirenians, including dugongs and manatees, includes coastal waters, estuaries, and freshwater rivers. Dugongs can be found in marine habitats from eastern Africa to the Ryukyu Islands, Indo-Australian Archipelago, western Pacific and Indian oceans. Manatees can be found in tropical western Africa, including the Niger-Benue Basin, the tropical western Atlantic coast, the Caribbean Sea, and in the Amazon and Orinoco River basins (Rathbun 1984). The extinct Steller's sea cow range included the Bering Sea.

The present distribution of the West Indian manatee includes the coasts and rivers of Florida, the Greater Antilles, eastern Mexico and Central America and northern and eastern South America (Husar 1977, Lefebvre *et al.* 1989). *T. manatus latirostris* ranges from Texas to Rhode Island. The cooler winters along the U.S. coast of the Gulf of Mexico, in combination with the deep water and strong currents of the Straits of Florida, create a barrier between the Antillean and Florida manatee; the resulting isolation contributes to their status as subspecies (Domning and Hayek 1986).

The seasonal distribution of the manatee is affected by water temperatures. Waters colder than 20 degrees C increase the manatees' susceptibility to cold-stress and cold-induced mortality. Because of this temperature restriction, manatees seek out warm water refuges to help reduce energetic maintenance costs.

The manatee occurs throughout the southeastern United States. The only year-round populations of manatees occur throughout the coastal and inland waterways of peninsular Florida and Georgia (Hartman 1974). During the summer months, manatees may range as far north along the East Coast of the U.S. as Rhode Island, west to Texas, and, rarely, east to the Bahamas, FWS 1996, Lefebvre *et al.* 1989). There are reports of occasional manatee sightings from Louisiana, southeastern Texas, and the Rio Grande River mouth (Gunter 1941, Lowery 1974).

In Florida, manatees are commonly found from the Georgia/Florida border south to Biscayne Bay on the east coast and from Wakulla River south to Cape Sable on the west coast (Hartman 1974, Powell and Rathbun 1984) (Figure 1). Manatees are also found throughout the waterways in the Everglades and in the Florida Keys. Although temperatures are suitable for manatees in the Florida Keys, the low number of manatees has been attributed to the lack of fresh water (Beeler and O'Shea 1988). Manatees also occur in Lake Okeechobee.

In warmer months (April to November), the distribution of manatees along the east coast of Florida tends to be greater around the St. Johns River, the Banana and Indian rivers to Jupiter Inlet, and Biscayne Bay. On the west coast of Florida, larger numbers of manatees are found at the Suwannee, Crystal and Homosassa rivers, Tampa Bay, Charlotte Harbor/Matlacha Pass/San Carlos Bay area, the Caloosahatchee River and Estero Bay area, the Ten Thousand Islands, and the inland waterways of the Everglades.

On the west coast, manatees winter at Crystal River, Homosassa Springs, and other warm mineral springs (Powell and Rathbun 1984, Rathbun *et al.* 1990). In the winter, higher numbers of manatees are seen on the east coast at the natural warm waters of Blue Spring and near man-made warm water sources on or near the Indian River Lagoon, at Titusville, Vero Beach, Ft. Pierce, Riviera Beach, Port Everglades, Ft. Lauderdale, and throughout Biscayne Bay and nearby rivers and canals (FWS 1996). They also aggregate near industrial warm water outflows in Tampa Bay, the warmer waters of the Caloosahatchee and Orange rivers (from the Ft. Myers power plant), and in inland waters of the Everglades and Ten Thousand Islands.

Manatees frequently migrate throughout the waterways in South Florida. The South Florida Ecosystem region is home to the most resident manatee populations and transient migrants in Florida. In South Florida, manatees are most prominent year-round in the following areas: Indian River, Biscayne Bay, Everglades and Ten Thousand Island area, Estero Bay and Caloosahatchee River area, and Charlotte Harbor area. Some of the largest winter aggregations (50 or more manatees) occur in south and central Florida (FWS 1996).

Habitat

Manatees occur in both fresh- and saltwater habitats within tropical and subtropical regions. They depend on areas with access to natural springs or manmade warm water refugia and access to areas with vascular plants and freshwater sources (Humphrey 1992). Several factors contribute to the distribution of manatees in Florida. These factors are habitat-related and include proximity to warm water during cold weather, aquatic vegetation availability, proximity to channels of at least 2 m in depth, and location of fresh water sources (Hartman 1979).

Manatees are also dependent upon location of foraging sites. Normally, manatees feed on a variety of submergent, emergent, and natant (floating) vegetation. Manatees usually forage in shallow grass beds that are adjacent to deeper channels (Hartman 1979, Powell and Rathbun 1984). The proximity of these deeper channels may allow easy access to and from feeding areas.

Manatees often seek out quiet areas in canals, creeks, lagoons or rivers. These areas provide habitat not only for feeding, but also for resting, cavorting, mating, and calving. Deeper channels are often used as migratory routes (Kinnaird 1983). Natural or artificial freshwater sources are sought by manatees, especially manatees that spend time in estuarine and brackish waters (FWS 1996).

Critical Habitat

Critical habitat was designated for the manatee in the early 1970s, although no specific primary or secondary constituent elements were included in the designation (50 CFR 17.95). Critical habitat for the manatee identifies specific areas occupied by the manatee, which have those physical or biological features essential to the conservation of the manatee and/or may require special management considerations.

Behavior

Manatees have low metabolic rates indicating a possible adaptation to their large size and low nutrient food sources, or to permit long dives, since manatees have less advanced diving abilities than other marine mammals. Manatees can remain submerged for several minutes, with the longest submergence record lasting 24 minutes (Reynolds 1981). Manatees increase submergence times while feeding and resting. Female manatees coordinate their breathing and submergence times with their calves. Manatees do not appear to be fast swimmers, but they usually swim 4 to 10 km an hour and may attain faster speeds in short bursts (Husar 1977).

Manatees are not overly gregarious, but they do aggregate at warm-water refugia and during mating. Manatees have been observed displaying playful behaviors such as chasing, tumbling, and nuzzling (Hartman 1979, Bernier 1985).

Reproduction

The manatee population sex ratio is considered to be 1:1 for both adults and calves (Rathbun *et al*. 1992). Females reach sexual maturity at 3 to 5 years of age (Marmontel 1993) and males may reach sexual maturity at 3 to 4 years of age. Individuals at least 275 cm in length may be reproductively mature, although the modal female may not successfully rear young until 6 years or older (Marmontel 1993). Manatee longevity has been estimated at 50 years or more and they appear to be able to reproduce their entire adult life (Marmontel *et al*. 1992). Odell *et al*. (1995) reported a captive female manatee reproduced throughout its 34 years at the Miami Seaquarium.

The combination of suitable seagrass beds, nearby deeper water access, and minimal boat traffic may be indicative of important mating, calving, and nursery grounds for manatees (Smith 1993). Reproduction can occur throughout the year, although sperm production in male manatees is low during the winter (Hernandez *et al*. 1995). Most manatee calves are born in the spring or early summer (Irving and Campbell 1978). Breeding usually commences when one or more males are attracted to an estrous female, but permanent pair bonds are not formed (Marmontel *et al*. 1992). Manatees may form large breeding herds. Larger, presumably older males, dominate mating herds and may be responsible for most pregnancies (Rathbun *et al*. 1992).

The minimum interval between manatee birth is 2 years, but not all female manatees are this fecund. On average, 33 percent of mature, female manatees may be pregnant, which suggests a 3-year interval between calving (Marmontel 1993). If the interval between calving is 3 years and continues over a 36-year period, a female manatee could produce approximately 12 calves during her lifespan (Marmontel 1993). Calving intervals may be affected by the age and health of the female manatee. Although sexual activity may occur, female manatees may experience infertile estrous periods (Hartman 1979). Injuries caused by watercraft may also disrupt the manatee’s estrous cycle (Marmontel 1993).

Gestation of the single calf takes 12 to 14 months (Reid *et al*. 1992). Age to weaning varies from 1 to 2 years. Calves usually stay close to their mothers during their first several years. Twin calves have been reported (D. O’Dell, Sea World, personal communication 1998).

Per capita reproductive rates in Florida manatees have been estimated from a low of 0.15 ($\pm$0.060) in the Blue Spring population to a high of 0.19 ($\pm$0.009) in the Atlantic coast population (Eberhardt and O’Shea 1995). The maximum potential rate of population increase has been estimated at 2.0 to 7.0 percent; this rate is most sensitive to changes in adult survival and, secondarily, subadult survival (Packard 1985, Marmontel 1993). For many years, the FWS (among others) has expressed concern about how the mortality rate will affect the survival and recovery of the manatee. These concerns were confirmed by the population viability analysis conducted by Marmontel (1993), which evaluated the probability of the manatee’s persistence and the mean time to its extinction.

Foraging

Manatees feed with the help of their two muscular lips, which are flexible and move independently, in a fashion similar to an elephant’s trunk or human fingers. The lips are capable of manipulating food: grasping and moving food into the mouth. Manatees also use their forelimbs to dig into the sediment to remove seagrass rhizomes or roots (Hartman 1979, Provancha and Hall 1991, Lefebvre and Powell 1990). Manatees usually spend more time foraging in the late autumn (6.9 hours/day) than in early spring (3.2 hours/day)(Bengston 1983). Manatees must eat large amounts of aquatic vegetation to meet their metabolic requirements and may consume up to 20 percent of their body weight per day in aquatic plants (Zieman 1982).

These animals frequently forage at depths of 1 to 3 meters where aquatic vegetation is abundant. Manatees are opportunistic herbivores and feed on a variety of submerged, emergent, or floating aquatic plant species, including seagrasses, bank grasses, and overhanging mangroves (see Hurst and Beck 1988, and Smith 1993 for complete review). They may also feed on algal complexes attached to rocks, pilings, and dams (Reynolds 1981), and may occasionally eat fish or invertebrates while feeding on floating or submerged vegetation (Powell 1978, Smith 1993). In South Florida, manatees feed primarily on submerged vegetation such as turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), Cuban shoal grass (*Halodule wrightii*), and *Halophila* spp., although a variety of other emergent and floating vegetation is also eaten. Manatees may also forage on a variety of shoreline vegetation including red mangrove (*Rhizophora mangle*) leaves and cordgrass (*Spartina alterniflora*) (Longieliere 1994). In fresh water, manatees feed primarily on submerged aquatic macrophytes such as *Myriophyllum* spp. and hydrilla (*Hydrilla verticillata*).

Preferred manatee habitat in South Florida is characterized by the availability of submerged aquatic vegetation (SAV) (Smith 1993). Due to light limitations, most SAV, such as seagrass beds, are limited to shallow, nearshore waters. Seagrasses comprise the largest component of the manatee's diet, especially in South Florida (Hartman 1979, Zieman 1982, Smith 1993). Some manatees have been observed to return to the same seagrass beds to feed year after year and may show preferences for certain areas (USGS/BRD 1993, Smith 1993). Preference may also be shown for areas with healthy seagrass beds adjacent to relatively deeper waters with little boat traffic (Kadal and Patton 1991,USGS/BRD 1993). Manatees exhibit diel feeding patterns during the winter; they rest in warm waters during the day and head out in the late afternoon to feed in surrounding, sometimes, cooler areas (Bengston 1981).

Migration

Manatees normally migrate along shorelines and use deeper corridors to access shallow-water feeding and resting areas (Kinnaird 1983). Telemetry research suggests that calves learn migratory patterns from their mothers (USGS/BRD 1993). Migration patterns often vary between individuals. Some manatees may undertake extensive migrations along the coast and up rivers and canals (Reeves *et al*. 1992). Manatees may travel 40 km/day for several consecutive days, usually traveling directly and rapidly to a particular destination site, with males ranging longer distances than females (Bengston 1981, USGS/BRD 1993). On the east coast manatees migrate northward in the springtime and southward in the fall and winter (Moore 1951). Manatees do not range far offshore, but may travel along the coast (Beeler and O'Shea 1988).

The increase in the number of manmade warm-water sources over the years has influenced manatee migratory patterns. Manatees frequent coastal, estuarine, and riverine habitats and are capable of extensive north-south migrations throughout the year (Reeves *et al*. 1992). Manatees have been observed migrating great distances northward in the springtime and southward in the fall and winter (Longieliere 1994); and as a result, abundances in regional populations change seasonally (Hartman 1974). There are 17 major aggregation sites in Florida (Garrott *et al.* 1994). These aggregation sites occur at or near manmade or natural warm-water refugia. Manatees will migrate to these warmer areas when water temperatures drop below 20 degrees C. Large aggregations of manatees occur at these warm-water areas. With the rise in water temperatures in the spring, some manatees may begin to migrate away from their winter refugia, while others remain relatively close. Manatees often return to the same winter refugia each year (Powell and Rathbun 1984, Reid *et al*. 1991). In the winter, manatees stay closer to warm-water during the day, then move to vegetated areas in the late afternoon or at dusk to feed.

Warm-water sources offer manatees refugia to escape the stresses of cold water temperatures. Most research has concentrated on developing methods to determine population trends at these sites, but little work has investigated manatee behavior in relation to man-made water sources.

Boat channels are often used by manatees to travel from one region to another (Curran 1989, USGS/BRD 1993). Although these channels may provide deeper waters for manatees to avoid or escape oncoming boats, for reasons not yet understood, they do not always move out of the way of approaching boats. Manatees are also vulnerable to collisions with boats in narrow waterways and shallow water areas. During high tide, manatees are able to access foraging habitat that is normally inaccessible during low tide (Smith 1993). Although watercraft may utilize deeper navigation channels, coastal shallow areas are used intensively for fishing and general sightseeing. The shallow depths of these areas increase the likelihood of manatee injury or death if a powerboat passes over them.

Relationship to Other Species

The manatee is an indicator species for aquatic habitats, including seagrasses and mangroves, in the South Florida Ecosystem. Because this species is dependent upon the health of its entire habitat, the status of the manatee acts as a signal for the condition of many of the other flora and fauna that rely upon aquatic systems. For example, seagrass beds and mangroves provide important areas for manatee foraging, calving, resting, and mating. They also provide important habitat resources for other aquatic species such as wading birds, crocodiles *(Crocodylus acutus)*, turtles, fish and invertebrates. The stability of these aquatic communities is essential for manatees and many other species.

Manatees have no known predators, except for humans. Manatees and their habitats are continually threatened by human activities, such as habitat loss for residential and commercial purposes, increased turbidity levels from upland urbanization activities, pollution from sewage discharge and stormwater runoff, aquatic recreational and commercial activities, and alterations of natural hydrology. Several threatened and endangered sea turtles use the same seagrass beds as manatees for juvenile refugia and feeding. In addition, many migratory birds, and fish rely on the aquatic habitats manatees use. Habitat requirements of all of these species need to be considered and balanced in order to conserve and protect these resources.

Human interferences with natural water flows have affected the dynamics of vegetative communities in the South Florida Ecosystem. Changes in these flow regimes may affect not only manatees but other species as well, including the endangered American crocodile and pink shrimp (*Penaeus duorarum*), an important fishery species. Returning hydrologic flows to mimic more natural conditions will allow more fresh water into northeastern Florida Bay and may increase the amount of suitable crocodile nesting habitat. A decline in the pink shrimp fishery has been attributed to a lack of freshwater inflow into Florida Bay and a loss of seagrass habitat. The effects of hydrologic conditions on manatees is not well known; but effects on habitat have been observed.

Although reactions may be different, manatees are susceptible to the same natural and human disturbances other aquatic organisms experience, such as changes in water quality, loss of habitat, and susceptibility to diseases and natural catastrophes. Considering man is the only known predator of manatees, it is our responsibility to ensure our actions do not jeopardize the continued existence of this species nor those other species that share its home.

Status and Trends

The Federal government has recognized the threats to the continued existence of the Florida manatee for over 30 years. The West Indian manatee was first listed as an endangered species in 1967 under the Endangered Species Preservation Act of 1966 (16 U.S.C. 668aa(c)) (32 FR 48:4001). The Endangered Species Conservation Act of 1969 (16 U.S.C. 668aa(c)) continued to recognize the West Indian manatee as an endangered species (35 FR 16047), and the West Indian manatee was also among the original species listed as endangered pursuant to the Endangered Species Act of 1973. Critical habitat was designated for the manatee in 1976. The justification for listing as endangered included impacts to the population from harvesting for flesh, oil, and skins as well as for “sport,” loss of coastal feeding grounds from siltation, and the volume of injuries and deaths resulting from collisions with the keels and propellers of powerboats. Manatees are also protected under the provisions of the Marine Mammal Protection Act of 1972, as amended (16 U.S.C. 1361 *et seq*.) and have been protected by Florida law since 1892.

Historic information on *T. manatus* distribution indicates manatees were once more common in pre-Colombian times. Manatees were highly utilized for their meat, oil, bones, and hide; hence, their early decline has been attributed to overhunting (Lefebvre *et al.* 1989). Extirpation and range contraction is evident throughout the manatee's range; areas previously with abundant populations now contain few or none. For example, manatees have been extirpated from some coastal areas in Mexico, Virgin Islands, and Honduras.

Florida is at the northern limit of *T. manatus'* year-round range. Exact estimates of the historic manatee population are uncertain, but overhunting between the 1700s and 1900s is believed to be responsible for reducing the manatee population to only a few relict groups (Hartman 1979).

The geographic distribution of manatees within Florida has changed since the 1950s and 60s (Lefebvre *et al.* 1989) and prominent shifts in seasonal distribution are also evident. Before man introduced warm effluents from power plants to the natural environment in the early 1950s, the winter range of the manatee in Florida was most likely limited on its northern bounds by the Sebastian River on the east coast and Charlotte Harbor on the west coast (Moore 1951). Since that time, manatees altered their normal migration patterns and appreciable numbers of manatees began aggregating at new sites. As new powerplants became operational, more and more manatees began taking advantage of the sites by traveling great distances just to bask in the warm waters. The introduction of powerplants and paper mills in northern Florida, southern Georgia, Louisiana, and Texas has given manatees the opportunity to expand their winter range to areas not previously frequented (Hartman 1979).

As discussed earlier, determining exact population estimates or trends is difficult for this species. The best indicator of population trends is derived from mortality data and aerial surveys (Ackerman *et al.* 1992, Ackerman *et al.* 1995, Lefebvre *et al.* 1995). Aerial surveys conducted over the past 19 years have shown an increase in numbers, but this information is not an accurate account of trends since data has been obtained using different survey methods. O'Shea (1988) found no firm evidence of a decrease or increase between the 1970s and 1980s, even though aerial survey counts have increased. Increases in the number of recovered dead manatees have been interpreted as evidence of increasing mortality rates (Ackerman *et al*. 1992, Ackerman *et al.* 1995). Because manatees have low reproductive rates, these increases in mortality may lead to a decline in the population (O'Shea *et al.* 1988, 1992). Until better survey techniques are developed, efforts to reduce human-caused manatee deaths, like boat strikes, need to continue.

Although there are no accurate estimates of manatee population size, DEP's 1996 synoptic aerial surveys conducted between February 18-19, determined there were at least 2,639 manatees in Florida's waters. DEP conducted two synoptic surveys in 1997. The January survey determined that 2,229 manatees were present in Florida's waters: 900 on the east coast and 1,329 manatees on the west coast. The February survey determined that 1,709 manatees were present in Florida's waters: 791 manatees on the east coast and 918 on the west coast.

Surveys conducted by DEP in 1996 and 1997 determined that numbers of manatees on the east coast and west coasts of Florida are almost equal (Rathbun *et al.* 1992). These estimates represent the minimum number of manatees in Florida waters and may not represent the total population size (for discussions on bias in aerial surveys, see Garrott *et al.* 1995 and Lefebvre *et al.* 1994). Although this has been the highest estimate of manatees since the synoptic surveys were started, the results of these surveys may vary because of such factors as sampling methodology, manatee behavior, and weather conditions. Because of this variation and the high degree of uncertainty in surveying, it is difficult to correlate these manatee population estimates with overall manatee population trends (Ackerman *et al.* 1995).

Despite the lack of accurate estimates of the manatee population size, human activities have significantly affected manatees by eliminating or modifying suitable habitat, altering migratory access routes, increasing mortality, and decreasing abundance, all of which in turn, can affect manatee reproduction, recruitment, distribution, and behavior. To understand manatee mortality trends in Florida, Ackerman *et al.* (1995) evaluated the number of recovered carcasses between 1974 and 1992 and categorized the causes of death. During that time interval, the number of manatees killed in collisions with watercraft increased each year by 9.3 percent. The number of manatees killed in collisions with watercraft each year correlated with the total number of pleasure and commercial watercraft registered in Florida (Ackerman *et al.* 1995). Other human-related threats include manatee death or injury from flood-control structures and navigational locks, entanglement in fishing line, entrapment in culverts, and poaching. These other threats accounted for 162 known mortalities between 1974 and 1993.

Deaths from flood control structures and other human-related deaths did not change significantly but deaths due to these categories decreased more than deaths from other causes (Table 1). Of interest is the increase in the number of perinatal deaths of 11.9 percent/year. The frequency of perinatal deaths (stillborn and newborn calves) has been consistently high over the past 5 years and represented 24 percent of all manatee deaths in 1994. This estimate may not be a true representation of the actual number of perinatal deaths that occur because the carcasses of these young animals may not be recovered. The cause of the increase in perinatal deaths is uncertain, but may result from a combination of factors that includes pollution, disease, or environmental change (Marine Mammal Commission 1992). It may also result from the increase in collisions between manatees and watercraft because some newborn calves may die when their mothers are killed or seriously injured by boat collisions, when they become separated from their mothers while dodging boat traffic, or when stress from vessel noise or traffic induces premature births (Marine Mammal Commission 1992). As a result of the high perinatal death rate, there are fewer young age classes present in the population.

Table 1. Number of manatee (*Trichechus manatus*) deaths in Florida (1974-1997).

Year	Watercraft collision	Flood gate/canal lock	Other human-related	Perinatal	Other Natural	Undetermined	Total
1974	3	0	2	0	0	2	7
1975	6	1	1	7	1	13	29
1976	10	4	0	14	2	32	62
1977	13	6	5	9	1	80	114
1978	21	9	1	10	3	40	84
1979	24	8	9	9	4	23	77
1980	16	8	2	13	5	19	63
1981	24	2	4	13	9	64	116
1982	20	3	1	14	41	35	114
1983	15	7	5	18	6	30	81
1984	34	3	1	25	24	41	128
1985	33	3	3	23	19	38	119
1986	33	3	1	27	13	45	122
1987	39	5	2	30	16	22	114
1988	43	7	4	30	24	25	133
1989	50	3	5	38	32	40	168
1990	47	3	4	44	67	41	206
1991	53	9	6	53	14	39	174
1992	38	5	6	48	20	46	163
1993	35	5	6	39	24	36	145
1994	49	16	5	46	37	40	193
1995	42	8	5	56	35	55	201
1996	60	10	0	61	118	166	415
1997	54	8	8	61	46	65	242
Total	749	136	86	688	561	1,037	3,270

Of the 1,907 manatee carcasses that have been recovered in Florida between 1989 and 1997, (DEP 1998) nearly half were female. The reduction of mature females places an additional burden and pressure on younger, less-experienced females to be the foundation for population growth. Younger females may be more apt to abandon their calves and less successful in calf rearing (Marine Technical Advisory Council 1994). A loss of mature, experienced males may also reduce the likelihood of successful mating.

The greatest present threat to manatees is the high rate of manatee mortalities caused by watercraft collisions. O' Shea *et al.* (1985) recognized the dramatic increase in the rate of boat use in manatee habitat and, consequently, the increase in the potential of boat-related manatee injury or death. Between 1986 and 1992, watercraft collisions accounted for 37.3 percent of all manatee deaths, where the cause of death could be determined (Ackerman *et al.* 1995).

The significance of manatee mortalities related to watercraft appears to be the result of dramatic increases in vessel traffic. Ackerman *et al.* (1995) showed a strong correlation between the increase in recorded manatee mortality and increasing boat registrations. In 1960, there were approximately 100,000 registered boats in Florida; by 1990, there were more than 700,000 registered vessels in Florida (Marine Mammal Commission 1992, Wright *et al.* 1995). Approximately 97 percent of these boats are registered for recreational use. The most abundant number of registered boats are in the 16 foot to 26 foot size class. Between 1974 and 1997, there were 3,270 known manatee mortalities in Florida. Of these, 749 were watercraft-related. Since 1974, an average of 31 manatees have died from watercraft-related injuries each year; between 1983 and 1993, manatee mortalities resulting from collisions with watercraft reached record levels (DEP 1994). Approximately twice as many manatees died from impacts suffered during collisions with watercraft than from propeller cuts; this has been a consistent trend over the last several years. Most lethal propeller wounds are caused by medium or large-sized boats, while impact injuries are caused by fast, small to medium-sized boats (Wright *et al.* 1992). Watercraft-related mortalities were most significant in the southwest and northeast regions of Florida; deaths from watercraft increased from 11 to 25 percent in southwestern Florida. In all of the counties that had high watercraft-related manatee deaths, the number of watercraft and the seasonal abundance of manatees was high (Ackerman *et al.* 1995).

In addition to direct collisions with boats, secondary effects from boating activity include such stresses as disruption of normal breeding behavior, disruption of cow-calf bonding, interference with migration routes and patterns, and the loss of feeding areas. An increase in these effects is likely to increase the probability of unsuccessful mating, perinatal mortality, prevention of reaching freshwater resources and warm-water refugia, and decreasing the availability of food resources. In addition, these effects are likely to decrease the recruitment of young manatees into the breeding population and decrease the number of successful reproductions.

The second most significant threat to manatees is the loss and degradation of habitat, due primarily to direct damage by aquatic recreational and commercial boating activity, coastal construction, and pollution from sewage discharge and stormwater runoff (Marine Mammal Commission 1992, Smith 1993). Coastal land conversion accompanying the growth of Florida's human population has occurred largely along coastal waters and rivers used by manatees. Siltation, eutrophication, other forms of water pollution, and the destruction or degradation of wetlands to promote shoreline development degrade the coastal and riverine communities. This degradation reduces manatee food supplies and eliminates the secluded areas that are used by manatees to mate, calve, and nurse (Marine Mammal Commission 1992).

In Florida, manatees rely primarily on seagrass beds for foraging, mating, and calving. These seagrass beds incur most of their direct damage from boat propellers (Zieman 1982). Boat-induced turbidity results from propeller dredging of bottom habitats and propeller wash and wave wake disturbance. Sediments around seagrasses become unconsolidated and suspended, delaying recolonization for 2 to 5 years or longer, depending upon species type. Several bays in Florida formerly possessed extensive seagrass resources, but dredge and fill operations as well as other human disturbances have greatly reduced their extent (Zieman 1982).

Seagrasses along the coast of Florida have been declining since the 1950s. In Tampa Bay, about 16,188 ha of seagrass flourished along the shallow shelf of the bay. By 1982, only 8,741 ha remained baywide (Tampa Bay National Estuary Program 1995). In Sarasota Bay, seagrasses have declined by 30 percent (Sarasota Bay National Estuary Program 1994). From 1945 to 1982, seagrass acreage declined by 29 percent in Charlotte Harbor; with an additional 809 to 3,238 ha of seagrasses destroyed or damaged by boat propellers (Haddad and Sargent 1994). More than 100,000 acres of seagrasses have "died off" in Florida Bay since 1987 (FWS 1994). For the Indian River Lagoon, the total coverage of submerged aquatic vegetation (seagrasses and macroalgae) in the 1970s was 31,777 ha. In 1992, the total coverage decreased to 28,385 ha, an 11 percent reduction in seagrass distribution (Indian River Lagoon National Estuary Program 1994).

An unusual manatee mortality event was detected in southwest Florida in 1996. Between March 5 and April 29, 149 manatee deaths were attributed to this unusual die-off. Most of the manatee carcasses were recovered from Lee County followed by Collier, Charlotte, and Sarasota counties. After thorough investigations, red tide was indicated as the cause. Final reports on the 1996 manatee die-off concluded that brevetoxins from a bloom of dinoflagellates (*Gymnodinium brevii*), more commonly known as red tide, were responsible for the deaths of those manatees. Brevetoxins were found in the manatee carcasses in liver, kidney, and lung tissues and also in stomach contents. The majority of animals that died were large animals (greater than 275 cm long), although some smaller (younger) animals also died. The sex ratio of dead manatees was nearly one to one. High concentrations of red tide organisms were also found in water samples taken in the geographic vicinity of the die-off. Researchers continue to look for the cause of the red tide outbreak, method of toxicity, organ selection of the toxin, and most importantly, ways to minimize the effects of another red tide event.

Other threats to the manatee include natural catastrophic events such as low temperatures, and hurricanes (Ackerman *et al.* 1995). Most catastrophic mortality, however, is due to low temperatures (O'Shea *et al.* 1985). Lethal temperatures and lethal exposure times are not well known, but manatees cannot survive indefinitely in water colder than 16 degrees C (Ackerman *et al.* 1995). Although deaths from natural weather events cannot be prevented by humans, these mortalities must be considered because they play an important factor in the overall status of the manatee.

The FWS has concentrated on controlling those factors that will respond to direct human intervention. The FWS has worked with the State to minimize the number of mortalities caused by watercraft collisions, and with the COE to reduce the number of manatees killed by floodgates and canal locks. The number of manatees killed by floodgates and canal locks has declined from a high of 8.8 percent (between 1976 and 1980) to 3.2 percent. The FWS is continuing to work with the COE to develop new technologies to further reduce the number of manatees killed in these water control structures. The FWS has also worked to reduce the number of manatees killed by other human causes. Since 1973, the number of manatees killed by poaching, net entanglement, and vandalism has declined from a high of 8.3 percent to 2.6 percent by 1992 (Ackerman *et al.* 1995).

Marmontel's (1993) population viability analysis (PVA) model discussed previously suggest that a 10 percent mortality rate is probably a critical threshold for the survival and recovery of manatees. Although the minimum population estimate reached a record high in 1996 with approximately 2,639 manatees, the number of manatees killed in the first quarter of 1996 almost equals 10 percent of that minimum population estimate. According to DEP, 415 manatees died in 1996.

Although Marmontel's (1993) PVA had limitations resulting from the lack of specific life history information on the manatee, her simulations represent the best information available regarding the consequences of human activities on the manatee. First, she noted that the small population size of the manatee lessens their probability of persistence and increases the chances that the populations will be adversely affected by environmental variation or additional mortalities. Second, her simulations projected that a 10 percent increase in overall manatee mortality would reduce the manatee below the critical threshold of 500 animals in about 100 years. Finally, her simulations projected that reducing the mortality of adult manatees by watercraft would be the most productive mechanism to increase the probability of manatee survival and recovery.

Management

Perhaps the first management action taken to conserve manatees was the 1892 prohibition on killing instituted by Florida law. The manatee was federally listed as an endangered species in 1967. Some of the first research conducted on manatees began in the mid-1960s (Hartman 1979). Additional research continued in 1974 when the University of Miami and Gainesville Field Station of the FWS began focusing their efforts on manatee research. These efforts provided a foundation for later research and management activities. By 1978, Florida passed the Florida Manatee Sanctuary Act and by 1984, Florida Department of Natural Resources (now DEP) dedicated more resources to protect the manatee.

In 1980, the first manatee recovery plan was approved and a manatee coordinator was hired by the FWS to oversee the recovery of the manatee. The recovery plan was revised in 1989 and again in 1996. The primary goal for recovery of the manatee is to restore manatee populations to sustainable levels that will permit their reclassification from endangered to threatened. To progress with the recovery goals, the FWS's 1996 recovery plan for the manatee established four objectives: (1) identify and minimize causes of manatee disturbance, injury, and mortality, (2) protect essential manatee habitat, (3) determine and monitor the status of manatee populations and essential habitat, and (4) coordinate recovery activities, monitor and evaluate progress, and update and/or revise the recovery plan (FWS 1996).

Building upon efforts that began in the 1960s, an array of Federal, State, local, and private groups have contributed to the protection of the manatee. A considerable collaborative effort has been put forth and continues today to minimize human-induced effects on manatees and assist in its recovery. Current efforts include manatee salvage programs, population biology research, population surveys, habitat protection, public awareness programs, and growth management activities. Thirteen counties in Florida were designated in 1989 as "key" counties by the Governor of the State of Florida. This designation recognized the necessity of implementing protection measures in these counties, where 80 percent of the manatee mortalities occurred.

Accomplishments resulting from this collaboration include: (1) the protection of essential and critical manatee habitat, (2) implementation of speed zones in manatee-sensitive areas, (3) increased public awareness and support, (4) the initiation of a manatee rescue, rehabilitation and release network, and (5) advanced techniques for surveying and tracking manatees (FWS 1996).

Identify and Minimize Causes of Manatee Injury and Mortality

In response to the high number of manatee deaths due to floodgates and navigation locks, efforts began in the early 1980s to modify gate opening procedures to ensure manatees were not killed. A task force with representatives from the FWS, SFWMD, the COE, the DEP, and the Miami-Dade County DERM are overseeing ways to reduce these deaths. As a result of these efforts, the number of manatees killed by floodgates and canal locks declined between 1976 and 1980. The COE, SFWMD, and Harbor Branch Oceanographic Institution are developing and testing automatic reversal mechanisms to prevent manatee deaths. When these technologies become available, the COE will retrofit the structures with the mechanisms, in accordance with section 1135 of the Water Resources Development Act of 1986, as amended.

The FWS, through section 7 of the ESA, reviews permit applications for various projects that may affect manatees. As part of these reviews, the FWS recommends ways to avoid, reduce, or minimize the effects of projects on manatees. In addition, the FWS has developed speed and access rules for motorboats within the boundaries of Merritt Island NWR, and similar guidelines are being recommended for other Federal facilities in manatee habitat. The DEP, through its manatee protection plan, is developing guidelines to reduce manatee watercraft injuries and deaths by implementing waterway speed and access (*e.g*., no entry) zones in the 13 key counties.

Public education is an important management tool in protecting and recovering the manatee. Several groups, especially the Save the Manatee Club, have participated in the efforts to educate the public about manatee protection and habitat conservation, including ways to decrease the number of boat-caused manatee deaths, improve water quality, and reduce habitat degradation. The FWS is coordinating with the COE to develop manatee education and boating programs for proposed projects such as marinas, boating facilities, and boat ramps in an effort to reduce the number of manatees killed in collisions with watercraft.

Protect Essential Manatee Habitat

Through the NWR System, the FWS has acquired thousands of acres of land important to manatees in the Crystal, Homosassa, and Suwannee rivers. Three new manatee sanctuaries have been established in Florida, as well as a motorboat-prohibited area in the Merritt Island NWR and the Kennedy Space Center. The State of Florida has several programs to protect and acquire lands including the Conservation and Recreational Lands (CARL) Program which dedicates five percent of its program budget to habitat-related purchases for the manatee.

Determine and Monitor the Status of Manatee Populations

Several groups have contributed to the overall understanding and information available on the life history of the manatee, including the FWS, Sirenia, DEP, Georgia DNR, academic institutions, and marine zoological parks. Important components of past and ongoing research efforts include the carcass recovery and necropsy program, radio tracking and satellite telemetry studies on manatee movements and habitat use, the manatee individual photo-identification system (MIPS), aerial surveys to determine minimum population size and identify distribution patterns, a geographical information system (GIS) database to integrate available manatee information, and several additional studies on manatee biology and ecology.

Advance Techniques to Protect Manatees

The FWS established the Interagency/Oceanaria Working Group to coordinate captive manatee management and rehabilitation. An extensive program is now in place to facilitate the rescue, rehabilitation, and release of manatees. Several long-term captive manatees have been direct-released in Everglades NP, and monitoring of these individuals continues.

Literature Cited

Ackerman, B.B., S.D. Wright, R.K. Bonde, C.A. Beck, and D.J. Banowetz. 1995. Analysis of watercraft-related mortality of manatees in Florida, 1979-1991. Pages 259-268 *in* T.J. O'Shea, B.B. Ackerman, and H.F. Percival, eds. Population biology of the Florida manatee: Information and technology report I. U.S. Department of the Interior, National Biological Service; Washington, D.C.

Ackerman, B.B, S.D. Wright, R.K. Bonde, D.K. Dell, and D. Banowetz. 1992. Trends and patterns in manatee mortality in Florida, 1974-1991. Page 22 *in* T.J. O'Shea, B.B. Ackerman, and H.F. Percival, eds. Interim report of the technical workshop on manatee population biology. Manatee population research report no. 10. Florida Cooperative Fish and Wildlife Research Unit, University of Florida; Gainesville, Florida.

Beeler, I.E. and T.J. O' Shea. 1988. Distribution and mortality of the West Indian manatee (*Trichechus manatus*) in the southeastern United States: a compilation and review of recent information. Report prepared by the U.S. Fish and Wildlife Service for the U.S. Army Corps of Engineers. PB 88-207 980/AS. National Technical Information Service; Springfield, Virginia.

Bengtson, J.L. 1983. Estimating food consumption of free-ranging manatees in Florida. Journal of Wildlife Management 47: 1186-1192.

Bengtson, J.L. 1981. Ecology of manatees in the St. Johns River, Florida. Ph.D. dissertation. University of Minnesota; Minneapolis, Minnesota.

Bernier, B.J. 1985. A comparison of differences in behaviors of captive-born and natural-born manatees (*Trichechus manatus*) as a measure of adjustment to a contained natural environment. Master's Thesis, Florida Institute of Technology; Melbourne, Florida.

Curran, A.P. 1989. Analysis of the effect of boat traffic on manatee (*Trichechus manatus*) densities in four selected study areas in Brevard County, Florida. Unpublished master's thesis, Florida Institute of Technology; Melbourne, Florida.

Domning, D.P. 1982. Evolution of manatees: a speculative history. Journal of Paleontology 56(3): 599-619.

Domning, D.P., G.S. Morgan, and C.E. Ray. 1982. North American Eocene sea cows (Mammalia: Sirenia). Smithsonian Contributions to Paleobiology; Washington, D.C.

Domning, D.P. and L.C. Hayek. 1986. Interspecific and intraspecific morphological variation in manatees (Sirenia: Trichechus). Marine Mammal. Science. 2:87-144.

Eberhardt, L.L. and T.J. O'Shea. 1995. Integration of manatee life-history data and population modeling. Pages 269-279 *in* T.J. O'Shea, B.B. Ackerman, and H.F. Percival, eds. Population biology of the Florida manatee: Information and technology report I. U.S. Department of the Interior, National Biological Service; Washington, D.C.

Florida Department of Environmental Protection. 1998. Manatee salvage data base: Summary report. Florida Marine Research Institute; St. Petersburg, Florida.

Florida Department of Natural Resources [DEP]. 1994. Manatee salvage data base: Summary report. Florida Department of Natural Resources, Florida Marine Research Institute; St. Petersburg, Florida.

Garrot, R. A., B.A. Ackerman, J.R. Cary, D.M. Heisey, J.E. Reynolds III, P.M. Rose, and J. R. Wilcox. 1994. Trends in counts of Florida manatees at winter aggregation sites. Journal of Wildlife Management 58(4): 642-654.

Garrott, R.A., B.A. Ackerman, J.R. Cary, D.M. Heisey, J.E Reynolds, III, and J.R. Wilcox. 1995. Assessment of trends in sizes of manatee populations at several Florida aggregation sites. Pages 34-55 *in* T.J. O'Shea, B.B. Ackerman, and H.F. Percival, eds. Population biology of the Florida manatee: Information and technology report I. U.S. Department of the Interior, National Biological Service; Washington, D.C.

Gerstein, E.R. 1994. Hearing abilities of the West Indian manatee (*Trichechus manatus*). Manatee hearing study, phase I: Experiments 1, 2, & 3. Technical report no. 119. Florida Atlantic University; Boca Raton, Florida.

Gunter, G. 1941. Occurrence of the manatee in the United States, with records from Texas. Journal of Mammalogy 22: 60-64.

Haddad, K. and F. Sargent. 1994. Scars under the water. The Florida Naturalist Winter: 9-11.

Harlan, R. 1824. On a species of lamantin (*Manatus latirostris* n.s.) resembling *Manatus senegalensis* (Cuvier) inhabiting the east coast of Florida. Journal of Academy of Natural Science Philadelphia 3: 390-394.

Hartman, D.S. 1979. Ecology and behavior of the manatee (*Trichechus manatus*) in Florida. Special publication: American Society of Mammologists special report no. 5: 1-153.

Hartman, D.S. 1974. Distribution, status and conservation of the manatee in the United States. National technical information service. PB81-140725; Springfield, Virginia.

Hatt, R. 1934. A manatee collected by the American Museum Congo Expedition, with observations on the recent manatees. Bulletin of American Museum of Natural History 66: 533-536.

Hernandez, P., J.E. Reynolds, III, H. Marsh, and M. Marmontel. 1995. Age and seasonality in spermatogenesis of Florida manatees. Pages 84-97 *in* T.J. O'Shea, B.B. Ackerman, and H.F. Percival, eds. Manatee population biology of the Florida manatee, information and technology report I. U.S. Department of the Interior; Washington, D.C.

Hurst, L.A. and C.A. Beck. 1988. Microhistological characteristics of selected aquatic plants of Florida with techniques for the study of manatee food habits. U.S. Department of Interior, Fish and Wildlife Service, Research and Development, biological report 88(18); Gainesville, Florida.

Husar, S.L. 1978. *Trichechus manatus*. Mammalian species no. 93: 1-5.

Husar, S.L. 1977. The West Indian manatee (*Trichechus manatus*). United States Department of Interior, Fish and Wildlife Service, Wildlife research report 7; Washington, D.C.

Irving, A.B. and H.W. Campbell. 1978. Aerial census of the West Indian manatee, *Trichechus manatus*, in the southeastern United States. Journal of Mammalogy 59: 613-617.

Kadel, J.J. and G.W. Patton. 1991. Aerial studies of the West Indian manatee (*Trichechus manatus*) on the west coast of Florida from 1985-1990: A comprehensive six year study. Mote Marine Laboratory technical report no. 246; Sarasota, Florida.

Ketten, D.R., D.K. Odell and D.P. Domning. 1992. Structure, function, and adaptation of the manatee ear. Pages 77-95 *in* J. Thomas, R.A. Kastelein, and A. Ya. Supin (eds.) Marine mammal sensory systems. Plenum Press, New York.

Kinnaird, M.F. 1983. Evaluation of potential management strategies for the reduction of boat-related mortality of manatees. Research report number 3, Florida Cooperative Fish and Wildlife Research Unit, U.S. Fish and Wildllife Service.

Lefebvre, L.W., B.B. Ackerman, K.M. Portier, and K.H. Pollock. 1995. Aerial survey as a technique for estimating trends in manatee population size-problems and prospects. Pages 63-74 *in* T.J. O'Shea, B.B. Ackerman, and H.F. Percival, eds. Population biology of the Florida manatee: Information and technology report I. U.S. Department of the Interior, National Biological Service; Washington, D.C.

Lefebvre, L.W., T.J. O'Shea, G.B. Rathbun, and R.C. Best. 1989. Distribution, status, and biogeography of the West Indian manatee. Pages 567-610 *in* C.A. Wood, ed. Biogeography of the West Indies. Sandhill Crane Press; Gainesville, Florida.

Lefebvre, L.W. and J.A. Powell. 1990. Manatee grazing impacts on seagrasses in Hobe Sound and Jupiter sounds in southeast Florida during the winter of 1988-89. Prepared for the U.S. Marine Mammal Commission; Washington, D.C.

Longieliere, T.J. 1994. Manatee spatial and temporal distribution between the Sebastian and St. Lucie inlets, Florida, during the winter and spring 1993-1994. Unpublished M.S. thesis. Florida Institute of Technology; Melbourne, Florida.

Lowery, J.H., Jr. 1974. The mammals of Louisiana and its adjacent waters. Louisiana University Press.

Manatee Technical Advisory Council [MTAC]. 1994. Update. Florida Department of Environmental Protection; Tallahassee, Florida.

Marine Mammal Commission [MMC]. 1992. Annual report to Congress, 1991. Marine Mammal Commission; Washington, D.C.

Marmontel, M. 1993. Age determination and population biology of the Florida manatee, *Trichechus manatus latirostris*. Unpublished Ph.D. dissertation. University of Florida; Gainesville, Florida.

Marmontel, M., D.K. Odell, and J.E. Reynolds III. 1992. Reproductive biology of South American manatees. Pages 293-312 *in* W.C. Hamlett, ed. Reproductive biology of South American vertebrates. Springer-Verlag; New York, New York.

Moore, J.C. 1951. The range of the Florida manatee. Quarterly Journal Florida Academy of Science 14: 1-19.

Odell, D.K. 1982. The West Indian manatee, *Trichechus manatus* Linnaeus. Pages 828-837 *in* J.A. Chapman and G.A. Feldhamer, eds. Wild mammals of North America. John Hopkins University Press; Baltimore, Maryland.

Odell, D.K. 1981. Growth of a West Indian manatee, *Trichechus manatus*, born in captivity. Pages 131-140 *in* R.L. Brownell, Jr. and K. Ralls, eds. The West Indian manatee in Florida. Proceedings of a workshop held in Orlando, Florida 27-29 March 1978. Florida Department of Natural Resources; Tallahassee, Florida.

Odell, D.K., G.D. Bossart, M.T. Lowe, and T.D. Hopkins. 1995. Reproduction of the West Indian manatee, *Trichechus manatus*, in captivity. Pages 192-193 *in* T.J. O'Shea, B.B. Ackerman, and H.F. Percival, eds. Population biology of the Florida manatee. National Biological Service Information and technology report 1.

O'Shea, T.J. 1995. Waterborne recreation and the Florida manatee. Pages 297-311 *in* R.L. Knight and K.J. Gutzwiller, eds. Wildlife and Recreationists: Coexistence through management and research. Island Press; Washington, D.C.

O'Shea, T.J. 1988. The past, present, and future of manatees in the southeastern United States: Realities, misunderstandings, and enigmas. Pages 184-204 *in* R.R. Odum, K.A. Riddleberger, and J.C. Ozier, eds. Proceedings of the third southeastern nongame and endangered wildlife symposium. Georgia Department of Natural Resources, Game and Fish Division; Atlanta, Georgia.

O'Shea, T.J., B.B. Ackerman, and H.F. Percival, eds. 1992. Interim report of the technical workshop on manatee population biology. Manatee population research report no. 10. Florida Cooperative Fish and Wildlife Research Unit, University of Florida; Gainesville, Florida.

O' Shea, T.J., C.A. Beck, R.K. Bonde, H.I. Kochman, and D.K. Odell. 1985. An analysis of manatee mortality patterns in Florida 1976-1981. Journal of Wildlife Management 49: 1-11.

O'Shea, T.J. and M.E. Ludlow. 1992. Florida manatee. Pages 190-200 *in* S.R. Humphrey, ed. Rare and endangered biota of Florida. Volume I. Mammals. University Press of Florida; Gainesville, Florida.

Packard, J.M. 1985. Preliminary assessment of uncertainty involved in modeling manatee populations. Manatee population research report no. 9. Technical report no. 8-9. Florida Cooperative Fish and Wildlife Research Unit. University of Florida; Gainesville, Florida.

Powell J.A., Jr. 1978. Evidence of carnivory in manatees (*Trichechus manatus*). Journal of Mammalogy 59(2): 442.

Powell, J.A. and G.B. Rathbun. 1984. Distribution and abundance of manatees along the northern coast of the Gulf of Mexico. Northeast Gulf Science 7(1): 1-28.

Provancha, J.A. and C.R. Hall. 1991. Observations of associations between seagrass beds and manatees in east central Florida. Florida Scientist 54(2): 87-98.

Rathbun, G.B. 1984. Sirenians. Pages 537-547 *in* S. Anderson and J.K. Jones, Jr., eds. Orders and families of recent mammals of the world. John Wiley and Sons, Inc.; New York, New York.

Rathbun, G.B., J.P. Reid, R.K. Bonde, and J.A. Powell. 1992. Reproduction in free-ranging West Indian manatees (*Trichechus manatus*). Pages 19-20 *in* T.J. O'Shea, B.B. Ackerman, and H.F. Percival, eds. Interim report of the technical workshop on manatee population biology. Manatee population research report no. 10. Florida Cooperative Fish and Wildlife Research Unit, University of Florida; Gainesville, Florida.

Rathbun, G. B., J. P Reid, and G. Carowan. 1990. Distribution and movement patterns of manatees (*Trichechus manatus*) in northwestern peninsular Florida. State of Florida, Department of Natural Resources, Florida Marine Research Institute, Florida Marine Research Publications, no. 48; St. Petersburg, Florida.

Reeves, R. R., B.S. Stewart, and S. Leatherwood. 1992. West Indian (Caribbean, Florida) manatee, *Trichechus manatus*. Pages 260-270 *in* The Sierra Club handbook of seals and sirenians. Sierra Club Books; San Francisco, California.

Reid, J.P., R.K. Bonde, and T.J. O'Shea. 1992. Reproduction, mortality, and tag loss of telemetered and recognizable individual manatees on the Atlantic Coast of Florida. Pages 20-21 *in* T.J. O'Shea, B.B. Ackerman, and H.F. Percival, eds. Interim report of the technical workshop on manatee population biology. Manatee population research report no. 10. Florida Cooperative Fish and Wildlife Research Unit, University of Florida; Gainesville, Florida.

Reid, J. P., G. B. Rathbun, and J. R. Wilcox. 1991. Distribution patterns of individually identifiable West Indian manatees (*Trichechus manatus*) in Florida. Marine Mammal Science 7(2): 180-190.

Reinhart, R.H. 1951. A new genus of sea cow from the Miocene of Columbia. University of California Department of Geological Science series B 28: 203-213.

Reinhart, R.H. 1959. A review of the Sirenia and Desmostylia. University of California Publications of Geological Science 36: 1-146.

Reynolds, J.E. 1979. Internal and external morphology of the manatee (sea cow). The Anatomical Record 193 (3): 663.

Reynolds, J.E., III. 1981. Behavior patterns in the West Indian manatee, with emphasis on feeding and diving. Florida Scientist 44(4): 233-241.

Simpson, G.G. 1932. Fossil Sirenia of Florida and the evolution of the Sirenia. Bulletin of the American Musuem of Natural History 59: 419-503.

Smith, K.N. 1993. Manatee habitat and human-related threats to seagrass in Florida: A review. Department of Environmental Protection, Division of Marine Resources; Tallahassee, Florida.

U.S. Geological Service Biological Resources Division.[USGS/BRD] 1993. Annual report on the radio telemetry of manatees in Puerto Rico. Sirenia Project; Gainesville, Florida.

U.S. Fish and Wildlife Service [FWS]. 1996. Florida manatee recovery plan. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Wright, S.D., B.B. Ackerman, R.K. Bonde, C.A. Beck, and D.J. Banowetz. 1995. Analysis of watercraft-related mortality of manatees in Florida, 1979-1991. Pages 259-268 *in* T.J. O'Shea, B.B. Ackerman, and H.F. Percival, eds. Population biology of the Florida manatee: Information and technology report I. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Wright, S.D., B.B. Ackerman, R.K. Bonde, C.A. Beck, and D.J. Banowetz. 1992. Analysis of watercraft-related mortality of manatees in Florida, 1979-1991. Page 23 *in* T.J. O'Shea, B.B. Ackerman, and H.F. Percival eds. Interim report of the technical workshop on manatee population biology. Manatee population research report no. 10. Florida Cooperative Fish and Wildlife Research Unit, University of Florida; Gainesville, Florida.

Zieman, J.C. 1982. The ecology of the seagrasses of south Florida: a community profile. U.S. Fish and Wildlife Service, Office of Biological Services; Washington, D.C. FWS/OBS-82/25.

Recovery for the West Indian Manatee

Trichechus manatus

Recovery Objective: **RECLASSIFY** to threatened, then delist.

South Florida Contribution: Reduce human-related mortality in South Florida; control or reduce threats to essential manatee habitat in South Florida.

Recovery Criteria

The statewide manatee recovery plan states that the West Indian manatee can be considered for reclassification to threatened when data and population models are available to assess population size and trends; when analyses indicate that the population is growing or stable; when mortality factors are controlled at acceptable levels or are decreasing; and when critical habitats are secure and threats to them are controlled or decreasing (FWS 1996).

Species-level Recovery Actions

S1. **Support the investigation of the distribution and status of the manatee and its habitat in South Florida by continuing flying synoptic statewide aerial surveys.** Aerial survey sighting data have provided and continue to provide useful data on manatee distribution and, in some situations, relative abundance. When combined with telemetry data, certain types of aerial sightings provide a sound basis for determining habitat use patterns. Aerial sightings also provide useful information on the proportion of calves. Because of uncertainty in the number of animals not seen in turbid water, uncertainty as to the proportion of the population within a survey area, and other problems, however, aerial sighting data generally do not permit scientists to estimate or detect trends in population size.

S1.1. **Continue flying synoptic statewide aerial surveys.** In 1991, the Florida Marine Research Institute began flying coordinated statewide aerial surveys of all known winter manatee habitat. The surveys are flown following cold fronts when manatees aggregate at warm water refuges in greatest numbers. They involve large numbers of observers flying simultaneously over different segments of known winter manatee habitat. Although problems limit the use of this sighting data to measure population size or trends, the surveys have provided high counts that improve the lower bound of the range of the estimated number of animals. If correction factors for uncertainties noted above can be developed, the resulting data also may be used in the future to determine population trends. As appropriate, such surveys should be continued. For South Florida, aerial surveys should emphasize both manmade and natural warmwater sites; particularly the waterways of Florida Bay and Everglades NP.

S1.2. Undertake regional or local aerial surveys. In some areas, aerial surveys are needed to improve information on local habitat use patterns. The information obtained through these surveys has been an important basis for developing and analyzing new speed zones and other management measures. As appropriate and possible, local aerial surveys should be undertaken or continued in the Indian, Miami, and Caloosahatchee rivers; Sarasota, Estero, and Rookery bays; Coral Gables Waterway, Ten Thousand Islands region, and Whitewater Bay as well as other areas to improve information on local habitat use patterns and trends in relative abundance.

S1.3. Continue aerial surveys of aggregation sites after cold fronts. Florida Power & Light Company has supported aerial surveys of manatees at warm-water powerplant outfalls each winter since 1977. In addition to data on the numbers of animals sighted at these warm-water refuges, this long-term data set includes calf counts that provide valuable information on reproduction. If correction factors can be developed to account for sighting uncertainties, the data may be useful in the future for assessing past population trends.

S1.4. Support a dedicated aerial survey specialist and convene an Aerial Survey Working Group. During a 1992 workshop on manatee population biology (O'Shea *et al.* 1992), participants reviewed aerial survey methodology and identified steps that might be taken to improve information generated by aerial surveys. Participants concluded that better interpretation of aerial data could help detect regional (though perhaps not statewide) trends in abundance. Improvements are needed in stratifying survey effort by type, refining information on diving behavior, defining acceptable sighting conditions, and testing strip transect methodology. A dedicated aerial survey specialist should be supported to monitor progress on aerial survey research, improve survey methodology, and develop correction factors for sighting uncertainties. In addition, an Aerial Survey Working Group chaired by the specialist should be convened at least annually to provide further advice and assistance.

S1.5. Analyze available aerial survey data. Re-evaluate the results of past aerial surveys to improve estimates of selected parameters and population trends. Aerial survey data sets should be evaluated regionally to determine whether they are sufficiently complete and up-to-date. Areas that need to be resurveyed should be identified. In addition, new methodologies and analytical techniques might be applied to ongoing aerial surveys. As possible, such analyses should be undertaken.

S2. Protect and enhance existing populations by identifying and minimizing causes of manatee injury, mortality, and disturbance. Manatees are killed and injured as a result of interactions with boats, floodgates, navigation locks, marine debris, and fishing gear. In rare cases, manatees are killed by vandals and poachers. Additional mortalities, from natural causes such as severe cold weather or red tide, may also significantly affect the status of the manatee population. To permit growth of the manatee population and reach an optimal sustainable population level, such causes of mortality must be reduced. This section of the recovery plan identifies activities needed to monitor and reduce such sources of mortality.

S2.1. Maintain and improve the salvage and necropsy program. The manatee salvage/necropsy program is fundamental to identifying causes of manatee mortality and injury. The program is responsible for collecting and examining virtually all manatee carcasses reported in the southeastern U.S., determining the causes of death, monitoring mortality trends, and disseminating mortality information. Program data help identify, direct, and support essential management actions (*e.g*., promulgating watercraft speed rules and reviewing permits for construction in manatee habitat). The program was begun by the Sirenia Project and the University of Miami in 1974. Procedures and protocols to standardize necropsies were developed in the early 1980s (Bonde *et al*. 1983) and expanded significantly early in the 1990s. Now part of the DEP's Florida Marine Research Institute, the major program duties include: receiving manatee carcass reports from the field; collecting and examining dead animals; maintaining accurate mortality records; and carrying out special studies to improve understanding of mortality causes, rates, and trends. Program staff also coordinate rescues of injured or distressed manatees.

S2.1.1. Ensure prompt and complete reporting of manatee carcasses. To obtain manatee carcasses for necropsy, the carcass recovery and necropsy program relies on reports of carcasses from members of the public. These reports are usually provided through the Florida Marine Patrol, officers in the GFC, or local officials. To provide the best possible understanding of manatee mortality causes and trends, it is important not only to obtain as many reports as possible, but also to assure that reports are received promptly so that carcasses are as fresh as possible when necropsied. The following tasks will facilitate reporting from the field.

S2.1.1.1. Provide training for law enforcement officials on carcass reporting procedures. Most manatee carcasses are found by the public and reported to the Florida Marine Patrol or local law enforcement officials. To ensure that program staff are notified of all reported carcasses, officials likely to receive such reports need to be advised and reminded of the data needs and procedures for reporting carcasses to the salvage and necropsy program staff and the importance of doing so promptly. Periodic presentations by program staff and/or mailings should be made to the Florida Marine Patrol Academy, to Florida Marine Patrol officers in the field, and to other law enforcement groups, such as the GFC, the U.S. Coast Guard, local police departments, and county sheriffs. To maintain interest and involvement, efforts to provide feedback to law enforcement officials on the results of necropsies and program findings should be undertaken routinely.

S2.1.1.2. Encourage public reporting of carcasses. Most manatee carcasses are found by boaters, shoreline residents, and other members of the public frequenting waterways and shorelines. To increase public reporting, information on procedures for reporting carcasses and the importance of doing so promptly should be included in posters and appropriate public education materials. Periodic mailings and/or presentations and public service announcements targeting appropriate groups such as homeowners associations, boating, diving, and fishing groups, and others should be prepared and sent.

S2.1.2. Maintain salvage and necropsy field stations and staff. The salvage and necropsy program includes a central necropsy facility operated by DEP at Eckerd College in St. Petersburg, three field stations on the east coast located at Jacksonville, Melbourne, and Tequesta, and one field station on the west coast at Port Charlotte. The stations collect, examine, and dispose of carcasses, and record, analyze, and distribute mortality data. Support must be provided to maintain an adequate program staff and provide the necessary equipment.

S2.1.2.1. Provide support for salvage and necropsy program staff and equipment. Salvage and necropsy program staff are part of DEP's Florida Marine Research Institute. Field station personnel are responsible for promptly collecting dead animals and related data in the field and transporting the carcasses to the central necropsy facility. The central facility's staff is responsible for conducting all necropsies; collecting, examining, and archiving tissue samples; distributing tissue samples to other researchers; photo-documenting wounds and scars on all salvaged carcasses; recording and analyzing data; performing special studies; preparing monthly and annual mortality summary reports; and administering and coordinating all salvage and necropsy program work. Staffing must be continued to properly conduct this program. In addition, annual funding is needed to repair, replace, upgrade, and otherwise maintain such equipment and supplies necessary to carry out necropsy work.

S2.1.2.2. Develop and coordinate out-of-state salvage efforts. During summer, some Florida manatees migrate north into Georgia, South Carolina, North Carolina, and Virginia or west into Alabama and Louisiana. To maintain accurate mortality data, arrangements are needed to collect carcasses and data from animals that die in these areas. This requires (1) alerting State and local officials in these areas of the importance of reporting dead manatees, and (2) supporting travel and other expenses associated with collecting carcasses and mortality data. The FWS and the salvage and necropsy program staff should cooperate in contacting appropriate officials outside of Florida to alert them as to reporting needs and procedures for manatee carcasses found in their respective areas, and ensuring funds are available for collecting manatee carcasses and mortality data promptly.

S.2.1.3. Undertake special studies and analyses to improve understanding of mortality causes and trends. Special studies are needed to better define and explain various factors, phenomena, or events influencing poorly understood mortality trends.

S2.1.3.1. Assess manatee carcass reporting rates. While it is believed that most dead manatees are found and reported, an unknown proportion go unreported, resulting in an under-representation of annual manatee mortality totals. To assess the number of manatee carcasses that go unreported, studies of carcass detection and reporting rates should be undertaken.

S2.1.3.2. **Undertake a workshop and/or studies to identify the proximal cause(s) of perinatal mortality.** In recent years, perinatal mortality has increased at a rate greater than any other mortality category and now constitutes approximately 25 percent of the total annual mortality. The causes of increased perinatal mortality are uncertain. It may be related to pollution, injuries and stress from increased vessel traffic and other human activities, changes in the age structure of mature breeding females, habitat changes, or some combination of these and other possible causes. It also may be due to a greater number of births. A workshop should be held to investigate available information on perinatal mortality, research needs, and mitigation measures. Possible contributing factors and any regional differences should be examined.

S2.1.3.3. **Undertake routine and periodic tissue analyses.** To obtain maximum information from carcasses and wild and rescued manatees, it is necessary to examine and analyze tissues for contaminant levels, reproductive status, age at death, *etc.* In addition, to improve understanding of disease and immunotoxicological processes, salvaged tissues, organs, and organ systems should be studied. Serum from wild and rescued manatees should also be screened to assess the incidence of exposure to various viral, bacterial, parasitic and other pathogenic organisms. A centralized serum bank should be established to analyze diseases.

S2.1.3.4. **Investigate and respond to potential unusual mortality events.** From time to time there are unusual mortality events in which large numbers of manatees die or become moribund. For example, over 45 animals died in association with a severe cold front in late December 1989, and at least 149 animals died in association with a red tide event that struck southwest Florida populations in 1996. A plan for responding to such an event has been prepared by the FWS as required by the Marine Mammal Stranding Act of 1992. If a large-scale mortality event occurs, the FWS and the salvage and necropsy program will need to coordinate response efforts using contingency plans and funding specifically designed for these events.

S2.2. **Minimize collisions between manatees and watercraft.** The largest source of human-related manatee mortality is collisions between manatees and watercraft. Known watercraft deaths now constitute at least 20 to 22 percent of the total known annual mortality. Watercraft may cause additional deaths or reduced population growth due to indirect effects of injuries and stress on the reproductive success of mature females (Marine Mammal Commission 1993). Actions to address specific needs are discussed below.

S2.2.1. **Develop and refine State waterway speed and access rules.** The State of Florida has begun promulgating waterway speed and access rules to reduce the number of collisions between manatees and watercraft. The rules seek to create a system of speed and access zones tailored to local manatee habitat use-patterns and boating needs. Rulemaking is an intensive process that requires compiling and reviewing voluminous site-specific environmental data, particularly on manatee habitat-use patterns and boating activity; extensive coordination between county and DEP officials to develop rule provisions; public hearings and review; and approval by the Secretary of DEP. As directed by the Florida Governor and Cabinet in 1989, priority attention has been focused toward 13 key counties. Rules for 12 of the 13 key counties are complete. Over the next 5 years, the need for manatee protection measures in the remaining key county and some 20 other counties with important manatee habitat should be considered. Also, rule refinements likely will be needed to increase rule and sign uniformity and to reflect new information on manatee habitat-use patterns and boating activity.

S2.2.2. **Develop and refine Federal waterway speed and access rules.** For certain Florida waterways, particularly those in or adjacent to NWRs, the FWS has promulgated Federal rules regulating vessel speed and access. These rules, which complement State rules, are issued under authority of the ESA, the Marine Mammal Protection Act, and/or the NWR System Administration Act. Federal rules issued by the COE to control vessel speeds adjacent to navigation locks also may enhance manatee protection. Although the principal purpose of the latter rules is vessel safety around navigation locks, they also reduce the risk of manatee-vessel collisions and should be encouraged for both reasons at locks used by manatees along the Okeechobee Waterway, Cross Florida Barge Canal, and elsewhere. As necessary and appropriate, such Federal rules should be modified and new rules promulgated in cooperation with the State of Florida and other concerned parties.

S2.2.3. **Post and maintain regulatory signs.** To advise watercraft operators of speed and access restrictions, regulatory signs are posted strategically along waterways. As proper posting is a prerequisite for enforcing and prosecuting violations, signage is as important as the rules themselves. The extensive new rules necessitate posting thousands of new signs along thousands of miles of waterway. On the east coast, the Florida Inland Navigation District is responsible for sign posting and maintenance. Elsewhere the task is shared by the DEP, the West Coast Inland Navigation District, and the counties. Once county rules are adopted, the DEP's Office of Protected Species Management develops or reviews signage plans, the Florida Marine Patrol issues permits for sign placement, and the entity responsible for printing and posting then proceeds with actual posting. As rules are completed or modified, signs should be posted promptly by the responsible agency. Once posted, they should be inspected periodically and repaired or replaced as needed. Signage changes may be warranted based on enforcement or navigation needs or efforts to make sign messages clearer and more uniform.

S2.2.4. **Enforce and encourage manatee protection regulations.** The Florida Marine Patrol is the principal agency in Florida responsible for enforcing speed and access rules as well as other manatee protection rules. Federal and State officers assigned to selected parks, refuges, and reserves, the GFC, and the U.S. Coast Guard also assist with enforcement. Effective enforcement requires training to ensure that officers are aware of the purposes and provisions of the rules and how to enforce them. It also requires cooperation among various Federal and State enforcement officials, and the judiciary.

S2.2.4.1. **Focus and increase officer time dedicated to enforcing manatee protection rules.** Manatee protection rules are but a few of the myriad of rules which law enforcement officers must enforce. To maximize the effectiveness of enforcing rules concerning manatees, steps should be taken to: (1) concentrate efforts at times and areas where boat and manatee densities are greatest; (2) increase the amount of time dedicated to enforcing manatee protection rules; and (3) provide speed guns and training to appropriate field officers. The Florida Marine Patrol, GFC, the Office of Protected Species Management, and the FWS should periodically review needs and strategies for concentrated enforcement efforts.

S2.2.4.2. **Develop and implement a strategic plan to strengthen cooperative interagency enforcement.** Enforcement of manatee protection rules involves field officers in various Federal, State, and local agencies as well as judicial, legislative, and regulatory support. Although waterway speed and access rules demand the greatest time and effort to administer, rules for poaching, incidental take in fisheries, harassment, *etc*., also require attention. A strategic enforcement plan should be developed and implemented to establish a cooperative interagency field enforcement network that is backed by a supportive judiciary and legislature. The strategic plan should address interagency agreements as may be needed for effectively cross-deputizing and coordinating Federal, State, and local field officers; develop and update officer training programs and explanatory materials on manatee protection rules and enforcement needs; conduct periodic training and refresher courses for enforcement units at all levels; coordinate interagency enforcement exercises; make regulations as clear and as uniform as possible; educate the judiciary and otherwise facilitate prosecutions of manatee-related rule violations; and work with the legislature to ensure fines, penalties, and other statutory provisions are clear and as effective as possible.

S2.2.4.3. **Conduct surveys to assess compliance with rules.** Field surveys should be done to monitor the extent to which watercraft comply with regulatory measures. Periodic surveys on selected waterways in each key county should be undertaken.

S2.2.4.4. **Encourage and cooperate with efforts to develop unified statewide boating safety measures.** Proposals for state-wide speed limits, boat operator licenses, and mandatory boater education have been considered in the past. Such measures would complement and enhance efforts to reduce watercraft-related manatee deaths by offering opportunities to educate boaters about manatees. Although such boating safety measures have been rejected to date, similar measures may be proposed and adopted in the future. To the extent possible, new proposals to establish statewide boating safety measures should be encouraged. Particular efforts should be made to integrate manatee protection concerns into any new boater education programs.

S2.2.5. **Establish policies for authorizing boat races and other water sport events.** Certain organized water sports events, such as boat races, water-ski contests, and fishing tournaments, involve boats traveling at high speed. In certain areas and times, these activities pose threats to manatees. Permits for such events typically are required from the U.S. Coast Guard. The U.S. Coast Guard considers advice from the FWS and DEP on whether a permit should be granted, denied, or granted conditionally given possible effects on manatees. To help planning for boat races, representatives from DEP, the FWS, and boat racing organizations developed guidelines on when, where, and under what conditions such events could be held consistent with manatee protection objectives. The guidelines are used by the FWS and DEP to review permit requests and by event organizers to plan events. The FWS and DEP should keep such guidelines under review and modify or expand them as needed to address other types of water sport events. The FWS, and the U.S. Coast Guard should continue to consult on the issuance of permits for sporting events that involve high speed boats in manatee habitat.

S2.2.6. **Indicate speed and access zones on nautical charts.** NOAA publishes nautical charts and a "Coast Pilot" to help vessel operators navigate in coastal waters. As new speed and access rules are adopted, NOAA and other organizations publishing navigation charts should update their publications.

S2.2.7. **Assess and reduce mortality caused by large vessels.** Large slow-moving ships (*e.g.*, tugs and cargo vessels) are known to kill manatees. Some animals appear to be pulled into propeller blades by the sheer power of generated water currents and others are crushed between the bottom and the hull of deep-draft ships. When moored, large vessels also can crush manatees between their hulls and adjacent wharves or ships. To prevent the latter problem, some ports (*e.g.*, the Mayport Naval Station) have begun using fenders to maintain minimum stand-off distances between moored vessels and wharves. To address the threat of propellers on large tugs operating at the Kings Bay Naval Base, the Navy recently designed and installed propeller shrouds on its C-tractor tugs. These approaches may be useful in other areas.

To consider applying such measures more widely, a study should review mortality data for evidence of deaths attributable to large vessels; examine barge, tug, and other large vessel traffic patterns relative to manatee distribution; assess the feasibility and cost of installing propeller guards or shrouds on large vessels or tugs routinely plying waterways used by manatees; consider rules to require fenders when mooring large vessels in manatee habitat; evaluate ways to educate harbor pilots about the threats large vessels pose for manatees; and identify other possible mitigation measures. Actions to implement appropriate measures should be taken based on study findings.

S2.2.8. **Evaluate the feasibility of propeller guards or alternative propulsion technology for small watercraft.** In the past, propeller guards have been examined as a possible solution to recreational watercraft-related manatee mortality. They also have been considered for improving human safety and protecting seagrass beds. While new designs are developed periodically, their effect on vessel speed and steerage have discouraged general use. Broad use of propeller guards should reduce propeller-caused manatee injuries; however, it may only marginally reduce overall injuries and deaths since the impact of a propeller guard on a fast-moving boat is as injurious to manatees as the wounds from propellers. Nevertheless, as new designs are developed, they should be tested and evaluated. Once efficient and effective guards are available, incentive-based programs should be explored to encourage greater use of propeller guards.

S2.2.9. **Continue section 7 and State reviews of boating facilities and watersport events.** Marinas, boat ramps and other boating facilities increase local boat traffic. They can therefore influence the frequency of watercraft collisions with manatees in areas where manatees are common. Facility construction and the resulting traffic also can degrade habitat features, such as seagrass beds, which are important to manatees. Such facilities require permits from the COE, environmental resource permits from the DEP, and submerged land leases from Florida's Board of Trustees. As noted above, watersport events also may affect manatees and require permits from the U.S. Coast Guard. Under section 7 of the ESA and other Federal regulations, the FWS reviews and comments on permit applications whenever they may affect endangered species and other natural resources. This formal review process is a fundamental part of the manatee recovery program and must be continued.

S2.3. **Minimize manatee deaths in water control structures.** Late in the 1970s, eight to nine manatees per year were killed in floodgates and navigation locks. To reduce this mortality, steps were taken to modify gate opening procedures. Annual mortality initially decreased in the early 1980s. The number of deaths subsequently increased and in 1994, 16 deaths were recorded. An ad hoc interagency task force was established with representatives from the SFWMD, the COE, the FWS, and DEP to examine other steps to prevent such deaths. Support the development, testing, and implementation of new alternative measures at water control structures to reduce the number of manatee injuries and deaths. Coordinate with the South Florida Ecosystem Restoration Task Force to ensure alterations in the quantity or quality of water flow do not negatively affect the manatee and its habitat (*i.e.*, effects of alterations of water flow in the C & SF, Caloosahatchee River, St. Lucie Waterway, and Whitewater Bay).

S2.3.1. **Develop, test, and implement new alternative measures.** The interagency task force has identified several possible alternatives to reduce floodgate and navigation lock deaths. They include adjusting gate opening sequences, installing slotted gates or gates with new top-flow designed structures, adding detection devices to alert gate operators when manatees are present, and/or installing automatic door reversing mechanisms similar to safeguards on elevator doors. A pressure-sensitive unit has been designed and tested on two water control structures by the SFWMD with inconclusive results. The COE is preparing a Section 1135 Project Modification Report on Manatee Protection at Select Navigation and Water Control Structures. The devices and techniques that resulted from this study should be installed, tested for effectiveness, and implemented in a timely manner.

S2.3.2. **Promptly investigate structure-related deaths.** Gate-and lock-related manatee mortality should be kept under continual review by FWS, DEP, and the agencies directly responsible for the structures. Structures at which multiple deaths occur should be investigated immediately to identify and correct contributing factors.

S2.4. **Assess and minimize manatee injuries and deaths caused by fisheries.** In some years, as many as six manatees have been killed in commercial fishing gear. Most are caught and drowned in nets of inshore shrimp boats in northeast Florida; others are entangled in float lines for crab traps. Commercial fisheries in coastal Florida are managed cooperatively by the Florida Marine Fisheries Commission and the DEP. To minimize adverse interactions between fisheries and manatees, the following steps are needed.

S2.4.1. **Minimize manatee drownings in shrimp nets.** The Florida Marine Fisheries Commission has completed portions of a statewide shrimp fishery management plan. The Commission, DEP, and FWS should review and, as necessary, update measures to prevent manatees from being caught and drowned in shrimp nets. As an initial step, DEP has printed and distributed brochures to advise shrimp fishermen of the problem and the steps they can take to minimize drownings (*e.g.*, reducing tow times and immediately retrieving nets when heavy objects are encountered). If such education efforts do not resolve the problem, other measures (*e.g.*, gear, season, and/or area closures) should be considered, incorporated into the plan, and implemented.

S2.4.2. **Minimize injuries and deaths in crab pot lines and other fishing gear.** Manatees are entangled in crab pot float lines, various types of fishing nets, and monofilament line used by recreational fishermen. Information on interactions with such fishing gear should be kept under review by DEP and FWS. Steps should be taken to improve reporting of animals caught in fishing gear, particularly those that are released or escape alive.

Steps to identify and implement measures to reduce or avoid such interactions should be taken, if needed.

S2.4.3. **Identify locations where fishing gear impacts manatees and implement measures to mitigate impacts.** In certain areas where commercial and recreational fishing is particularly heavy and/or where manatees tend to aggregate, interactions with fishing gear may be particularly common. At some east coast aggregation sites, manatees are snagged by lines, lures, and treble hooks of recreational fishermen. These sites should be identified and, as warranted, steps should be taken to assess and implement actions to prevent potentially threatening interactions with fishing gear.

S2.5. **Investigate and prosecute all incidents of poaching and malicious vandalism.** Poaching, shooting, butchering, and other malicious vandalism against manatees are rare occurrences. All reports and evidence regarding such incidents should be turned over to the FWS's law enforcement agents for investigation and prosecution to the fullest extent of the law. As appropriate, a reward system should be established to help investigate and prosecute violations.

S2.6. **Rescue, rehabilitate, and release distressed manatees.** Reports of injured or distressed manatees are frequently received by officials in the manatee recovery program. While many prove false, some form of rescue action is deemed necessary in about 15 to 25 cases per year. In some cases, animals are treated and released immediately. In others, rehabilitation in captivity is needed and marine zoological parks make facilities, resources, and expertise available to transport and care for animals prior to their release back into the wild. Such actions help reduce manatee mortality but require extensive cooperation among Federal and State agencies, zoological parks, and other institutions and organizations. The FWS, with the assistance of an Interagency/Oceanaria working group, maintains oversight of work to rescue, rehabilitate, and release animals. The Florida Marine Research Institute's manatee salvage and necropsy program has agreed to coordinate rescue response work on a day-to-day basis. The FWS's Jacksonville field office coordinates captive program activities and manatee releases. In addition, under state law, DEP has been authorized and directed to provide partial reimbursement to cooperating parks and organizations to help defray rescue and rehabilitation costs. This program should continue.

S2.6.1. **Authorize cooperative participation in the manatee rescue/ rehabilitation network.** The FWS has overall responsibility for work to rescue, rehabilitate, and release injured or otherwise distressed manatees. To meet this obligation, the FWS's Office of Management Authority issued an endangered species/marine mammal enhancement permit to authorize related work by cooperating facilities and organizations. Letters of authorization under this permit are issued by the FWS to qualified groups interested in participating in the rescue/rehabilitation network. The letters set forth the scope of their respective involvement in (1) verifying, (2) rescuing and transporting, and/or (3) treating and maintaining distressed animals. Activities under letters of authorization need to be reviewed continually. Every effort should be made to provide training opportunities to members of authorized groups to ensure continuous improvement in local rescue assessment and logistic capabilities. The FWS should update or modify the terms of existing letters and/or issue new authorization letters to additional qualified facilities or organizations as such needs are identified.

S2.6.2. Coordinate and oversee day-to-day rescue operations. To assure prompt, effective responses to distressed manatees, a rescue coordinator has been designated to receive initial reports of such animals and to mobilize and coordinate rescue network teams. The Director of the Florida Marines Research Institute's manatee salvage and necropsy program currently serves as the rescue coordinator. Reports of distressed animals should continue to be directed to the rescue coordinator who in turn contacts authorized rescue network teams to organize a response for verification, rescue, and transport to available treatment facilities as necessary, and notifies the FWS of ongoing rescue operations, and unusual or significant incidents as necessary.

S2.6.3. Ensure adequate rehabilitation facilities. In the past the number of captive manatees has ranged from about 40 to 50 animals. Three "Pre-Act" animals (animals brought into captivity prior to enactment of the ESA) have been in captivity for several decades. Some captives have been judged unreleasable due to the nature of their injuries or concern about their ability to adapt to the wild (*e.g.*, long-term captive animals that were born in captivity), and the remainder are animals in varying stages of rehabilitation.

Captive Florida manatees are held at eight marine facilities and zoological parks:

1. Sea World of Florida* - Orlando, Florida
2. Miami Seaquarium* - Miami, Florida
3. Lowry Park Zoo* - Tampa, Florida
4. Homosassa Springs State Wildlife Park - Homosassa Springs, Florida
5. Epcot's Living Seas - Lake Buena Vista, Florida
6. South Florida Museum -Bradenton, Florida
7. Sea World of California - San Diego, California
8. Mote Marine Laboratory - Sarasota, Florida

(* = Critical Care Treatment Facility)

Space for captive animals is limited and maintenance costs to feed and care for them are relatively high (at least $ 25-40,000 per animal per year). To assure space is available to maintain animals rescued in the future, steps are being taken to return rehabilitated animals to the wild as quickly as possible. To provide additional options for management, captive maintenance facilities at the Homosassa Springs State Wildlife Park and elsewhere should be expanded and improved, as needed.

S2.6.4. Convene periodic meetings of the Interagency/Oceanaria working group and the Captive Manatee Planning Committee. The FWS convenes periodic meetings of an Interagency/Oceanaria working group to help coordinate rescue, rehabilitation, and release work and to manage captive maintenance activities in ways that will best meet manatee recovery objectives. Among other things, the working group reviews the status of manatee rescue and rehabilitation work; maintains records of captive manatees; charts the progress of animals towards their release; assists the FWS in developing and reviewing protocols and criteria for the rescue, transport, rehabilitation, maintenance, and release of animals; and exchanges information and expertise with respect to rescue, rehabilitation, maintenance, and release procedures.

Captive manatees also provide unique opportunities to study physiological processes and other aspects of manatee ecology that may add to the information base on habitat requirements and recovery needs. Such work, however, should not impede rehabilitation and release of captive animals. To help evaluate and direct research on captive animals the FWS has established a Captive Manatee Planning Committee. In part, the Committee is responsible for reviewing all research proposals and management options involving captive manatees and making recommendations to the FWS's manatee coordinator. At least two meetings per year of both the full working group and its planning committee should be held.

S2.6.5. **Facilitate and evaluate animal releases.** As soon as animals taken into captivity for rehabilitation or care are judged suitable for release back into the wild, steps should be taken to do so. Decisions on releases should be made by the FWS in coordination with the facility maintaining the animal and the Interagency/Oceanaria working group following established criteria.

S2.6.5.1. **Develop protocols and criteria to govern releases and evaluate the manatee's readaptive success.** To assure that released animals will readjust to the wild, criteria and protocols need to be developed and kept under review for assessing the physical health of animals in release pens and their fitness to be released. The guidance in these criteria and protocols should be modified as necessary based on the success or failure of animals with different histories and medical records to adapt to wild conditions. Veterinarians in the Interagency/Oceanaria working group, in coordination with the FWS, should develop and keep such protocols and criteria under review. Similar guidance also should be developed to help with decisions on whether and when to recapture animals not satisfactorily acclimating to the wild.

S2.6.5.2. **Radio-tag and track released manatees.** To help assess readjustment and survival of rehabilitated manatees returned to the wild, certain released animals should be followed by telemetry upon release and all released animals should be tagged with Passive Integrated Transponders (PIT) tags. This will aid in assessments of whether animals adopt normal habitat-use patterns, interact with other manatees, and readapt successfully to the wild. If problems arise, it also may help in locating and recapturing animals. Over the next five years, 5 to 10 animals are expected to be released annually. Telemetry tags, staff, and other support needed to track about 5 to 7 released animals annually will be required.

S2.7. **Minimize other human-related disturbances and harassment.** Disturbance and harassment by boaters, divers, fishermen, and others can alter manatee behavior and reduce the suitability of some areas as manatee habitat. Waterway speed and access restrictions partially address causes of disturbance and harassment. However, general guidance and advice for certain user groups and the general public also are needed on ways to minimize or avoid interactions that alter natural behavior and movement of manatees. The following tasks are needed to develop regulations, guidelines, and/or practical principles that define proper conduct by divers, boaters, and others with respect to feeding, watering, approaching, viewing, or otherwise interacting with manatees.

S2.7.1. **Prepare and adopt guidelines for the development of manatee viewing areas.** Interest in developing facilities to allow members of the public to view wild manatees is increasing. While such facilities offer public education and awareness opportunities, they also increase the potential for harassment of animals and perhaps even malicious injuries. Proposals for such facilities need to be examined carefully. To respond to future proposals to create manatee viewing facilities, guidelines should be prepared for determining when such facilities would be consistent with manatee recovery objectives and what design features or other conditions should be required.

S2.7.2. **Prepare and adopt guidelines or regulations on feeding and watering manatees.** Even when well-intentioned, public feeding or watering of wild manatees may alter natural behavior in ways that ultimately change manatee distribution patterns or place individual animals at risk. It may condition animals to approach boats or areas that are hazardous, or encourage them to remain in areas during times that could expose them to thermal stress. The development of guidelines and public education programs and, if necessary, regulations to discourage such activities should be evaluated and implemented. Enforcement policies must be adopted by responsible agencies. Special attention is needed at areas where feeding or watering by the public is done routinely.

S2.7.3. **Develop and keep under review guidelines governing close approaches to manatees.** At times, manatees and people, particularly divers, come in close and even direct physical contact with one another. While manatees occasionally invite such contact, people often chase after manatees that are trying to avoid them. This constitutes harassment, which is a violation of Federal law and may cause animals to leave preferred habitats. The latter is an issue of particular concern at the Crystal River NWR. The FWS has prepared a brochure advising divers at Crystal River on proper conduct when encountering wild manatees. Current policies and provisions governing close encounters between manatees and people in the wild should be kept under continuing review and their form and content modified if they are found to afford inadequate protection for manatees.

S2.7.4. Coordinate with the FWS' Contaminant Program and other entities to minimize contaminant effects on the manatee in South Florida. Investigate contaminant effects on the manatee, including red tide, nutrients, and heavy metals. Support the development and implementation of management actions to minimize negative effects from contaminants.

S3. Support research on the physiology, life history, and ecology of the manatee. Studies of physiology, life history, and ecology are needed for understanding population status and trends, and to help assess what habitats are most important to manatees and why. Collect additional biological information on number of individuals, age-class structure, habitat use, reproductive viability, food use and availability, and threats.

S3.1. Maintain and analyze manatee "scar catalog" data. Many manatees have scars from boat strikes or other sources. When carefully photographed, they provide a means of identifying individual animals. Photographs of distinctively marked animals collected by researchers in the field are compiled in a manatee scar catalog held by the Sirenia Project with support from the Florida Power & Light Company. The catalog has been expanded and improved and is now a computerized system of photos on compact-disc, the Manatee Individual Photo-identification System. The Florida Marine Research Institute now assists in maintaining portions of the catalog. The data provide valuable information on movements, site-fidelity, age at first reproduction, calving intervals, and other vital parameters. Recent analyses indicate resighting data can be used to derive survival rates. This database should continue to be maintained and analyzed.

S3.1.1. Continue to collect photographs of individually identifiable manatees in the field. Photographs of individually identifiable manatees should be routinely collected from the field. In particular, photographs should be obtained at winter aggregation sites. The routine collection of photographs from the field and their incorporation into the catalog will ensure that information on movement patterns, site-fidelity, reproductive histories, survival rates, and related databases remains current.

S3.1.2. Maintain staff support to collect, enter, check, retrieve, and analyze scar catalog data. Some 6,000 new photographs are submitted annually by field researchers for inclusion in the catalog. Comparison of photographs with previously identified animals, proper entry of new data, and retrieval of data for analyses requires a dedicated staff member who is proficient and familiar with both the classification system and the identified individuals. Continued support, including a dedicated scar catalog archivist, to maintain and upgrade the scar catalog for both the east and west coasts should be provided. Standardized protocols for describing and coding data collected by photographers have been distributed for use by all cooperators submitting photographs to the catalog. Distribution of photographs of carcasses must continue so that dead manatees can be removed from the active catalog files.

S3.1.3. Upgrade and maintain computer/camera equipment for the scar catalog. The scar catalog is presently maintained as a computer-based system that uses a CDROM. The catalog now includes over 1,000 animals and nearly 15,000 sighting and resighting records (Beck and Reid 1995). Computer and camera equipment to store, sort, and retrieve photographs and sighting data must be purchased, maintained, and upgraded to facilitate and enhance use of the catalog's data.

Photographs of carcasses taken by the Florida Marine Research Institute should be shared with the Sirenia Project so that dead animals can be removed from the active scar catalog. It will also provide information on minimum ages of manatees in the system, permitting analysis of age-specific reproduction and survival. Carcass recovery data may also be combined with resighting data in some recently developed survival models to further enhance the accuracy and precision of survival estimates.

S3.1.4. **Analyze scar catalog data to determine annual survival rates and other population parameters.** One of the most important parameters for estimating trends in population status is age-specific survival. Scar catalog data on animals at Crystal River, Blue Spring, and along Florida's east coast are now sufficiently extensive to estimate survival rates in those areas (O'Shea and Langtimm 1995). Analyses of survival rates, as well as calving intervals, age of first reproduction, and other parameters should be undertaken and/or refined as new records are entered.

S3.2. **Continue and expand long-term studies of individual animals.** Long-term studies of the reproductive traits, behavior, and life history of individual females provide data on age-specific birth rates and success in calf rearing. Such data, in turn, are important for assessing potential population growth rates. Although long-term records on individual females are best from Crystal River and Blue Spring, useful data also have been collected at other locations. Relevant data are included in the scar catalog, in long-term telemetry results for individual females through routine monitoring programs at major warm-water refuges, by long-term telemetry studies on selected manatees, and through reports from various researchers. Efforts to gather and analyze data on the reproductive history and behavior of known females should be continued and expanded to other study areas. Research should address the behavioral/ environmental causes of perinatal mortality by focusing on cow-calf behavior and interaction with conspecifics, especially during the perinatal period.

S3.3. **Analyze data on calf production.** The total number of calves produced is uncertain and may vary regionally. Calf counts from research at Crystal River and Blue Spring and from aerial surveys and data on the reproductive status of females recovered in the salvage necropsy program should be analyzed to estimate and identify possible regional differences in reproductive rates.

S3.4. **Continue aerial photogrammetry analyses.** Aerial photographic techniques to estimate the size, and hence age class, of individual animals are being investigated as a way to determine the age-structure of manatee populations. If the results suggest that further work is needed, studies should be designed, and equipment and support should be provided to collect and analyze aerial photogrammetric data.

S3.5. **Continue opportunistic deployment of passive integrated transponder (PIT) tags.** PIT tags are small tags inserted under the skin of animals to identify them if they are recaptured or recovered in the salvage and necropsy program. By comparing data on an animal's size, reproductive status, and general condition between time of tagging and recovery, one can increase the amount of information obtained on life history parameters. PIT tags are applied opportunistically by the Florida Marine Research Institute, the Sirenia Project, or an authorized veterinarian whenever animals are caught for radio tagging or rehabilitation or released from captivity. PIT tags should continue to be applied as opportunities arise and PIT tag readers should be purchased and made available to individuals and groups likely to handle manatees.

S3.6. Conduct additional physiological studies of thermal tolerances. Although it is known that manatees are sensitive to cold stress, precise information on thermal tolerances and the effects of cold on physiological processes of different manatee age and sex classes is not known. Such information may be useful for assessing the percentage of the manatee population likely to aggregate at warm-water refuges at different ambient water temperatures, when different age/sex groups are likely to arrive at and depart from refuges, when emergency situations are likely to arise from unexpected changes in thermal discharges, *etc*. Studies to assess thermal tolerances and physiological effects of cold stress should be designed and undertaken.

S3.7. Conduct additional studies to assess hearing capabilities. Manatees, particularly mothers and calves, communicate vocally. Noise from boats or other sources may interfere with such communications or be a source of stress. Hearing capabilities, however, have been poorly understood. Recent studies indicate that manatees may have a wider range of hearing than previous studies suggested (Gerstein 1994). There is a need for further research on hearing capabilities and the effects of noise on manatees.

S3.8. Complete and conduct additional studies of manatee food habits. Nutritional characteristics of manatee food plants and the importance of different food sources for different age and sex classes in various regions are poorly understood. Such information is needed to help assure that adequate food resources are protected in different portions of the population's range. Ongoing studies should be completed to identify manatee food habits and feeding patterns, the nutritional value of different aquatic plants important to manatees, and the regional food resources most in need of protection and management.

S3.9. Continue genetic analyses from manatee tissue samples. New molecular techniques to examine genetic material provide an opportunity to update information on the genetic sub-structure of manatee populations, male mating success, paternal contributions, and frequencies of kinship that vary within social groups. This genetic analysis also identifies regional homozygosity and possible effects due to localized matrilineages, *etc*. Such information could improve understanding of the structure and social interactions of populations, influencing management objectives for different groups of manatees.

These studies should also be interrelated to physiological findings; management efforts should reflect an accurate assessment of the influence that the existing gene pool may have on lowered reproductive potential, enhanced susceptibility to disease, and other factors. Research to examine a number of these points has already been initiated. In addition, a number of researchers are interested in conducting other analyses. For some questions, the genetic data alone will not yield insights into manatee biology without a simultaneous field effort to collect the appropriate behavioral data. To determine the role of kinship in social interactions it will be necessary to collect data on association patterns and interactions among known individuals. Likewise, assessment of paternity for a large number of males will provide data on variance in male reproductive success but will not shed light on factors affecting male success. Associated data on male physical characteristics (*e.g.*, size, body condition, age) and behavioral traits (*e.g.*, movement patterns, "dominance" in a mating herd), as well as extended observations of mating herds will be important for understanding reproductive activity among males. Tasks that facilitate and coordinate research related to manatee genetics should be initiated.

S3.10. **Conduct additional studies to identify requirements for fresh water.** In estuarine and marine areas manatees are attracted to, and drink from, freshwater sources. While this attraction is well known, the physiological need for fresh water is not clear. Studies have been initiated to examine processes by which manatees regulate internal salt levels and the physiological role of drinking fresh water. The results of these studies should be reviewed and, if warranted, further research should be undertaken.

S3.11. **Convene a population status working group to develop methodology, data and models to assess population size and trends.** Information on trends in the size of Florida manatee populations is essential for assessing the effectiveness of manatee recovery actions. It also is needed to develop objective, measurable criteria required by the ESA for determining when manatee populations may be reclassified as threatened or removed from the endangered species list. Given the present difficulty in measuring population size and trends directly, assessments of these parameters in the foreseeable future will benefit from information derived from population models. Models should use estimates of mortality, reproduction, survivorship, age/sex structure that stem from various other research tasks. Models should be developed, evaluated, and improved as needed.

As more information on manatee life history parameters is obtained, population models will tend to become highly complex. It is important for those developing manatee population models to coordinate their activities, and interact directly with biologists who have collected manatee life history data or who are authorities on manatee ecology. Biologists will better understand how models were derived, and the modelers will obtain feedback on the validity of their assumptions and interpretation of their results. The working group should be convened at least once every 2 years chaired by the staff of the Sirenia Project.

S3.12. **Conduct research to better understand manatee-boat interactions.** More data is needed to assess how manatees respond to a variety of boat types and traffic patterns. Innovative research techniques such as remote observations using airships should be investigated. Research should be conducted to develop various devices, such as propeller guards, in an effort to minimize manatee injury or death caused by passing boats.

S4. **Support the monitoring of manatee populations in South Florida.** The success of efforts to develop and implement measures to minimize manatee injury and mortality and to protect manatee habitat will depend on the accuracy and completeness of data on manatee life history and ecology, population status, and habitat condition. Good data in these areas are needed to identify and define problems, make informed judgments on appropriate management alternatives, establish an information base to justify selected actions, and provide a basis for determining whether or not the actions taken are achieving the desired result.

S4.1. **Maintain a manatee telemetry program.** Telemetry programs are currently the only reliable means by which to generate detailed information on manatee movement and habitat-use patterns. Manatees are netted, belted, and tagged with transmitters for remote and visual monitoring. These monitoring programs provide information used to identify key use areas and travel corridors, and to tabulate reproductive histories, monitor use of powerplant effluents, and trace the progress of re-introduced captive manatees. This information is used to develop specific recommendations for manatee protection and to support habitat management initiatives.

S4.1.1. **Maintain adequate telemetry capabilities.** Telemetry studies require personnel, tags, tag attachments, receivers, boats, vehicles, airplanes and other equipment to capture and tag animals and to retrieve or replace transmitting units. They also require computer hardware and software and personnel to process the data and funding for the cost of satellite data retrieval. Presently the Sirenia Project and the Florida Marine Research Institute can track up to 20 and 15 animals, respectively. This level of capability should be maintained exclusive of telemetry needs for tracking released rehabilitated animals, work in Puerto Rico (see the Puerto Rican manatee recovery plan), or cooperative studies in other countries.

S4.1.2. **Enter telemetry locations into the manatee Geographic Information System (GIS) database.** Accurate information on manatee habitat-use patterns provides a sound scientific basis for identifying and supporting management decisions on waterway speed and access rules, permits for facility construction in manatee habitat, *etc*. To assure access to new data by managers, telemetry data should be processed by researchers for entry into the Florida Marine Research Institute's GIS. A standardized methodology to interpret and display telemetry data should be developed with the results distributed to the appropriate management agencies and cooperating groups annually through the Manatee GIS Working Group.

S4.1.3. **Prepare and distribute monthly updates, annual progress reports, and final summaries of telemetry results.** To keep managers and researchers involved in the recovery program abreast of progress and new findings from manatee tagging and tracking studies, monthly updates on the status of tagged manatees should be compiled and distributed. Summary progress reports should be circulated annually and final research findings and conclusions should be made available as soon as possible following the completion of regional study elements.

S4.1.4. **Develop regional atlases of telemetry location data.** Telemetry research has proceeded as a series of regional studies with tracking work concentrated in different areas over time. To date, studies have been conducted or are underway in the upper St. Johns River, along the east coast of Florida and southeastern Georgia, in the Crystal River area, Lee County, Tampa Bay area, and along the southwest Florida coast. Upon the completion of a regional study, an atlas of telemetry results should be compiled to summarize habitat-use patterns of different age and sex classes by season.

S4.1.5. **Develop a long-term strategy for telemetry studies.** Presently, telemetry studies are being done on the east coast by the Sirenia Project and along the west-central Florida coast by the Florida Marine Research Institute. In the future, telemetry work may be needed in areas of the State not well studied (*i.e.*, Everglades, Okeechobee Waterway and Lake

Okeechobee) as well as in areas that have been previously studied. The latter is important to identify possible shifts in habitat use patterns over time. To ensure telemetry capabilities address recovery program data needs as effectively as possible, a set of goals with a long-term strategy for telemetry work in Florida should be developed. The goals and strategy should be reviewed by FWS, the Sirenia Project, and the Florida Marine Research Institute and updated as needed. A working group composed of FWS, Sirenia Project, and the Florida Marine Research Institute should be formed to develop the long-term strategies for telemetry studies.

S4.2. Maintain and improve the GIS for data on manatees and manatee habitat. The Florida Marine Research Institute has developed a GIS to store, synthesize, and retrieve large volumes of data on manatees and manatee habitat. This data management system can store, manipulate, analyze, and display site-specific data on manatee carcass recovery sites; manatee sighting data from aerial surveys, ground research, telemetry studies; water depths, vegetation coverage, waterway speed and access zones, shoreline characteristics and development patterns, etc. The hardware, software, and database are used by Federal, State, and local officials for scientific analyses, permit reviews, developing waterway speed and access rules, and preparing county manatee protection plans.

S4.2.1. Maintain the hardware, software, and expertise to operate the GIS. Hardware, software, personnel, and training to access the GIS should be provided and maintained by involved agencies. GIS work stations already exist at the DEP's Florida Marine Research Institute and Office of Protected Species Management, and the FWS's Jacksonville field office, and Sirenia Project. Other work stations should be established and maintained at appropriate agency offices (*e.g.*, COE District Office and other divisions of DEP). These agencies should assign trained staff to serve as GIS operators and analysts responsible for providing maps and data summaries needed by staff planners, managers, and scientists. DEP and/or FWS should provide sufficient staff support to respond to requests for needed information from cooperating agencies and organizations which lack the hardware, software, or expertise necessary to use the database (*e.g.*, some county planners).

S4.2.2. Convene regular meetings of the Manatee GIS Working Group. Optimum use of the GIS database requires that the staff of agencies, offices, laboratories, and organizations responsible for key research and management tasks have access to GIS databases pertinent to their analytical needs. To promote interactions between system users and system curators, a GIS Working Group composed of representatives from governmental agencies and interest groups wanting to use manatee GIS data should be convened on a regular basis. The Working Group should meet to review data processing needs, access procedures, and available data; encourage and organize cooperative efforts to acquire ancillary data sets that would contribute to the manatee GIS; and provide opportunities to instruct users in the use of available data and new technologies. Working Group members should be responsible for overseeing their agency's participation in manatee GIS-related work. Funding to convene this group should be provided as needed.

S5. Increase public awareness. Develop curricula and educational materials for schools and host public workshops to increase awareness about the manatee and instill a sense of stewardship for the protection of this endangered species. Increase the availability of manatee education services and materials in South Florida to provide better technical assistance to the public. Design and implement a program to evaluate the effectiveness of education in recovering the manatee. Initiate and implement a standard education program for marinas and develop standards for evaluating the effectiveness of this education program. It is essential that the public be made aware of the manatee and the efforts to protect and maintain the population.

S5.1. Develop curricula and materials for schools. Most manatee protection and conservation measures need to remain in place indefinitely. To provide a sound base of understanding and support for conservation measures by future generations of Floridians and Georgians, materials and curricula on manatees and manatee conservation should be updated periodically and made available for use at various academic levels from elementary to high school.

S5.2. Develop and update materials for target user groups. Information important to achieve manatee conservation objectives differs for different user groups (boaters, divers, fishermen, commercial ship operators, shoreline owners) and different areas (people using a particular protected area, residents of coastal areas in Florida, tourists). By the same token, appropriate media (films, posters, brochures, public service announcements, personal presentations) also differ according to user groups and areas. Agencies and organizations carrying out public education and outreach programs should cooperate in assuring that pertinent information in appropriate formats is made available to relevant sectors of the public.

S5.3. Maintain avenues to encourage and direct voluntary contributions in support of needed recovery work. A significant amount of the funding to support the State of Florida's manatee recovery work is obtained from voluntary contributions in the form of a special state license plate and an optional contribution on boat registration applications as authorized by the Florida Legislature. Some equipment and funding also are provided from donations to the Save the Manatee Club and other environmental organizations. These voluntary contributions form a significant part of the funding base for the recovery program and permit much work to be done that would not otherwise be possible. Innovative approaches to obtain and direct voluntary support to needed program work should be tested and maintained.

S6. Coordinate recovery activities, monitor and evaluate progress, and update/revise this narrative. The actions necessary to support and implement recovery are beyond the abilities or scope of any one agency. They require the participation and cooperation of many Federal, State, and local agencies, as well as public, private, and industry organizations. To ensure that the work of involved agencies and groups is carried out in a timely, cost-effective manner that addresses priority recovery needs, the following administrative and coordination tasks should be carried out.

S6.1. Maintain Federal and State manatee coordinator staff positions. Given the central role of the FWS and the DEP, each agency should designate a full-time manatee coordinator and provide basic support staff. The level of support must be adequate to carry out administrative functions for which each is responsible and to work directly with involved agency and organization officials on a day-to-day basis.

The primary responsibility of the **FWS' manatee coordinator** and support staff is to provide Federal oversight, guidance, and support for the overall manatee recovery effort as outlined in the recovery plan. Additional responsibilities include preparing rules for Federal Manatee Sanctuaries; reviewing and providing guidance on development permits and section 7 consultations; assisting and monitoring recovery-related work by participating agencies and organizations; developing a die-off response plan; overseeing efforts to rescue, rehabilitate, and release distressed manatees; assisting and coordinating manatee land acquisitions; helping develop state waterway speed and access regulations and county manatee protection plans; assisting in the development of manatee-related provisions, programs and facilities at NWRs; updating the manatee recovery plan and preparing annual status reports; and chairing and convening meetings of the manatee recovery team.

Tasks for the **State manatee coordinator** and support staff include developing state waterway speed and access rules and overseeing efforts to post and enforce established zones; reviewing environmental resource permits and state submerged land leases; providing advice and assistance to responsible agencies on resolving mortality caused by flood gates and fishing gear; assisting and coordinating manatee-related land acquisition; assisting in the development of manatee-related provisions, programs, and facilities at state parks, reserves, and aquatic preserves, and other State lands; assisting counties in developing county manatee protection plans; serving as staff for the Manatee Technical Advisory Committee; and carrying out relevant public education and awareness work.

S6.2. **Convene periodic meetings of the Florida Manatee Recovery Team and Manatee Technical Advisory Council.** The FWS has constituted and periodically convenes meetings of a Manatee Recovery Team composed of the principal involved agencies and groups. Chaired by the FWS's manatee coordinator, the team reviews progress on the recovery program tasks; develops advice on program priorities and needs; and helps coordinate work and support on recovery tasks among involved agencies and groups. In addition, DEP has established a Manatee Technical Advisory Council. The Council provides advice to the Secretary of this agency on progress and priority needs with respect to DEP involvement in the manatee recovery program. Both groups complement each other. They meet at times when advice and assistance is most timely and have become an important means of reviewing, guiding, and coordinating ongoing activities. The FWS's manatee coordinator provides staff support for the recovery team and DEP's manatee coordinator serves as staff for the Advisory Council. Support to convene periodic meetings of both groups should be provided.

S6.3. **Develop an annual progress report.** As a means of documenting and monitoring progress on recovery tasks, the FWS, with the assistance of involved agencies and groups, prepares annual progress reports reviewing activities on all identified tasks. The annual reports provide a means of tracking ongoing work, identifying areas in need of further attention, and projecting priorities for the coming year. The preparation of annual status reports should continue.

S6.4. **Update the Florida Manatee Recovery Plan.** The Florida Manatee Recovery Plan identifies and interrelates fundamental recovery tasks. It also identifies task priorities, agency involvement, and funding needs for a 5-year period. Agency involvement and funding projections are included as guides rather than commitments and are provided solely for planning purposes. In this regard, it is used by the FWS and other agencies as a principal reference to develop annual budget requests for manatee-related work. Given progress on listed tasks, new information on manatees, environmental changes, changes in agency administration, and other factors that are difficult or impossible to predict accurately more than a few years in advance, the plan is limited to a 5-year period and should be updated at least once every 5 years. Responsibility for doing so rests with the FWS, with assistance from the Florida Manatee Recovery Team.

S6.5. **Convene a panel or workshop to evaluate the effectiveness of the manatee recovery program.** The revised recovery plan assumes that more extensive boat speed regulations will minimize the major source of human-related mortality, and that local manatee protection plans, land acquisition, and development permit reviews will achieve adequate manatee habitat protection. While these assumptions seem reasonable and appropriate, it remains to be demonstrated that they will in fact be successful. A workshop or panel should be convened prior to the next revision of the recovery plan to identify and evaluate fundamental issues in the Florida Manatee Recovery Program, to evaluate whether present strategies and assumptions prove ineffective. To obtain a fresh, independent assessment of options, the panel or workshop should be heavily weighted toward expert scientists and wildlife managers not directly involved in the manatee recovery program.

S6.6. **Share experience and expertise developed through the manatee recovery program.** The Florida Manatee Recovery Program is a model for potential or evolving manatee recovery programs in other countries. The experience and expertise that has been gained in Florida should be applied to other southern states and U.S. territories with sirenian populations to encourage conservation efforts.

S6.6.1. **Develop cooperative agreements with other states and countries.** Manatees also occur in Georgia, occasionally in other southeastern states, and in Puerto Rico. Research and management techniques developed to protect manatees in Florida could be applied to protect manatees in those areas as well. Steps should be taken to establish working relationships with appropriate officials in other states or territories to transfer expertise and experience.

Similarly, other countries developing manatee conservation programs should be encouraged to enter into agreements with the FWS and the Sirenia Project to facilitate the transfer of information, experience, and expertise related to manatee research and management. Such agreements might involve the exchange of personnel for training purposes or cooperation in carrying out specific projects. Where opportunities arise to establish such agreements, they should be pursued and supported.

S6.6.2. **Participate in and assist with manatee-related work under the Caribbean Environment Program.** Under a regional SEAS program sponsored by the United Nations Environment Program, nations in the wider Caribbean region, including the U.S., cooperate in the Caribbean Environment Program. The program is guided by provisions set forth in an action plan and the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean (*i.e.*, the Cartagena Convention). In 1991, parties to the Convention signed a Protocol on

Specially Protected Areas and Wildlife. Convention members have an interest in the development of national or regional recovery plans for manatees. Participants in the Florida manatee recovery program should assist in recovery programs envisioned under this protocol and the Caribbean Environment Program.

S6.6.3. Participate in national and international manatee conservation and research activities. Results from the manatee recovery program are of interest not only to scientists and managers involved in manatee conservation, but also to other scientists and resource managers. In addition, the experience of other wildlife scientists and managers may provide insights of value to the manatee recovery program. Agencies should encourage individuals involved in the recovery program to present papers or otherwise participate in national and international activities involved in wildlife research and management, including conferences, training, and technical assistance.

Habitat-level Recovery Actions

H1. Prevent degradation of existing manatee habitat in South Florida. In addition to controlling direct sources of manatee injury and mortality, manatee recovery depends on maintaining the availability of habitat suitable to support a larger manatee population. Manatee habitat requirements include adequate sources of aquatic vegetation for food; sources of fresh water; secluded areas in which to mate, bear and nurse their young, and rest; warm-water refuges during cold periods; and safe travel corridors between these areas. Availability of these habitat features may be affected by coastal development and human activity patterns along waterways used by manatees. The challenge for managers is to provide for human needs while, at the same time, protecting the availability and quality of a network of essential habitat components. These essential habitat components reflect seasonal manatee movement patterns and maintain a full complement of habitat needs throughout the principal range of both the east and west coast manatee populations. This section of the recovery plan identifies the tasks needed to protect essential manatee habitat.

Ongoing dredge-and-fill and water quality permit review programs involving the FWS, the COE, the NMFS, and the EPA at the Federal level (section 10 of the Rivers and Harbors Act, section 404 of the Clean Water Act, and section 7 of the ESA), DEP and water management districts and Georgia Department of Natural Resources at the State level, and local environmental permitting agencies, should continue to review and comment on permit applications that have the potential to adversely impact manatees and/or their habitat.

H1.1. Support the acquisition of manatee habitat in South Florida. Federal and State systems of refuges, reserves, preserves and parks in Florida contain important manatee habitat. Management of those areas offers assurance that habitat will be maintained so as to protect the features (*e.g.*, grassbeds, quiet secluded waterways, warm-water springs, *etc*.) important to manatees. In the last 10 years, considerable cooperative effort has been devoted to acquiring essential manatee habitat and adding it to Federal and State protected area systems. These efforts are beginning to form regional protected area networks that contain many important habitat features essential for the long-term survival of manatee populations. These efforts need to continue as well as efforts to manage key protected areas in ways that enhance achievement of manatee recovery objectives.

H1.1.1. **Support the acquisition and incorporation of essential manatee habitats to the NWR, park, and preserve system.** Several NWRs managed by the FWS contain essential manatee habitat and are adjacent to other essential manatee habitat that is not similarly protected. Expanding refuges to add these areas would significantly improve protection not only for manatees, but also for many other species. Particularly important areas in this regard are along the Crystal River near the Crystal River NWR; Homosassa River near the Chassahowitzka NWR; and St. Johns River and associated waterways in and adjacent to the Lake Woodruff NWR. As possible, the FWS should pursue acquisitions, in cooperation with the State of Florida, to expand these and other refuges.

H1.1.2. **Support the acquisition and incorporation of essential manatee habitats to state reserve, preserve, and park systems.** Florida's Conservation and Recreation Lands (CARL) Program and the Save Our Rivers Programs administered by the five regional water management districts have acquired many areas that will further manatee habitat protection. They also have many important acquisition projects in varying stages of development. As possible, administrators of the two State programs, in cooperation with the FWS, should place special emphasis on completing acquisition projects important to manatees.

H1.1.3. **Review and provide advice on priority habitat acquisitions relative to manatees.** The CARL trust fund provides a significant source of funding for manatee habitat acquisition projects. In allocating these funds, the Office of Protected Species Management in the DEP provides comments and advice to the Division of State Lands and the Program's Land Acquisition Advisory Council on listed acquisition projects of particular importance to manatees. DEP and the FWS should continue to provide advice to this program and the Save Our Rivers program. Particular efforts should be made to solicit acquisition advice from manatee biologists with the DEP's Florida Marine Research Institute and field research biologists with the USGS/BRD’s Sirenia Project.

H1.1.4. **Identify and propose new land acquisition projects.** As new information on manatee habitat-use patterns and essential habitat becomes available, new areas for acquisition may be identified. New land acquisitions can connect areas of essential manatee habitat to create regional protected systems. Periodic efforts should be undertaken to review manatee distribution and movement patterns to identify and propose new land acquisition projects. A task force to undertake this work should be created and convened as necessary.

H1.1.5. **Encourage and coordinate Federal, State, and private land acquisition efforts.** Manatee-related land acquisitions that help create regional networks of essential manatee habitat are particularly important. In this regard, identification of priority areas must include regional manatee habitat requirements and relationships among essential manatee habitats. To promote and guide complementary projects, the FWS and the

DEP should designate an individual to convene meetings, act as a clearinghouse on the status of manatee acquisition projects, and otherwise help coordinate relevant land acquisition by Federal and State agencies, The Nature Conservancy, and others.

H1.2. Protect and manage habitat in South Florida.

H1.2.1. Support the designation, management, and maintenance of Federal manatee sanctuaries and refuges in South Florida. Under authority of the Marine Mammal Protection Act and the ESA (50 CFR Part 17), the FWS may designate certain waters as manatee sanctuaries (areas in which all waterborne activities are prohibited) or manatee refuges (areas in which certain waterborne activities may be regulated). Six seasonal manatee sanctuaries have been designated by the FWS (FWS 1995). Established areas must be posted and enforced. As necessary, the FWS should modify existing rules and designate other sanctuaries or refuges.

H1.2.2. Support the maintenance of safe, reliable artificial warm-water refuges in South Florida. Many Florida manatees have come to rely on warm-water outfalls from certain power plants and other industrial facilities to avoid thermal stress during periods of extreme winter cold. If warm-water discharges used regularly by manatees are disrupted or otherwise fail to provide needed warmth during the winter, animals which have learned to use them may be exposed to cold stress and perhaps die before they can find or reach alternative heat sources. In addition, water intake canals, pipe openings, *etc*. could trap manatees attracted to these facilities. Management agencies should conduct a review of these artificial warm-water discharges and develop recommendations based on the importance of each outfall to the long-term survival of the manatee. For those discharges that are determined to be essential for the survival of the manatee, written agreements should be established between the FWS and relevant industries on appropriate courses of action.

To minimize discharge interruptions and other threats to artificial refugia, National Pollution Discharge Elimination System permits issued by the EPA or the DEP should be reviewed by the FWS pursuant to its authority under the ESA and the Clean Water Act. Manatee site protection plans should be developed by permittees as requirements of issued permits and should address such issues as: (1) disruptions to warm-water outflows during winter; (2) inadequate discharge temperatures to sustain manatees during extreme cold events; (3) precautions to minimize hazards to manatees at intake and outfall areas; and (4) timely communication to manatee recovery program personnel of any long-term changes in the availability of warm-water discharges and/or unanticipated problems that may affect manatees in outfall areas.

H1.2.3. Protect and promote regeneration of seagrass beds in South Florida. Implement new measures to protect and recover seagrasses. Particular attention should be given to establishing monitoring procedures and standards for water clarity in areas of existing or historic seagrass beds. In addition, guidelines should be established to assist in the review of applications for state environmental resource permits issued by the DEP and requests for state submerged lands leases issued by the Florida Board of Trustees that may affect the quality of seagrass beds important as manatee feeding areas. Assess threats to seagrass habitats and develop protection strategies. Develop and implement alternative measures to mitigate threats to, and promote regeneration of, seagrasses. Primary areas in need of protection include Lee, Collier, and Miami-Dade counties.

H1.2.4. **Support the review and implementation of aquatic plant control programs.** Essential freshwater food supplies for manatees outside of protected areas may be damaged by dispersal of herbicides to control exotic aquatic plants. The FWS and the DEP Office of Protected Species Management should routinely review treatment plans developed by aquatic plant control programs to ensure that neither manatees nor their essential food sources are adversely affected by these herbicides. Mechanical or biological plant control alternatives should be considered, if possible. Such alternatives may not always be appropriate. For example, mechanical plant removal may be inadvisable in some areas when manatees are present in large numbers.

H1.2.5. **Incorporate manatee protection measures into management systems for protected areas and State-owned submerged lands.** Depending on local conditions and human activity patterns, management measures may be needed to ensure that activities and development projects within protected area boundaries or affecting state-owned submerged lands do not adversely affect manatees or their essential habitat.

H1.2.5.1. **Include manatee protection and monitoring measures in management plans for Federal and State protected areas.** As appropriate and possible, managers of Federal and State refuges, reserves, parks, *etc*. should adopt measures to develop and enforce waterway speed and access rules to avoid vessel traffic patterns that threaten manatees; manage aquatic plant control programs to avoid impacts to manatees or their food supplies; protect and monitor the quality and quantity of water flowing from natural warm-water springs used by manatees; and identify and avoid uses incompatible with protection of manatees and manatee habitat. They also should carry out programs to monitor and record manatee habitat-use patterns in and around unit boundaries. Such measures should be developed, reviewed, and modified periodically with the assistance of the FWS's manatee coordinator and the State's Office of Protected Species Management. Needed measures should be incorporated into unit management plans.

H1.2.5.2. **Develop policies and provisions to guide decisions on leasing State-owned submerged lands.** Most essential manatee habitat in Florida overlies publicly owned sovereignty submerged lands. Private use of these lands to construct marinas, docks or other facilities potentially affecting manatees requires a lease from the Florida Board of Trustees. To ensure that the use of such areas is consistent with manatee recovery objectives, there is a need to develop policies, guidelines, and/or other provisions to help review lease requests involving activities or projects that may directly or indirectly affect manatees and manatee habitat.

H1.2.6. Develop, implement, and update county manatee protection plans. To develop effective, fair manatee protection schemes, site-specific conditions and information should be reviewed and protection measures should be integrated into local policies and ordinances. Comprehensive, multi-faceted county manatee protection plans are considered appropriate and vital. It is anticipated that such plans would be implemented as amendments to local government comprehensive plans required by the State's Comprehensive Growth Management Act of 1985 and reviewed for consistency by DCA. Steps to encourage manatee protection plans already have been taken for the 13 key counties where manatee mortality has been greatest and manatees occur most frequently. Two of the most important components of these plans are county waterway speed zones and measures to balance plans for new boating facilities with manatee protection needs. Regarding the latter point, the Governor and Cabinet have directed that limits be placed on the construction and expansion of boating facilities pending the implementation of more comprehensive plans. Eventually, such plans should be prepared for all counties with important manatee habitat.

H1.2.6.1. Assist counties to develop manatee protection plans. To develop and approve manatee protection plans, county planners and DCA need reliable information on local manatee habitats and habitat-use patterns. To varying degrees, counties also may need help to identify and evaluate appropriate planning provisions. Such information and assistance should be provided by DEP’s Office of Protected Species Management, FWS's Jacksonville Field Office, and USGS’s Sirenia Project. The staff of these agencies should cooperatively synthesize and provide accurate, up-to-date data on manatee distribution and habitat within county boundaries to county officials and work closely with them to develop appropriate planning measures. DEP and FWS should coordinate with DCA to draft local, county or State manatee protection programs. Once completed, the plan should be approved and implemented. DEP, FWS, and the Sirenia Project must allocate the staff and resources needed to provide such assistance.

H1.2.6.2. Assist in implementing manatee protection plans. Approved manatee protection plans should be provided to Federal and State agencies to aid in decision making with regard to permitting, leasing submerged lands, project review, or other activities that may have an affect on manatees. Of particular importance in this regard are DEP, the COE, and FWS.

H1.2.6.3. **Periodically assess, review, and modify manatee protection plan provisions.** As new information becomes available, there may be a need to modify manatee protection plans. One of the most critical needs in this regard is data on boating activity patterns. While efforts are underway to gather these data in the 13 key manatee counties, it should be collected state-wide. Accordingly, the Office of Waterway Management and the Office of Protected Species Management in DEP should cooperate in developing a state-wide database that includes data on: (1) boat traffic patterns; (2) areas of concern for boating safety; (3) the location of existing marine facilities; and (4) proposed sites of future marine facilities. Based on this and other relevant data, county officials and staff of DCA, the Office of Protected Species Management, and FWS should periodically review county manatee protection plans.

Modification of county plans may be called for in the future, based on changes in available information. Plans would need to be strengthened as needed should human-caused mortality increase. Similarly, modifications to accommodate boaters may be warranted where manatee use of speed zone areas is demonstrated to be significantly less than previously documented.

H2. Restore and create manatee habitat in South Florida.

H2.1. Support the maintenance and restoration of water quality in freshwater sources. Coordinate with the South Florida Restoration Task Force to restore natural tidal flow and hydrology in manatee habitat. Maintain minimum flows and levels in manatee use areas.

H2.2. Enhance manatee habitat in South Florida. Improve habitat by planting or encouraging native plant species, such as seagrasses and mangroves. Wetland restoration in the Indian River Lagoon area may significantly benefit the manatee. Coordinate with the FWS's Coastal Program and other pertinent groups to conduct manatee habitat restoration efforts.

H3. Support research on manatee habitat in South Florida and how it affects the manatee's persistence. Ongoing research on manatee-seagrass grazing interactions should be continued and completed. Investigations of manatee grazing effects and seagrass recovery, using both exclosures and enclosures, have been conducted in the Banana River in Brevard County. Results from these studies should provide information useful in design of monitoring studies, estimation of manatee carrying capacity of seagrass beds in key areas, and better understanding of the manatee's role in maintaining healthy, diverse seagrass communities.

H3.1. Investigate how manatees use different habitat components for survival. Investigate the effect of habitat change in South Florida on the manatee. Determine how manatee distribution and abundance is affected by increased mortality, habitat degradation, and hydrological changes.

H3.2. Determine an index of habitat fragmentation in South Florida.

H3.2.1. Investigate movement patterns and the spatial use of habitat to identify important core areas and corridors in South Florida.

H3.2.2. Determine if the amount and configuration of habitat is sufficient to support a stable or increasing population of manatees in South Florida.

H4. Develop and implement a manatee habitat monitoring program. In addition to efforts to monitor the status of manatee populations, work should be undertaken to monitor the condition and status of manatee habitat. Information from such a program could provide an early warning of future threats to manatee populations and help explain observed manatee population trends. Presently, there is no systematic approach to monitoring the condition of key manatee habitats.

H4.1. Develop methodology and expertise to monitor the condition of essential manatee habitats. While basic manatee habitat requirements have been identified and many, if not most, of the essential areas providing those requirements are known, there is no systematic approach for monitoring the condition of those habitat features. For example, the condition of essential grassbed feeding areas and the discharge rates and water quality at natural warm-water refuges are not routinely monitored. To provide a means of detecting potential problems in the capacity of such areas to support manatee populations, methodologies and expertise to monitor the condition of essential manatee habitat features should be identified and tested.

H4.2. Coordinate and implement a long-term habitat monitoring program. A long-term program should be initiated to monitor key parameters, such as the species composition and extent of aquatic plant species at vital feeding areas and the discharge rates and water quality at warm-water refuges. To the extent possible, such efforts should rely on habitat monitoring programs and research already undertaken by Federal and State agencies or academic institutions.

H5. Establish effective manatee management programs at Federal and State protected areas. After essential manatee habitats are acquired and added to Federal and State holdings, the agencies responsible for administering those areas should incorporate manatee protection and public awareness measures into unit administration programs.

H5.1. Develop and maintain public education programs at selected protected areas. Because Federal and State protected areas attract thousands of visitors each year, those containing essential manatee habitat offer valuable opportunities for interpretive programs on manatee conservation. Visitors to refuges, preserves, and parks with essential manatee habitat must be made aware of special measures to protect manatees within these areas.

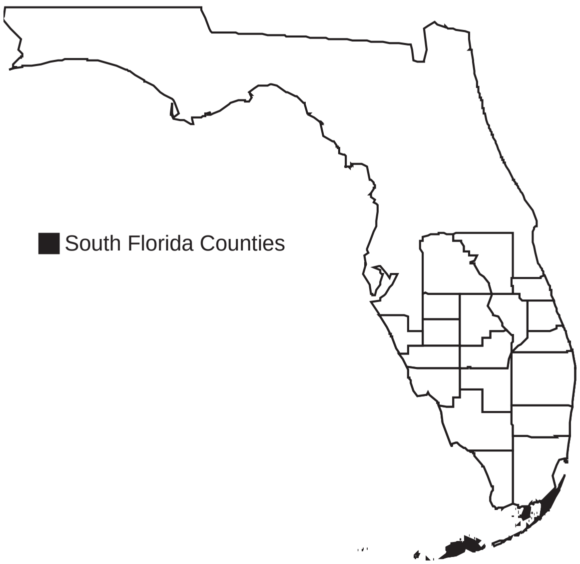
H5.2. Develop public awareness/education programs at other parks and refuges. FWS and the State should develop and maintain displays and education programs explaining manatee conservation issues at other refuges, reserves, preserves, and parks that include essential manatee habitat. This should also be a priority at manatee aggregation sites where managed public viewing and education opportunities exist.

Key Largo Cotton Mouse

Peromyscus gossypinus allapaticola

Federal Status:	**Endangered (August 31, 1984)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Original (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. Distribution of the Key Largo cotton mouse; this species is endemic only to Key Largo in the Florida Keys.



The cotton mouse is one of the most common small mammals in South Florida and throughout the southeastern United States, but the Key Largo cotton mouse is endemic to Key Largo. Once ranging throughout the tropical hardwood hammocks in the Upper Keys south to near Tavernier, the Key Largo cotton mouse is now restricted to the northernmost portion of Key Largo (Barbour and Humphrey 1982). Urbanization of Key Largo has decimated the forests of tropical hardwood hammocks and has reduced the availability of food, shelter, and habitat for the cotton mouse causing it to be in an endangered condition.

This represents the rangewide recovery plan for the Key Largo cotton mouse.

Description

Key Largo cotton mice are larger with a more reddish color than other subspecies of cotton mice from peninsular Florida. Its pelage is red dorsally, with dusky brown sides and white underparts. Its bicolored tail is darker brown on top and whiter underneath. Body length is 170 to 189 mm, tail length is 72 to 87 mm, and hind foot length is 21 to 23 mm.

Taxonomy

The Key Largo cotton mouse was first described as a distinct subspecies by Schwartz (1952a) and is distinguished as a separate subspecies because of its overall larger size (*e.g.*, total length, tail length, skull measurements) and more reddish-colored fur. Its name originates from the Seminole Indian term *allapattah* which stands for the tropical dry deciduous hammocks of South Florida (Humphrey 1992).

Distribution

Cotton mice are found throughout the southeastern U.S, but the Key Largo cotton mouse is an endemic subspecies that formerly occupied hardwood hammock forests on all of Key Largo, Monroe County, Florida (Figure 1). Historically, they were found as far south as Plantation Key, near Tavernier (Layne 1974, Brown 1978a, 1978b), but are currently restricted to hammocks on the northern portion of Key Largo (Humphrey 1992). Attempts to collect the cotton mouse in southern Key Largo have been unsuccessful in recent years and it is now restricted to that portion of the Key north of the U.S. 1-C.R. 905 intersection (Brown 1978a, b; Barbour and Humphrey 1982). This area is commonly referred to as "north Key Largo." The Key Largo cotton mouse was introduced to Lignumvitae Key in 1970 (Brown and Williams 1971), but was apparently unable to successfully establish a population.

Habitat

The Key Largo cotton mouse uses a variety of tropical hardwood habitats including recently burned, early successional, and mature hammock forests, and *Salicornia* coastal strands adjacent to these forests (Humphrey 1992). Hardwood hammocks are highly productive forests with a tall canopy (average 9.8 m) and an open understory (Ross *et al* 1992). Canopy trees include black ironwood (*Krugiodendron ferreum*), gumbo limbo (*Bursera simaruba*) Jamaican dogwood (*Piscidia piscipula*), mahogany (*Swietenia mahagani*), pigeon plum (*Coccoloba diversifolia*), poisonwood (*Metopium toxiferum*), strangler fig (*Ficus aurea*), and wild tamarind (*Lysiloma latisiliquum*). Hammock understory contains torchwood (*Amyris elemifera*), milkbark (*Drypetes diversifolia*), wild coffee (*Psychotria nervosa*), marlberry (*Aroisia escallonioides*), stoppers (*Eugenia* spp.), soldierwood (*Colubrina elliptica*), crabwood (*Gymnanthes lucida*), and velvetseed (*Guettarda scabra*). Ground cover contains cheese shrub (*Morinda royoc*) and snowberry (*Chicocoea alba*). Cotton mice have also been trapped in recently burned areas where bracken fern (*Pteridium aquilinum*) predominates (Goodyear 1985).

Behavior

Much of the information available for the Key Largo cotton mouse is inferred from other cotton mice populations in Florida. The Key Largo cotton mouse builds leaf-lined nests in logs, tree hollows, and rock crevices. The holes occupied by these mice measure 3 to 9 cm in diameter, are often partially covered by leaves or bark and may be located at the bases of trees and near or in woodrat nests (Goodyear 1985). The Key Largo cotton mouse can move at least 2 km in 1 to 2 days. Male cotton mice have larger home ranges than females and home ranges overlap because cotton mice do not defend territories. Other Florida populations of cotton mice are primarily nocturnal and often run and climb on

Key Largo cotton mouse. *Original photograph by Phil Frank.*

tree limbs (Ivey 1949, Humphrey 1992); Key Largo cotton mice probably share these behaviors. Cotton mice use a variety of short musical barking sounds to communicate, which is probably also true for the Key Largo cotton mouse.

Reproduction

The Key Largo cotton mouse breeds throughout the year. Florida populations of cotton mice have high reproduction in the fall and early winter (Bigler and Jenkins 1975, Smith and Vrieze 1979) and reproduction may be affected by agonistic behavior by males or decrease in food supply (Smith 1982, Smith *et al.* 1984). Key Largo cotton mice produce two to three litters a year, with an average of four young in each litter (Brown 1978a). Cotton mice are short-lived, with an average life expectancy of 5 months, although potential longevity is 2 to 3 years. Although seasonal population fluctuations have been documented for cotton mice in South Florida, Smith (1982) found highly variable breeding patterns of cotton mice in the Everglades.

Foraging

Key Largo cotton mice are omnivorous and feed on a wide variety of plant and animal materials (Calhoun 1941, Pournelle 1950, Brown 1978a). Over 70 percent of the tropical hardwood hammock trees and shrubs produce fruits and berries that may provide important food items for the Key Largo cotton mouse.

Relationship to Other Species

The Key Largo cotton mouse is most closely associated with the Key Largo woodrat (*Neotoma floridana smalli*) It is often found in woodrat holes, nests, or runways (Humphrey 1992). Both of these species are dependent upon the structure, composition, and quality of tropical hardwood hammocks. Several federally listed species occur in the same habitat or adjacent habitat, including the American crocodile (*Crocodylus acutus*), eastern indigo snake (*Drymarchon corais couperi*), and Schaus swallowtail butterfly (*Heraclides aristodemus ponceanus*). In addition, there are at least seven state-protected animals and 20 state-listed plants that also share the same habitat; such as the threatened white-crowned pigeon (*Columba leucocephala*) and Miami black-headed snake (*Tantilla oolitica*) and the endangered lignumvitae tree (*Guaiacum sanctum*), prickly apple (*Harrisia simpsonii*), tamarindillo (*Acacia choriophylla*), powdery catopsis (*Catopsis berteroniana*) and long strap fern (*Campyloneurum phyllitidus*).

Status and Trends

The Key Largo cotton mouse was recognized by the FWS in a notice of review on July 28, 1980 (45 FR 49961). It was listed as endangered for 240 days on September 21, 1983, through an emergency listing action (48 FR 43040). The emergency listing was necessary to provide full protection during FWS consultation on a loan from the Rural Electrification Administration to the Florida Keys Electric Cooperative. The loan was to upgrade electrical delivery capability, potentially accelerating residential development on north Key Largo. The cotton mouse was proposed as endangered with critical habitat on February 9, 1984 (49 FR 4951) and was listed as an endangered species on August 31, 1984 (49 FR 34504). The proposed critical habitat was withdrawn on February 18, 1986 (51 FR 5746).

Continual growth of the human population and residential and commercial activity in Key Largo has endangered the Key Largo cotton mouse and Key Largo woodrat. Before European settlement, the Upper Keys contained 4,816 ha of deciduous or hardwood hammock forests (Strong and Bancroft 1994). In 1830, the first Federal census counted 517 people in Monroe County, with most of them living in Key West (Simpson 1983). The Monroe County population increased to 5,657 in 1870, with only 60 residing on Key Largo. The Key Largo population increased from 2,866 people in the 1970s to 7,477 in 1980. The first subdivision was built on Key Largo in 1924; by the end of the 1950s, 77 percent of all subdivisions on Key Largo were established (Simpson 1983). The largest subdivision is Ocean Reef and covers more than 1,619 ha. The construction of residential and commercial structures had a dramatic permanent effect on the tropical hardwood forests.

Historically, north Key Largo was cleared primarily for agriculture, but sufficient hardwood hammock remained available to support the characteristic biota. The amount of habitat fluctuated depending on hurricanes, wildfires, historic land use, and subsequent vegetational succession, but the primary upland vegetation was hardwood hammocks. The original range of the cotton mouse included forested uplands of Key Largo south to Plantation. The apparent extirpation of the cotton mouse from Key Largo south of the U.S. Highway 1-C.R. 905 intersection has been generally attributed to land clearing for residential housing and commercial construction activities (Brown 1978a, 1978b; Hersh 1981). Effects of land conversion in tropical hardwood hammocks have been more extreme in the Upper Keys than in the Lower Keys (Strong and Bancroft 1994). By 1991, 41.2 percent of the deciduous seasonal forest (1,985 ha) had been either cleared or filled to meet human needs. Much of the tropical hardwood hammock vegetation on southern Key Largo has been totally removed or thinned, eliminating habitat for the cotton mouse and the woodrat. Today, Key Largo has the highest concentration of platted lots (4,178), comprising 72 percent of all lots in the Upper Keys. An analysis of this area in 1988 showed that 775 ha of vacant, dry, privately held lands with development potential remains (Monroe County 1989).

Habitat loss and fragmentation has caused the isolation of Key Largo cotton mouse populations. The physical separation caused by these activities makes it increasingly difficult to locate a mate and to disperse. Humphrey (1988) estimated that 851 ha of remaining forest on north Key Largo supported average cotton mice densities of 21.1/ha. Humphrey 1996 (personal communication) feels that numbers have decreased since then, and that the population may have been at high point in 1984. Tropical hardwood hammock fragments up to four ha in size remain on south Key Largo, but may no longer be able to support Key Largo cotton mice. These hammocks may be too small and isolated to support viable cotton mouse populations. Remaining hammocks on south Key Largo are small, isolated, and disturbed. GFC survey results from 1995 indicate a decline in the mouse toward the southern end of its range; also it appears to be extirpated from Lignumvitae Key as none have been present in 1993 or 1997 surveys (Frank *et al.*1997). The mice are vulnerable to invasion by animals associated with humans (dogs, cats, and black rats) which predate or outcompete cotton mice.

Habitat fragmentation, combined with a decreased range, makes the Key Largo cotton mouse more vulnerable to natural catastrophes such as hurricanes or fire; each of these have damaged significant portions of north Key Largo hammocks. Tropical storms and hurricanes pose serious threats to the viability of the remaining cotton mice populations. The small size and low elevation of the Keys uplands make it difficult for cotton mice to find shelter from damaging winds and storm surge. Monroe County has experienced 20 hurricanes between 1900-1990, with 11 of these Category III or greater (NOAA 1995). In 1992, over 240 ha of vegetation in north Key Largo were severely damaged by Hurricane Andrew. Since that time, there is still evidence of habitat destruction, but signs of cotton mouse use have been observed. Other threats, associated with an increase in urbanization, include dumping of trash, possible competition with black rats, and predation by domesticated cats. Dumping of trash increases the size of black rat populations and rodent control agents used for black rats (*Rattus rattus*) kill cotton mice. Black rats may compete against cotton mice and have caused the extinction of two other subspecies of cotton mice (*P. g. restrictus* and *P. g. anastasae*), but the effects on the Key Largo cotton mouse are not known.

Management

In an attempt to establish populations of Key Largo cotton mice in another location, 14 individuals were translocated to Lignumvitae Key State Botanical Site in 1970 (Brown and Williams 1971). Cotton mice are not native to Lignumvitae Key, although the tropical hardwood hammock habitats on this key are similar to those of Key Largo. One individual was trapped in 1977, indicating that reproduction had occurred for several years, but trapping efforts in 1984 and 1990 yielded no cotton mice (Pat Wells, DEP, personal communication 1996), suggesting this species was not able to establish a viable population.

The FWS has issued two major Biological Opinions, pursuant to Section 7 of the ESA, with regard to Federal activities on north Key Largo that have had a considerable impact on the future of the Key Largo cotton mouse. The first opinion (May 1980) addressed Farmers Home Administration's financing of the Florida Keys Aqueduct Authority's pipeline improvements in the Keys. The Biological Opinion concluded that the American crocodile and the Schaus swallowtail butterfly would be jeopardized by increased water supply to north Key Largo that would accelerate the rate of residential, commercial, and recreational construction. The Key Largo cotton mouse and woodrat were not federally listed at that time, but would also be affected in a similar way. To avoid the likelihood of jeopardy, the Farmers Home Administration chose to exclude certain areas from water delivery. Approximately 45 percent of cotton mouse habitat is located in these exclusion zones and should be provided protection from loss of habitat, but the most densely populated cotton mouse habitat occurs outside of the exclusion zones and is subject to loss of habitat.

The second Biological Opinion, issued by the FWS in October, 1983, addressed the Rural Electrification Administration's proposal to provide funding to the Florida Keys Electric Cooperative for the construction of a substation to increase electrical delivery to northern Key Largo. The FWS concluded the proposed action would jeopardize the continued existence of the Key Largo cotton mouse as well as the crocodile, Schaus swallowtail, and the Key Largo woodrat because the increased electrical delivery capacity would facilitate residential construction in the hammocks of north Key Largo. No new electrical hookups have subsequently been made to any of the exclusionary areas described in the Biological Opinion.

There have been discussions among various agencies concerning the conservation of remaining hardwood hammocks on north Key Largo, which would provide protection to the endangered Key Largo cotton mouse. In 1984, there was interest on the part of several landowners in developing a habitat conservation plan, pursuant to Section 10(a)(B)(1) of the ESA, to allow for residential and commercial development on North Key Largo, while conserving federally listed species in the area. The planning process was initiated, including representatives of landowners, conservation groups, and State agencies. Some incidental take permits have been issued to subdivisions for the authorized take of Key Largo cotton mice. Subsequent public land acquisition, however, largely precluded the need for an overall habitat conservation plan.

Public land acquisition on north Key Largo has been the most beneficial management action for the Key Largo cotton mouse. Most undeveloped land west of C.R. 905 has been acquired by the FWS as part of the Crocodile Lake NWR, while much of the undeveloped land on the east side of the road has been acquired by the DEP for inclusion in its Key Largo Hammocks State Botanical Site.

The Multi-Species Recovery Team has suggested several priority actions necessary to protect and conserve the Key Largo cotton mouse, including the stabilization of existing cotton mice populations, protection and restoration of habitat, monitoring of existing populations and re-evaluation of its status in 5 years, evaluating and minimizing secondary impacts (cats, black rats, fire ants), and developing reclassification and delisting criteria (FWS 1996). The Key Largo cotton mouse is a state-listed endangered animal and protection is provided to the animal but not its habitat.

Recently, the FWS consulted on how the administration of the National Flood Insurance Program (NFIP) by the Federal Emergency Management Agency (FEMA) affects threatened and endangered species in Monroe County. The Key Largo cotton mouse was one of ten species that was determined to be affected by FEMA's actions. Prior to this consultation, FEMA did not address listed species issues as required by Section 7 of the ESA. FEMA's responsibilities to consult arise from a sequence of events that begins before a structure is designed and ends with habitat destruction or modification for the construction of residential or commercial structures. Although FEMA is not the only entity involved in this sequence of events, it still has the obligation, as a Federal agency, to ensure its actions do not jeopardize the continued existence of a listed species, like the cotton mouse. The FWS concluded that the continued administration of the NFIP by FEMA in the Keys, with its attendant effects on land-use planning and zoning and incentives for landowners, is likely to jeopardize the continued existence of the Key Largo cotton mouse. As a reasonable and prudent alternative to alleviate jeopardy, FEMA committed to implement procedures to ensure their actions do not jeopardize the cotton mouse.

In conjunction with the GFC, the FWS produced geographic information system (GIS) maps of suitable Key Largo cotton mouse habitat to assist in making better management decisions. Areas in private ownership are the most vulnerable to loss. Based on our GIS analyses, 4,877 ha of Key Largo cotton mouse habitat on north Key Largo remain. Of this total, 4,445 hectares (91 percent) are protected and 432 ha are vulnerable to urbanization. Much of this unprotected acreage occurs in the golf course of the Harbor Course residential area on north Key Largo, with a small fragment south of the marina on the western edge of the residential area (west of Gateway Road) and other areas throughout north Key Largo. The FWS believes all remaining occupied and unoccupied suitable habitat should be protected in order to ensure the continued existence of the Key Largo cotton mouse. In addition, the FWS also recommends that a 500-m buffer zone around these areas should be put in place since adjacent areas are vulnerable to urbanization as well. The necessity for a protected buffer is based on the likelihood that human influences encroach upon and impact the cotton mouse. The distance of 500 m is based on the use of upland areas by this species and the estimated range of domestic cats. Upland and wetland buffers are important habitat because they provide connectivity between subpopulations and minimize secondary impacts such as road and cat mortality.

The National Audubon Society *et al.* (1990) identified areas of tropical hardwood hammocks throughout Key Largo for proposed acquisition by the State that would preserve the biological diversity of the hammock ecosystem. The FWS believes that protection, conservation, and management of these additional areas is critical to the survival and recovery of the Key Largo cotton mouse.

In the past, very little research focused primarily on the Key Largo cotton mouse and additional information about this species is needed. Density and distribution studies of the Key Largo cotton mouse have been conducted (Humphrey 1988), but the status of the current population is not known. Recently, the GFC, Marathon, and the Florida Cooperative Fish and Wildlife Research Unit, Gainesville, conducted a status survey of the cotton mouse and woodrat on north Key Largo. The study results are expected to provide information on the population density, population fluctuations, survival, reproduction, and movements of these rodents on north Key Largo (Quarterly Progress Report, FWS Research Work Order No. 123).

To increase recovery efforts to protect the Key Largo cotton mouse, the FWS has placed a refuge manager at Crocodile Lakes NWR to coordinate with other agencies and increase the level of law enforcement, restoration of habitat, and protection and monitoring of cotton mice. In addition, a Student Conservation Association intern assists the refuge manager and removes exotic vegetation on the refuge.

Literature Cited

Barbour, D.B. and S.R. Humphrey. 1982. Status and habitat of the Key Largo woodrat and cotton mouse (*Neotoma floridana smalli* and *Peromyscus gossypinus allapaticola*). Journal of Mammalogy 63(1): 144-148.

Bigler, W. J. and J.H. Jenkins. 1975. Population characteristics of *Peromyscus gossypinus* and *Sigmodon hispidus* in tropical hammocks of south Florida. Journal of Mammalogy 56(3): 633-644.

Brown, L.N. 1978a. Key Largo cotton mouse. Pg. 10-11 *in* J.N. Layne, ed. Rare and endangered biota of Florida. Mammals. University Press; Gainesville, Florida.

Brown, L.N. 1978b. Key Largo woodrat. Pg. 11-12 *in* J.N. Layne, ed. Rare and endangered biota of Florida. Mammals. University Press; Gainesville, Florida.

Brown, L.N. and R.L. Williams. 1971. The Key Largo woodrat (*Neotoma floridana smalli*) and cotton mouse (*Peromyscus gossypinus allapaticola*) on Lignum Vitae Key, Florida. Florida Naturalist 44: 95-96.

Calhoun, J.B. 1941. Distribution and food habits of mammals in the vicinity of Reelfoot Biological Station, III. Discussion of the mammals recorded from the area. Journal Tennessee Academy of Science. 16: 207-255.

Frank, P., F. Percival, and K. Britt. 1997. A status survey for the Key Largo woodrat (*Neotoma floridana smallii*) and Key Largo cotton mouse (*Peromyscus gossypinus allapaticola*) on North Key Largo, Monroe County, Florida. Florida Game and Fresh Water Fish Commission final report to the FWS, Jacksonville, Florida.

Goodyear, N.C. 1985. Results of a study of Key Largo woodrats and cotton mice: Phase I, spring and summer 1985. Unpublished report to North Key Largo Study Committee.

Hersh, S.L. 1981. Ecology of the Key Largo woodrat (*Neotoma floridana smalli*). Journal of Mammalogy 62(1): 201-206.

Humphrey, S.R. 1992. Key Largo cotton mouse (*Peromyscus gossypinus allapaticola*). Pages 110-118 *in* S.R. Humphrey, ed. Rare and endangered biota of Florida. Volume I. Mammals. University Press of Florida; Gainesville, Florida.

Humphrey, S.R. 1988. Density estimates of the endangered Key Largo woodrat and cotton mouse *(Neotoma floridana smalli* and *Peromyscus gossypinus allapaticola*), using the nested-grid approach. Journal of Mammalogy 69(3): 524-531.

Ivey, R.D. 1949. Life history notes on three mice from the Florida east coast. Journal of Mammalogy 30:157-162.

Layne, J.N. 1974. The land mammals of South Florida. Pg. 386-413 *in* P.J. Gleason, ed. Environments of South Florida: present and past. Memoir 2, Miami Geological Society; Coral Gables, Florida.

Monroe County. 1989. North Key Largo habitat conservation plan. Monroe County Growth Management Division; Monroe County, Florida.

National Audubon Society, Florida Natural Areas Inventory, and The Nature Conservancy. 1990. Tropical flyways, a proposal to: Conservation and Recreational Lands (CARL), State of Florida Department of Natural Resources.

National Oceanic and Atmospheric Administration. 1995. Draft management plan and environmental impact statement, Florida Keys National Marine Sanctuary. U.S. Department of Commerce, National Oceanic and Atmospheric Administration; Marathon, Florida.

Pournelle, G.H. 1950. Mammals of a north Florida swamp. Journal of Mammalogy 31(3): 310-319.

Schwartz, A. 1952a. Three new mammals from southern Florida. Journal of Mammalogy 33(3) 381-385.

Simpson, L. 1983. The island of Key Largo, Florida. Mayfield Printing Company; Mayfield, Kentucky.

Smith, A. 1982. Population and reproductive trends of *Peromyscus gossypinus* in the Everglades of south Florida. Mammalia 46(4): 467-475.

Smith, A.T. and J.M. Vrieze. 1979. Population structure of Everglades rodents: responses to a patchy environment. Journal of Mammalogy 60(4):778-794.

Smith, M.W., W.R. Teska, and M.H. Smith. 1984. Food as limiting factor and selective agent for genic heterozygosity in the cotton mouse *Peromyscus gossypinus*. America Midland Naturalist 112(1):110-118.

Strong, A.M. and G.T. Bancroft. 1994. Patterns of deforestation and fragmentation of mangrove and deciduous seasonal forests in the Upper Florida Keys. Bulletin of Marine Science 54(3): 795-804.

U.S. Fish and Wildlife Service [FWS]. 1996. Multi-Species Recovery Team/Keys Group meeting, April 1996.

U.S. Fish and Wildlife Service. 1984. Endangered and threatened wildlife and plants; determination of endangered status for the Key Largo woodrat and Key Largo cotton mouse. Federal Register 49(171):34504-34510.

Wells, P. 1996. Site visit of Lignumvitate Key State Botanical Preserve. May 3, 1996.

Recovery for the Key Largo Cotton Mouse

Peromyscus gossypinus allapaticola

Recovery Objective: RECLASSIFY to threatened.

Recovery Criteria

Information from recent surveys of the Key Largo cotton mouse and its habitat suggests that the Key Largo cotton mouse has lost more than 50 percent of its habitat to urbanization, that much of the remaining habitat has been fragmented or degraded, and that the nature of the habitat loss provides extremely limited potential for habitat restoration or rehabilitation. Consequently, the objective is to reclassify the Key Largo cotton mouse from endangered to threatened by protecting and managing its habitat on Key Largo, restoring potential habitat, and increasing the size of its population. This objective will be achieved when: further loss, fragmentation, or degradation of suitable, occupied habitat on Key Largo has been prevented; when domestic predators and competitors have been reduced by 80 percent; when all suitable, occupied habitat on priority acquisition lists on Key Largo is protected either through land acquisition or cooperative agreements; when the tropical hardwood hammocks that form the habitat for the Key Largo cotton mouse are managed on protected lands to eliminate trash and control exotics when potential habitat on these protected lands is restored or rehabilitated for the Key Largo cotton mouse; and when stable populations of the Key Largo cotton mouse are distributed throughout north Key Largo and three, additional, stable populations have been established elsewhere within the historic range of the Key Largo cotton mouse. These populations will be considered demographically stable when they exhibit a stable age structure and have a rate of increase (r) equal to or greater than 0.0 as a 3-year running average for 6 years.

Species-level Recovery Actions

S1. Determine the distribution and status of the Key Largo cotton mouse. Key Largo cotton mice formerly occupied hardwood hammock forests on all of Key Largo but are currently restricted to hammocks on the northern portion of Key Largo. Investigate suitable habitat for the presence of cotton mice.

S1.1. Conduct presence/absence surveys on north Key Largo. Survey the southern part of north Key Largo along the ecotone of human habitation and hardwood hammock. Evaluate the status of cotton mice here as compared to more contiguous, remote areas.

S1.2. Survey suitable areas in other parts of Key Largo for the presence of cotton mice. A few attempts have been made to collect cotton mice in southern Key Largo, but have been unsuccessful. Survey suitable habitat from north Key Largo south to Plantation Key.

S1.3. **Determine the status of cotton mice north of Key Largo.** Survey habitat on Palo Alto, Pumpkin, and Swan Keys, and Little Totten, and Old Rhodes keys in Biscayne NP. These areas contain suitable habitat, but have not been surveyed in detail.

S1.4. **Survey cotton mouse habitat.** Determine habitat characterization and use by cotton mice. Determine why cotton mice are absent in areas with suitable habitat. Assess the condition of occupied habitat and potential habitat. Compare presence of mice in areas of contiguous versus fragmented habitat.

S1.5. **Survey for the presence/absence of black rats simultaneously with cotton mice surveys.** Black rats might compete with cotton mice and may have caused the extinction of two other subspecies of cotton mice. Determine the prevalence of habitat use and overlap between cotton mice and black rats.

S1.6. **Maintain and improve the GIS database for cotton mouse information.** Compile additional survey information into the FWS' existing GIS databases.

S2. Protect and enhance existing populations.

S2.1. **Assign a biologist responsibility for implementing recovery actions for the threatened or endangered species of the Upper Florida Keys.** Recovery actions that benefit one of the threatened or endangered species in the Florida Keys (such as actions to recover the Key Largo cotton mouse) will benefit other threatened or endangered species in the same area. At the same time, the number of actions that will be necessary to recover threatened or endangered species in the Upper Florida Keys will require the attention of a biologist or similarly trained professional dedicated to addressing these recovery needs.

S2.2. **Utilize Federal regulatory mechanisms for protection.** Conduct section 7 consultations on Federal activities that may affect the cotton mouse and determine a jeopardy threshold. Coordinate with law enforcement to improve and increase enforcement under section 9 of the ESA, which prohibits take of the cotton mouse. Obtain evidence that shows habitat modification or degradation and secondary impacts (*e.g.*, black rats) have an adverse impact on the cotton mouse's ability to survive or recover and thus constitute take.

S2.3. **Provide cotton mouse information to State, county, and city agencies, including GIS information regarding the presence of cotton mice, their protection under the ESA, and ways to minimize impacts on the mice and their habitat.** Non-federal agencies that may influence the cotton mouse include DEP, DCA, GFC, DACS, Monroe County Mosquito Control, Florida Keys Aqueduct Authority, and Monroe County government.

S2.4. **Conduct cotton mouse reintroductions from natural wild populations.**

S2.4.1. **Develop a standard protocol for conducting, monitoring, and evaluating all reintroduction, translocation, and supplementation efforts of cotton mice using the IUCN/SSC Guidelines for Reintroductions.** Develop criteria that determine the type of release to be conducted; evaluate and select release sites; determine the source and health of release stock; develop short and long-term success indicators; and develop a policy on intervention. Ensure release sites are free of threats prior to any release of cotton mice.

S2.4.2. **Identify potential release sites.** Prioritize relocation sites based on population needs and habitat suitability. Ensure habitat is of sufficient size, is within historic range, contains suitable vegetation, and has long-term protection. Ensure sites have a sufficient carrying capacity to sustain growth of the reintroduced population for a minimum of 25 years.

S2.4.3. **Restore or improve habitat where possible to ensure sites are suitable for augmentation/reintroductions.**

S2.4.4. **Identify suitable release stock.** Identify donor populations and determine size and health of these populations. Determine the effects of translocation on the donor population.

S2.4.5. **Obtain stock for translocation.** Select the number, ages, and sex ratios of cotton mice to be translocated, and the timing of the translocation.

S2.4.6. **Release cotton mice into new sites.** First, augment populations in habitat on north Key Largo that has been restored. Second, reintroduce cotton mice in habitat on the periphery of the range. Third, establish new populations in other suitable areas within the historic range.

S2.4.7. **Monitor introduced populations to determine survival, growth, and reproductive success.**

S25. **Minimize and eliminate disturbance or mortality to the Key Largo cotton mouse.** The level of cotton mouse mortality has not been characterized, although sources of mortality are documented. Implement management actions that reduce mortality.

S2.5.1. **Remove nuisance predators.** Feral dogs and cats, black rats, raccoons, and fire ants can increase cotton mouse mortality. Eliminate food sources and home sites for raccoons and black rats, control free-roaming feral cats and dogs, and destroy fire ant colonies near and in cotton mouse habitat. Enforce deed restrictions of cat control in Ocean Reef Club and other areas.

S2.5.2. **Minimize the effects of pesticides and other biocides.** Mosquito spraying may impact the availability of food species. Rodent control agents used for black rats pose a threat to the cotton mouse. Investigate the effects of these biocides and eliminate any adverse effects on the cotton mouse.

S2.5.3. **Control blatant killing and poisoning**. Cotton mice may be killed by humans in an effort to get rid of nuisance mice and rats. Inform homeowners on the protection of cotton mice and ways to minimize impacts. Develop methods to prevent cotton mouse poisoning.

S2.5.4. **Reduce the effects of road mortality.** Investigate the effects of road mortality on the cotton mouse. Implement appropriate management actions to reduce impacts of road mortality if a need is demonstrated.

S2.5.5. **Minimize the effects of contaminants.** Investigate the effects of contaminants around the old Nike missile site on the refuge, the firing range at Harbor Course, and illegal dumpsites. Remove contaminants that pose an adverse threat to the cotton mouse.

S3. **Conduct research on the biology and life history of the Key Largo cotton mouse**. Conduct studies on the basic biology of the cotton mouse. Investigate reproductive success, productivity, longevity, population size, movements, and dispersal.

S3.1. **Determine if the total population size is large enough to prevent functional extinction and genetic extinction.** Populations fluctuate from year to year. Determine what is the effective population size necessary for survival. Conduct population modeling (*e.g.*, population viability assessment, risk assessment) to predict the persistence of this species.

S3.2. **Determine the number of subpopulations necessary to maintain a stable or increasing population.**

S3.2.1. **Identify subpopulations vulnerable to extinction.** Investigate whether populations on the periphery or near human habitation are more vulnerable to extinction.

S3.2.2. **Determine the necessary number of subpopulations and level of exchange that will enable the cotton mouse to persist for 100 years.**

S3.3. **Determine a stable age structure, sex ratio, and group size for the cotton mouse.**

S3.4. **Examine factors that affect the abundance and distribution of the cotton mouse.** Determine what aspects of this species' ecology makes it most vulnerable to extinction (*e.g.*, predation, lack of food, lack of nesting materials, inability to find a mate).

S4. **Monitor the status of the Key Largo cotton mouse .** Due to the short life span and normal population fluctuation, population declines could go unnoticed unless a continuous monitoring program is established and implemented.

S4.1. **Develop methods to monitor demographic parameters.** Develop methods to monitor sex ratios, age class structure, survivorship, home range size, age of dispersal, and dispersal distance of the cotton mouse.

S4.2. **Conduct long-term monitoring of the status of the cotton mouse.** Monitor presence/absence and degree of abundance semiannually until the cotton mouse is recovered.

S4.3. **Monitor sex ratios, age class structure, and survivorship.**

S5. **Increase public awareness and stewardship.** Develop educational materials and host public workshops to increase awareness about cotton mice and instill a sense of stewardship for the protection of this endangered species.

S5.1. **Prepare educational material for the general public.** Distribute materials at visitor information centers and local chambers of commerce.

S5.2. **Develop and implement a cat, black rat, fire ant, and raccoon control program.** Conduct workshops to educate residents about the necessity to control predation on cotton mice as well as to minimize the effects of black rats and fire ants.

S6. **Establish reclassification criteria**. Develop measurable reclassification criteria based on factors that constitute a stable population, including total population size, number of subpopulations, sex ratio, habitat condition and availability, and level of threats. Evaluate and monitor the cotton mouse's status in relation to reclassification criteria.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Over 90 per cent of occupied habitat has been purchased. Remaining habitat is restricted to north Key Largo.

H1.1. Acquire all occupied habitat first, then unoccupied. Identify priority areas for acquisition. Acquire all occupied suitable habitat first (Priority 1), then unoccupied (Priority 2). Unoccupied, but suitable habitat is important for future reintroduction activity. Inholding areas are also high priority.

H1.1.1. Continue Federal acquisition efforts. Continue acquisition efforts at Crocodile Lake NWR, which has developed a priority acquisition and restoration list.

H1.1.2. Support State, local, and non-governmental organizations' acquisition efforts. Support effort of entities to acquire cotton mouse habitat including state conservation easements, CARL, Monroe County Land Authority, Florida Community Trust, Florida Keys Land Trust, and The Nature Conservancy. Support the acquisition of lands to be incorporated into the Key Largo Hammocks State Botanical Site.

H1.2. Protect and manage Key Largo cotton mouse habitat.

H1.2.1. Protect cotton mice on private lands. Protect cotton mouse populations on private land through acquisition, conservation easements or agreements, and informing landowners. Develop agreements (*e.g.*, Memorandum of Agreement) between the FWS and private landowners to minimize impacts such as feral cats and exotics.

H1.2.2. Protect cotton mice on public lands. Develop a habitat management plan that outlines priority habitat for acquisition and methods to protect, restore, and minimize impacts on cotton mice and their habitat.

H1.2.3. Coordinate with Federal, State and Monroe County agencies and private entities to develop management actions to protect cotton mouse habitat. Coordinate with these entities to ensure proposed construction activities that result in land clearing or alteration do not impact the cotton mouse and its habitat. Coordinate with the Audubon Society to develop a management plan for Parcel 22. Coordinate with private landowners to protect and manage habitat and minimize impacts to the cotton mouse (*e.g.*, trash, feral cats, *etc.*).

H1.2.4. Avoid clearing or disturbing hammocks. Prevent clearing of hardwood hammocks. Steer construction activities towards already-cleared areas.

H1.2.5. Restrict access to cotton mouse habitat. Restrict access to remote habitat areas to prevent damage caused by campers, homesteaders, trash dumpers, and vehicular traffic.

H1.2.6. Establish and protect 500-m buffers around Priority 1 habitat. The necessity for 500-m protection buffer zones is based on the likelihood that human influences encroach and impact the cotton mouse.

H1.2.7. Prevent fires. Wildfires can quickly destroy large areas of hardwood hammocks. Develop effective fire suppression plans. Prohibit fires and smoking in or near hardwood hammocks.

H1.2.8. **Eliminate exotic vegetation.** Remove exotic vegetation in cotton mouse habitat and in adjacent upland buffers. Use deed restrictions, covenants, or other means to minimize the likelihood that exotic plants will invade hardwood hammocks. Remove exotic vegetation in refuge boundaries. Support the removal of exotics in other cotton mouse habitat, including Port Bougainvillaea and Ocean Forest Tract (ocean side of Harrison Tract).

H2. **Restore both suitable occupied and unoccupied cotton mouse habitat.** Several areas are suitable for restoration. Restoration efforts will benefit the hammock habitat, existing cotton mice populations, and future-released populations. Conduct and support restoration activities in cotton mouse habitat.

H2.1. **Prepare a hardwood hammock restoration plan for north Key Largo.** Several large-scale restoration efforts are underway in South Florida and it will be advantageous to have a plan to link into funding and project implementation opportunities.

H2.2. **Restore cotton mouse habitat on refuge property.** Restore habitat near the missile site, the borrow pit, gun range, the cockfighting ring, and radio tower.

H2.3. **Restore old CR 905 Road to promote cotton mouse habitat.**

H2.4. **Remove trash and debris.** Several old roads into the Crocodile Lake NWR are littered with trash and debris. Remove trash and debris from these and other areas in cotton mouse habitat.

H2.5. **Improve hydrology and water quality in cotton mouse habitat.** Restore hydrology of Dispatch Slough and other areas in need.

H2.6. **Improve habitat by planting or encouraging native plant species.** Plant native vegetation in areas that have been scarified or degraded.

H2.7. **Create habitat by refilling and recreating areas that have been dredged or altered.** This will not include refilling areas that are important to crocodiles.

H3. **Conduct research to determine habitat needs for the cotton mouse.**

H3.1. **Investigate how cotton mice use different habitat components for survival (*e.g.,* for food, shelter, nesting, traveling).**

H3.1.1. **Investigate stable home range and minimum area requirements.** Male cotton mice have larger home ranges than females and home ranges overlap because cotton mice do not defend territories.

H3.1.2. **Investigate the effect of habitat change.** Determine how the cotton mouse's distribution and abundance is affected by habitat degradation and other human factors.

H3.2. **Determine an index of habitat fragmentation.**

H3.2.1. **Investigate movement patterns and the spatial use of habitat to identify important core areas and corridors.**

H3.2.2. **Determine if the amount and configuration of habitat is sufficient to support a stable or increasing population of cotton mice.**

H4. **Monitor the status of cotton mouse habitat and examine ecological processes.** Conduct yearly monitoring evaluations of the status of the cotton mouse's habitat. Use GIS capabilities to determine locations and quality of habitat, including what patches are being altered or lost each year. Monitor the availability of cotton mouse habitat by updating the loss or change of habitat due to residential or commercial construction.

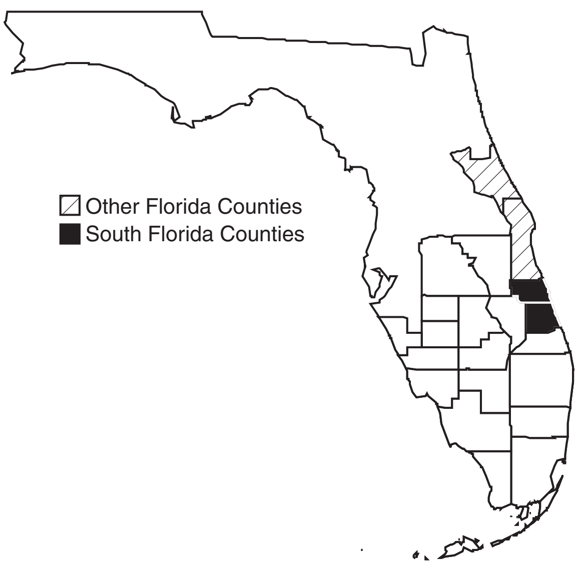
H5. **Increase public awareness of cotton mouse habitat and instill stewardship.** Conduct workshops with the public to inform private landowners about appropriate management practices to preserve cotton mouse habitat. Encourage private landowners to remove exotics, maintain natural waterflow, refrain from destroying mouse habitat, and restore disturbed areas. Prepare literature to provide information regarding the cotton mouse's habitat and ways to protect and conserve it.

Southeastern Beach Mouse

Peromyscus polionotus niveiventris

Federal Status:	**Threatened (May 12, 1989)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. County distribution of the southeastern beach mouse; this species is only found in coastal habitats within these counties.



The southeastern beach mouse is a subspecies of the oldfield mouse that occurs in coastal habitats along the east coast of Florida. Its range formerly extended along about 280 km of the coast, in beach dunes, from Volusia to Broward counties. It is now restricted to about 64 km of coastline, having been extirpated in the southern portion of its former range. Extensive habitat loss because of commercial and residential construction along the Atlantic coast has left a fragmented population in small pockets of suitable habitat. Surveys are needed to determine the status of the southeastern beach mouse in South Florida.

This account represents South Florida's contribution to the recovery of the southeastern beach mouse (FWS 1993).

Description

The southeastern beach mouse is the largest of the seven recognized subspecies of beach mice, averaging 139 mm in total length (range of 10 individuals = 128 to 153 mm), with a 52 mm tail length (Osgood 1909, Stout 1992). Females are slightly larger than males. These beach mice are slightly darker in appearance than some other subspecies of beach mice, but paler than inland populations of *P. polionotus* (Osgood 1909). Southeastern beach mice have pale, buffy coloration from the back of their head to their tail, and their underparts are white. The white hairs extend up on their flanks, high on their jaw, and within 2 to 3 mm of their eyes (Stout 1992). There are no white spots above the eyes as with *P. p. phasma* (Osgood 1909). Their tail is also buffy above and white below. Juvenile *P. p. niveiventris* are more grayish in coloration than adults, otherwise they are similar in appearance (Osgood 1909).

Taxonomy

Peromyscus polionotus is a member of the order Rodentia and family Cricetidae. The southeastern beach mouse is one of 16 recognized subspecies of oldfield mice *P. polionotis* (Hall 1981); it is one of the seven of those subspecies that are called “beach mice.” The southeastern beach mouse was first described by Chapman (1889) as *Hesperomys niveiventris*. Bangs (1898) subsequently placed it in the genus *Peromyscus*, and Osgood (1909) assigned it the subspecific name *P. polionotus niveiventris*.

Distribution

The oldfield mouse *(P. polionotus*) is distributed throughout dry, sandy habitats on inland sites in northeastern Mississippi, Alabama, Georgia, South Carolina, and Florida. Seven subspecies of the oldfield mouse occur on beaches and dunes of the Atlantic coast of Florida and the Gulf coast of Alabama and Florida, and are collectively known as “beach mice.”

Five subspecies of beach mice occur on the Gulf coast from Mobile Bay, Alabama to Cape San Blas, Florida: the Alabama beach mouse (*Peromyscus polionotus ammobates*), the Perdido Key beach mouse (*P. p. trissyllepsis*), the Choctawhatchee beach mouse (*P. p. allophrys*), the Santa Rosa beach mouse (*P. p. leucocephalus*) and the St. Andrews beach mouse (*P. p. peninsularis*); the latter four occur on the Gulf coast of Florida. The Anastasia Island beach mouse (*P. p. phasma*) and the southeastern beach mouse occur on the Atlantic coast of Florida, but their ranges do not overlap.

Historically, the southeastern beach mouse occurred along about 280 km of Florida’s southeast coast, from Ponce Inlet, Volusia County, southward to Hollywood, Broward County, and possibly as far south as Miami Beach in Miami-Dade County, Florida (Stout 1992). The type locality for the southeastern beach mouse is East Peninsula, Oak Lodge, opposite Micco, Brevard County, Florida (Osgood 1909). Based on the most recent published literature, this subspecies is currently restricted to about 80 km of beach, occurring in Volusia County, Brevard County, and scattered locations in Indian River and St. Lucie counties (Figure 1). The southeastern beach mouse is geographically isolated from all other subspecies of *P. polionotus*.

Habitat

Essential habitat of the southeastern beach mouse is the sea oats *(Uniola paniculata)* zone of primary coastal dunes (Humphrey and Barbour 1981, Humphrey *et al.* 1987, Stout 1992). This subspecies has also been reported from sandy areas of adjoining coastal strand vegetation (Extine 1980, Extine and Stout 1987, Rich *et al.* 1993), which refers to a transition zone between the foredune and the inland plant community (Johnson and Barbour 1990). Although individuals can occur and reproduce in the ecotone between the former sea oats zone and the shrub zone, they will not survive as a population there (L. Ehrhart, University of Central Florida, personal communication 1998). Beach mouse habitat is heterogeneous, and distributed in patches that occur both parallel and perpendicular to the shoreline (Extine and Stout 1987). Because this habitat occurs in a narrow band along Florida’s coast, structure and composition of the vegetative communities that form the habitat can change dramatically over distances of only a few meters.

Southeastern beach mouse. *Original photograph by Paul Tritaik.*

Primary dune vegetation described from southeastern beach mouse habitat includes sea oats, dune panic grass (*Panicum amarum*), railroad vine (*Ipomaea pes-caprae*), beach morning glory (*Ipomaea stolonifera*), salt meadow cordgrass (*Spartina patens*), lamb's quarters (*Chenopodium album*), saltgrass (*Distichlis spicata*), and camphor weed (*Heterotheca subaxillaris*) (Extine 1980, J. Stout, University of Central Florida, personal communication 1996). Coastal strand and inland vegetation is more diverse, and can include beach tea (*Croton punctatus*), prickly pear cactus (*Opuntia humifusa*), saw palmetto (*Serenoa repens*), wax myrtle (*Myrica cerifera*), rosemary (*Ceratiola ericoides*), sea grape (*Coccoloba uvifera*), oaks (*Quercus sp*.) and sand pine (*Pinus clausa*) (Extine and Stout 1987).

Although Extine (1980) observed this subspecies as far as 1 km inland on Merritt Island, he concluded that the dune scrub communities he found them in represent only marginal habitat for the southeastern beach mouse; highest densities and greater survival of mice were observed in beach habitat. In the same study site, Extine (1980) and Extine and Stout (1987) reported that the southeastern beach mouse showed a preference for areas with clumps of palmetto, sea grape, and expanses of open sand. In Indian River County, southeastern beach mice inhabit dunes that are only 1 to 3 m wide and dominated by sea oats and dune panic grass (Humphrey and Frank 1992). According to Stout (1992), southeastern beach mice do not occur in areas where woody vegetation is greater than 2 m in height.

Within their dune habitat, beach mice construct burrows to use as refuges, nesting sites, and food storage areas. Burrows of *P. polionotus*, in general, consist of an entrance tunnel, nest chamber, and escape tunnel. Burrow entrances are usually placed on the sloping side of a dune at the base of a shrub or clump of grass. The nest chamber is formed at the end of the level portion of the entrance tunnel at a depth of 0.6 to 0.9 m, and the escape tunnel rises from the nest chamber to within 2.5 cm of the surface (Blair 1951). A beach mouse may have as many as 20 burrows within its home range. They are also known to use old burrows constructed by ghost crabs (*Ocypode quadrata*).

Behavior

Not much is known about the life history and ecology of the southeastern beach mouse. Therefore, this section makes inferences about their biology using data from studies of other beach mice.

P. polionotus is the only member of the genus that digs an extensive burrow for refuge, nesting, and food storage (Ehrhart 1978). To dig the burrow, the mouse assumes a straddling position and throws sand back between the hind legs with the forefeet. The hind feet are then used to kick sand back while the mouse backs slowly up and out of the burrow (Ivey 1949). Burrows usually contain multiple entrances, some of which are used as escape tunnels. When mice are disturbed in their burrows, they open escape tunnels and quickly flee to another burrow or to other cover (Ehrhart 1978).

Beach mice, in general, are nocturnal. They are more active under stormy conditions or moonless nights and less active on moonlit nights. Movements are primarily for foraging, breeding, and burrow maintenance. Extine and Stout (1987) reported movements of the southeastern beach mouse between primary dune and interior scrub on Merritt Island, and concluded that their home ranges overlap and can reach high densities in their preferred habitats.

Reproduction and Demography

Studies on *Peromyscus* species in peninsular Florida suggest that these species may achieve greater densities and undergo more significant population fluctuations than their temperate relatives, partially because of their extended reproductive season (Bigler and Jenkins 1975, Smith and Vrieze 1979). Subtropical beach mice can reproduce throughout the year; however their peak reproductive activity is generally during late summer, fall, and early winter. Extine (1980) reported peak reproductive activity for *P. p. niveiventris* on Merritt Island during August and September, based on external characteristics of the adults. This peak in the timing and intensity of reproductive activity was also correlated to the subsequent peak in the proportion of juveniles in the population in early winter (Extine 1980). This pattern is typical of other beach mice as well (Rave and Holler 1992).

Sex ratios in beach mouse populations are generally 1:1 (Extine 1980, Rave and Holler 1992). Blair (1951) indicated that beach mice are monogamous; once a pair is mated they tend to remain together until death. He also found, however, that some adult mice of each sex show no desire to pair.

Nests of beach mice are constructed in the nest chamber of their burrows-a spherical cavity about 4 to 6 cm in diameter. The nest comprises about one-fourth of the size of the cavity and is composed of sea oat roots, stems, leaves and the chaffy parts of the panicles (Ivey 1949).

The reproductive potential of beach mice is generally high (Ehrhardt 1978). In captivity, beach mice are capable of producing 80 or more young in their lifetime, and producing litters regularly at 26-day intervals (Bowen 1968). Litter size of beach mice, in general, ranges from two to seven, with an average of four. Beach mice reach reproductive maturity as early as 6 weeks of age (Ehrhart 1978).

Dispersal of young mice and the disappearance of adults may be the primary reasons for population fluctuations in certain areas (Blair 1951). Young beach mice move an average of 432 m before establishing residence in a new area. Although reproductive potential is high, mortality of adult beach mice is also quite high. Only 19.5 percent of the beach mice present in Blair's study in January survived to May of that same year.

Foraging

Beach mice typically feed on seeds of sea oats and dune panic grass (Blair 1951). The southeastern beach mouse probably also eats the seeds of other dune grasses, railroad vine, and prickly pear cactus. Although beach mice prefer the seeds of sea oats, these seeds are only available as food after they have been dispersed by the wind. Beach mice also eat small invertebrates, especially during late spring and early summer when seeds are scarce (Ehrhardt 1978). Beach mice will store food in their burrows.

Relationship to Other Species

Southeastern beach mice co-occur with cotton mice (*P. gossypinus*) and cotton rats (*Sigmodon hispidus*), although local distributions and population variations may not be related (Extine 1980). It is unknown whether these species compete for food resources. Recent trap efforts south of Sebastian Inlet in Indian River County indicate that cotton mice are more prevalent in the coastal strand habitat, rather than the dune habitat preferred by the beach mouse. Ivey (1949) also states that cotton mice occur in a variety of vegetative communities, but prefer wooded and more mesic habitats. Cotton rats, however, are prevalent in both dune and coastal strand habitat.

Southeastern beach mice probably interact with house mice (*Mus musculus*), particularly in disturbed habitats where house cats are present. Humphrey and Barbour (1981) speculated that competitive exclusion by house mice was a factor in the extinction of the pallid beach mouse. Frank and Humphrey (1992) discuss the potential threat of house mice to the Anastasia Island Beach mouse, and Briese and Smith (1973) found that house mice competed with *P. polionotus* in Georgia for available habitat when the *Peromyscus* population became reduced because of disturbance or predation.

As stated previously, beach mice dig burrows in the dune; however, they are also known to occasionally use old burrows constructed by ghost crabs. In South Florida, the coastal habitat is also used by four species of endangered or threatened sea turtles; where the southeastern beach mouse occurs these are predominantly the loggerhead turtle (*Caretta caretta*) and the green turtle (*Chelonia mydas*). From an ecosystem perspective, conservation efforts should be implemented to benefit all of these species simultaneously, and management activities should avoid any potential conflict between these species.

Predation is the primary cause of mortality of adult beach mice (Blair 1951). Known and probable predators of the southeastern beach mouse include snakes, bobcats (*Lynx rufus*), gray foxes (*Urocyon cinereoargenteus*), raccoons (*Procyon lotor*), striped skunk (*Mephitis mephitis*), spotted skunk (*Spilogale putorius*), armadillos (*Dasypus novemcinctus*), owls, hawks, great blue herons (*Ardea herodias*), red-imported fire ants, and domestic cats and dogs.

Status and Trends

The distribution of the beach mouse is extremely limited due to modification and destruction of its coastal habitats. Along Florida's Gulf coast, the Alabama beach mouse, the Perdido Key beach mouse, and the Choctawhatchee beach mouse were federally listed as endangered in 1985. The St. Andrews beach mouse was federally listed as endangered in 1998. On the Atlantic coast of Florida, the Anastasia Island Beach mouse (*P. p. phasma*) and the southeastern beach mouse were federally listed as endangered and threatened, respectively, in 1989 (54 FR 20602). One additional subspecies, the pallid beach mouse (*P. p. decoloratus*), was formerly reported from two sites on the Atlantic coast, but extensive surveys conducted since 1959 provide substantial evidence that this subspecies is extinct (Humphrey 1992).

The distribution of the southeastern beach mouse has declined significantly, particularly in the southern part of its range. Historically, it was reported to occur from Ponce (Mosquito) Inlet, Volusia County, to Hollywood Beach, Broward County (Hall 1981). Bangs (1898) reported it as "extremely abundant on all the beaches of the east peninsula from Palm Beach at least to Mosquito (Ponce) Inlet." More recently, the southeastern beach mouse has been reported only from Volusia County (Canaveral National Seashore to about 11 km north of the Volusia-Brevard County line), Federal lands in Brevard County (Canaveral National Seashore, Merritt Island NWR, and Cape Canaveral Air Force Station), a few localities in Indian River County (Sebastian Inlet SRA, Treasure Shores Park, and several private properties), and St. Lucie County (Pepper Beach County Park and Fort Pierce Inlet SRA) (Humphrey *et al*. 1987, Robson 1989, Land Planning Group, Inc. 1991, Humphrey and Frank 1992, FWS 1993).

Large, healthy populations of the southeastern beach mouse are still found on the beaches of Canaveral National Seashore, Merritt Island NWR, and Cape Canaveral Air Force Station in Brevard County-all federally protected lands (U.S. Air Force 1989, Provancha and Oddy 1992). The distribution of this subspecies in the South Florida Ecosystem, however, is severely limited and fragmented. There are not enough data available in South Florida to determine population trends for the southeastern beach mouse; however, recent surveys reveal that it occurs in very small numbers where it is found (Table 1).

In Indian River County, the Treasure Shores Park population has experienced a significant decline over the past few years, and it is uncertain whether populations still exist at Turtle Trail or adjacent to the various private properties (P. Tritaik, Archie Carr NWR, personal communication 1996). Trapping efforts during the past 6 years in this area have documented a decline from an estimated 300 individuals down to numbers in the single digits (L. Ehrhart, University of Central Florida, personal communication 1998). The status of the species south of Indian River County is currently unknown. No beach mice were found during recent surveys in St. Lucie County; it is possible that this species is extirpated there. The southeastern beach mouse no longer occurs at Jupiter Island, Palm Beach, Lake Worth, Hillsboro Inlet or Hollywood Beach. Given these data and trends, it is likely that without

Table 1. Surveys conducted for *Peromyscus polionotus niveiventris* in South Florida.

Author	Date	Locality	Number Captured	Pop. Size	Trap Nights
Humphrey *et al.* (1987)	7/30-8/1 1986	Sebastian Inlet SRA, Indian River County	2		69.0
		Turtle Trail Public Beach Access, Indian River County	3		113.5
		Pepper Park, St. Lucie County	1		107.5
		Surfside Beach Park, St. Lucie County	1		78.5
Robson (1989)	8/12-8/15 1988	Sebastian Inlet SRA, Indian River & Brevard County	4		176.0
		Fort Pierce Inlet SRA, St. Lucie County	1		123.0
	3/03-3/05 1988	St. Lucie Inlet State Park, Martin County	0		62.0
	2/29-3/02 1988	MacArthur Beach State Park, Martin County	0		74.0
	1/31-2/03 1989	Malapan, Palm Beach County	0		250.0
Land Planning Group (1991)	3/04-07 1991	Seaview Subdivision, Indian River County	46		224.0
Humphrey and Frank (1992)	12/25-29 1991	Treasure Shores Park, Indian River County	191	303	859.0
Rich *et al.* (1993)	12/09-11 1992	Beach dune of Windsor Properties, Indian River County	34	7	68.0
	12/14-20 1992	Coastal strand, Windsor Properties, Indian River County	64	27	733.0
Weight (1995)	5/02-05 1995	Beach dune, Orchid Island Golf and Beach Club, Indian River County	4		158.0
	4/19-22 1995	Coastal strand, Orchid Island Golf and Beach Club, Indian River County	1		163.0
Bard (1997)	5/11 1995	Sebastian Inlet SRA, Indian River County	3		116.0
	7/26-27 1996		13		701.0
	5/9-10 1996		6		668.0
	4/9 1997		2		360.0
Ehrhart and Tritaik (1997)	4/25-26 1995	Archie Carr NWR, Indian River County portion	42		640.0
	4/18-19 1996		10		412.0
	4/24-25 1996	Archie Carr NWR, Treasure Shores Park, Indian River County	8	8	544.0
	11/29-30 1996	Archie Carr NWR, Treasure Shores Park, Indian River County	5		494.0
	2/18-19 1997	Treasure Shores/Seaview Subdivision, Indian River County	13		701.0
	4/9-10 1997		3		693.0
	6/30-7/1 1997		6		753.0
	12/15 1997		2		391.0
Jennings and Miller (1997)	3/31-4/3 1997	Fort Pierce Inlet SRA, St. Lucie County	0		296.0
		Pepper Beach County Park, St. Lucie County	0		276.0
		2 private parcels, St. Lucie County	0		344.0

management intervention the entire South Florida population of southeastern beach mice will be lost in the near future.

The primary threat to the survival and recovery of the southeastern beach mouse is the continued loss and alteration of coastal dunes. Large-scale commercial and residential development on the Atlantic coast has eliminated beach mouse habitat in Palm Beach and Broward counties. This increased urbanization has also increased the recreational use of dunes, and harmed the vegetation essential for dune maintenance. Loss of dune vegetation results in widespread wind and water erosion and reduces the effectiveness of the dune to protect other beach mouse habitat.

In addition to increased urbanization, coastal erosion is responsible for the loss of the dune environment along the Atlantic coast, particularly during tropical storms and hurricanes. The construction of inlets has exacerbated coastal erosion problems along the Atlantic coast. There are six man-made inlets on the Atlantic coast from Brevard County to Broward County that disrupt longshore sediment transport; because of this disruption beach habitat is gained on the north side of an inlet and becomes severely eroded immediately to the south. In Indian River County, for example, erosion has been nearly 2 m per year at Sebastian Inlet SRA (just south of Sebastian inlet); this is six times the average erosion rate for the county (J. Taber, Indian River County, personal communication 1996). Erosion of the dune habitat adjacent to the Treasure Shores Park has accelerated by nearly 0.3 m per year over the past 10 years (DEP 1996).

The encroachment of residential housing onto the Atlantic coast increases the likelihood of predation by domestic cats and dogs. A healthy population of southeastern beach mice on the north side of Sebastian Inlet SRA in Brevard County was completely extirpated by 1972, presumably by feral cats (R. Johns, Sebastian Inlet SRA, personal communication 1996). Urbanization of coastal habitat could also lead to potential competition of beach mice with house mice and introduced rats.

Management

Southeastern beach mice live in a dynamic, harsh environment that is exposed to recurring tropical storms. Historically, beach mice populations fluctuated in response to changes in the environment. In the past, local populations probably became extinct when storms destroyed their habitat; these areas were then recolonized by adjacent populations that survived the storms. Today, however, increased urbanization along the Atlantic coast has eliminated much of the coastal dune and created isolated patches of habitat available to the beach mouse.

Ongoing management practices within the range of the southeastern beach mice restrict beach access to designated crossovers (boardwalks) to minimize the human trampling of the dune systems. Since public beaches on Florida's east coast receive heavy public use, continuing to enforce these restrictions on dune access will be essential to the recovery of the southeastern beach mouse.

Beach nourishment projects are conducted periodically by the COE to maintain the beach in areas of greatest erosion. Southeastern beach mice could be adversely affected if dredged sand is placed on or near their habitat. It is critical that effects to beach mice also be evaluated for any land-modification projects in coastal habitat, and that any dredged material be compatible with existing beach sand.

Although there are a number of State and county regulations pertaining to residential, commercial and recreational development in coastal areas, none specifically address protection of beach mouse habitat. The regulations dictate requirements for siting and construction of buildings, utilities, and access corridors.

The Coastal Barriers Resources Act of 1982, as amended (16 U.S.C. 3501 *et seq*.) prohibits the expenditure of Federal funds that encourage development within the undeveloped, unprotected 186 units of the Coastal Barriers Resources System (CBRS); however, construction in these units is still proceeding, even with no Federal involvement. Examination of aerial photographs for 157 CBRS units revealed a 40.7 percent increase in the number of structures between 1982 and 1986/1988. Over half of this construction occurred in the State of Florida (Jones and Stolzenburg 1989).

Habitat fragmentation has created disjunct, isolated populations of southeastern beach mice in South Florida. Although the populations of *P. p. niveiventris* in Brevard County are large and healthy because they are protected on public lands, they are geographically, and thus genetically, isolated from populations in Indian River County because of Sebastian Inlet. No natural dispersal can occur from Brevard County populations to enhance the populations to the south. The five inlets between Indian River and Broward counties also create unnatural barriers to dispersal along this length of coast. As a result of this isolation, southeastern beach mouse populations are probably now ephemeral and have a high risk of extinction.

The long-term persistence of a given population may depend on the ability of mice from adjacent parts of the range to recolonize beaches. To avoid excessive risks of extinction from demographic, catastrophic, or genetic events, an attempt should be made to establish viable populations of southeastern beach mice in remaining areas of suitable habitat throughout their historic range. Although population viability analyses (a technique to estimate the probability of survival, for various time periods, of animal populations of differing effective breeding size) have not been done for beach mice, relocation experiments with other subspecies of beach mice have been successful. However, due to the limited amount of habitat available along the Atlantic coast, it may be difficult to establish new populations of *P. p. niveiventris* with good prospects for long-term survival. Three sites in South Florida that warrant evaluation as potential recipient sites are Fort Pierce Inlet SRA, Avalon SRA, and Pepper Beach County Park in St. Lucie County.

If translocation projects are attempted, proven reintroduction protocols should be followed. Holler *et al.* (1989) successfully re-established the Perdido Key beach mouse by translocating 15 pairs from Gulf State Park at Florida Point in Alabama to an unoccupied site at Gulf Islands National Seashore. Frank (1995) successfully translocated 55 Anastasia Island beach mice (27 females and 28 males) from two locations on Anastasia Island to a site at Guana River SP where the subspecies had been extirpated. In general, it is recommended that the source population of mice for a translocation come from a large, healthy population, and that the release site be an area that is protected and unoccupied. It is also recommended to move mice during the fall season when more food is available. Monitoring of the introduced population will determine whether additional augmentation is needed. In addition, once the translocated population is stable, mice should be exchanged with the donor population (N. Holler, Alabama Cooperative Fish and Wildlife Research Unit, personal communication 1996).

The State of Florida administers land acquisition programs that can be used to secure coastal dune habitat for the southeastern beach mouse and other endemic species. Reintroduction of this species into these protected areas, and managing the areas to avoid invasion by exotic vegetation and depredation of mice by domestic animals, may help to ensure the survival and recovery of the beach mouse over the long term. Likewise, the Archie Carr NWR was established in 1989 to protect beach habitat along a 20-mile section of coast in Brevard and Indian River counties. An ecosystem approach to coastal resource protection is being employed to link the beach and dune habitats, maritime forests, wetlands, and estuarine systems. As proposed, the refuge would protect four segments of Atlantic beach and dunes totaling 14.9 km.

Surveys to determine the status of the southeastern beach mouse in the South Florida Ecosystem in areas of suitable habitat are imperative. Monitoring protocols exist that suggest trapping should be conducted twice per year, early to mid-fall and late winter. A trapping protocol to determine presence/absence of beach mice has been standardized, and is included with each collecting permit issued by the GFC and FWS. This protocol describes how sampling should be done, and the appropriate number of traps to use. It also requires that material (such as cotton batting) be placed in traps when nighttime temperatures are forecast to be < 18.5 degrees C, and that traps be checked beginning at 11:00 p.m. when nighttime temperatures are forecast to be < 10 degrees C.

It is important to note that hantavirus is now a concern when trapping rodents. In Florida, the cotton rat has been identified as a carrier for the virus causing hantavirus pulmonary syndrome (CDC 1996). There have been no documented cases of hantavirus associated with beach mice work; however, because cotton rats may be present when trapping for beach mice, precautions should be taken to minimize the likelihood of exposure.

Literature Cited

Bangs, O. 1898. The land mammals of peninsular Florida and the coastal region of Georgia. Boston Society Natural History Proceedings 28:157-235.

Bard, A. 1997. Data summaries for southeastern beach mouse trapping effort at Sebastian Inlet State Recreation Area, Indian River County. On file at the U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Bigler, W.J. and J.H. Jenkins. 1975. Population characteristics of *Peromyscus gossypinus* and *Sigmodon hispidus* in tropical hammocks of South Florida. Journal of Mammalogy 56:633-644.

Blair, W.F. 1951. Population structure, social behavior and environmental relations in a natural population of the beach mouse (*Peromyscus polionotus leucocephalus*). Contributions Laboratory Vertebrate Zoology, University of Michigan 48:1-47.

Bowen, W.W. 1968. Variation and evolution of Gulf coast populations of beach mice (*Peromyscus polionotus*). Bulletin Florida State Museum of Biological Science 12:1-91.

Briese, L.A. and M.H. Smith. 1973. Competition between *Mus musculus* and *Peromyscus polionotus*. Journal of Mammology 54:968-969.

Centers for Disease Control and Prevention [CDC]. 1996. Hantavirus in the United States: a brief review. Centers for Disease Control and Prevention Document #0994929. 15 November 1996.

Chapman, F.M. 1889. Description of two new species of the genus *Hesperomys* from Florida. American Museum of Natural History Bulletin 2:117.

Florida Department of Environmental Protection [DEP] 1996. Unpublished data summaries of shoreline erosion measured in terms of the change in mean high water level, from Ocean Hideaway to Treasure Shores. On file at the U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Ehrhart, L.M. 1978. Pallid beach mouse. Pages 8-9 *in* J.N. Layne, ed. Rare and endangered biota of Florida, vol. 1: Mammals. University Presses of Florida; Gainesville, Florida.

Ehrhart, L.M. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. January 27, 1998.

Extine, D.D. 1980. Population ecology of the beach mouse, *Peromyscus polionotus niveiventris*. Unpublished M.S. thesis, Department of Natural Sciences, University of Central Florida; Orlando, Florida.

Extine, D.D., and I.J. Stout. 1987. Dispersion and habitat occupancy of the beach mouse *Peromyscus polionotus niveiventris*. Journal of Mammalogy 68:297-304.

Frank, P.A. and S.R. Humphrey. 1992. Populations, habitat requirements, and management of the endemic Anastasia Island beach mouse (*Peromyscus polionotus phasma*), emphasizing the potential threat of exotic house mice (*Mus musculus*). Final report no. NG88-006 to Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Frank, P.A. 1995. Re-establishment of the Anastasia Island beach mouse to the beaches of northern St. Johns County, Florida. Final report to the U.S. Fish and Wildlife Service for contract number 41910-3-0287. On file at the U.S. Fish and Wildlife Service South Florida Ecosystem Office; Vero Beach, Florida.

Hall, E.R. 1981. The mammals of North America, second edition. John Wiley and Sons; New York, New York.

Holler, N. 1996. Telephone conversation. 30 May 1996.

Holler, N.R., D.W. Mason, R.M. Dawson, T. Simons, and M.C. Wooten. 1989. Reestablishment of the Perdido Key beach mouse (*Peromyscus polionotus trissyllepsis*) on Gulf Islands National Seashore. Conservation Biology 3(4):397-404.

Humphrey, S.R. 1992. Pallid beach mouse. Pages 19-23 *in* S.R. Humphrey, ed. Rare and endangered biota of Florida. vol. I.: Mammals. University Presses of Florida; Gainesville, Florida.

Humphrey, S.R., and D.B. Barbour. 1981. Status and habitat of three subspecies of beach mice in Florida. Journal of Mammalogy 68:297-304.

Humphrey, S.R. , and P.A. Frank. 1992. Survey for the southeastern beach mouse at Treasure Shores Park. Final report to Indian River County Board of Commissioners. 22 January 1992.

Humphrey, S.R., W.H. Kern, Jr., and M.S. Ludlow. 1987. Status survey of seven Florida mammals. Florida Cooperative Fish and Wildlife Research Unit technical report no. 25. Gainesville, Florida.

Ivey, R.D. 1949. Life history notes on three mice from the Florida east coast. Journal of Mammalogy 30:157-162.

Jennings, D.P., and J.B. Miller. 1997. Data summaries for Southeastern beach mouse trapping effort in St. Lucie County. On file at the U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Johnson, A.F. and M.G. Barbour. 1990. Dunes and maritime forests. Pages 429-480 *in* R.L. Myers and J.J Ewel, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

Jones, E., and W. Stolzenburg. 1989. Building in the Coastal Barrier Resources System. Report prepared for the National Wildlife Federation. On file at the U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Johns, R. 1996. Interagency meeting on the southeastern beach mouse in Sebastian, Florida. May 10, 1996; 22 October 1996.

Land Planning Group, Inc. 1991. Southeastern beach mouse survey of Seaview Subdivision, Indian River County, Florida. Final Report to Financial Services Group, Inc., Stuart, Florida. On file at the U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Osgood, W.H. 1909. Revision of the American genus *Peromyscus*. North American Fauna 28. Government Printing Office; Washington, D.C.

Provancha, J.A. and D.M. Oddy. 1992. A mark and release study on the southeastern beach mouse (*Peromyscus polionotus niveiventris*) on the Kennedy Space Center, Florida. Florida Scientist (Supplement 1):28.

Rave, E.H. and N.R. Holler. 1992. Population dynamics of Alabama beach mice (*Peromyscus polionotus ammobates*) in south Alabama. Journal of Mammalogy 73(2):347-355.

Rich E. R., Morris, J. G. and Knight, Mcguire and Associates. 1993. Windsor: Southeastern beach mouse survey and habitat management plan. Prepared for Windsor Properties, Vero Beach Florida. On file at the U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Robson, M.S. 1989. Southeastern beach mouse survey. Nongame Wildlife Section Report, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Smith, A.T. and J.M. Vrieze. 1979. Population structure of Everglades rodents: responses to a patchy environment. Journal of Mammology 60:778-794.

Stout, I.J. 1992. Southeastern beach mouse. Pages 242-249 *in* S.R. Humphrey, ed. Rare and endangered biota of Florida. vol. I: Mammals. University Presses of Florida; Gainesville, Florida.

Stout, J. 1996. Interagency meeting on the southeastern beach mouse in Sebastian, Florida. 10 May, 1996; 22 October 1996.

Taber, J. 1996. Interagency meeting on the southeastern beach mouse in Sebastian, Florida. 22 October 1996.

Tritaik, P. 1996. Interagency meeting on the southeastern beach mouse in Sebastian, Florida. 10 May 1996; 22 October 1996.

Tritaik, P. 1997. Data summaries for southeastern beach mouse trapping effort at Treasure Shores Park. On file at the U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

U.S. Air Force. 1989. Biological assessment of potential impacts to federally listed threatened species: Florida scrub jay and southeastern beach mouse (*Aphelocoma coerulescens coerulescens* and *Peromyscus polionotus niveiventris*). Cape Canaveral Air Force Station, Florida.

U.S. Fish and Wildlife Service [FWS]. 1993. Recovery plan for the Anastasia Island and southeastern beach mouse. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Weight, R. L. 1995. Orchid Island Golf and Beach Club East of A1A, Indian River County, Florida. Confidential environmental assessment report for Orchid Island Golf and Beach Club, Vero Beach, Florida. On file at the U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Recovery for the Southeastern Beach Mouse

Peromyscus polionotus niveiventris

Recovery Objective: DELIST.

South Florida Contribution: PREVENT EXTIRPATION, then stabilize and increase population.

Recovery Criteria

The current, approved recovery plan for the southeastern beach mouse states that this species can be considered for delisting if 10 viable, self-sustaining populations can be established throughout a significant portion of its historic range. Meeting these criteria will be difficult, if not impossible, without management intervention in South Florida. Information from recent surveys in Indian River County indicates the southeastern beach mouse is rare, and may be threatened with extirpation due to erosion, habitat destruction, and predation by domestic animals. Recent surveys in St. Lucie County have shown no evidence of this species. The nature of the habitat loss provides limited potential for habitat restoration or rehabilitation in South Florida. Consequently, the recovery contribution for South Florida is to prevent the extirpation of the southeastern beach mouse by increasing the numbers of individuals in existing populations, and by increasing the numbers of populations.

This objective will be accomplished when: further degradation of suitable, occupied habitat due to trampling and coastal erosion has been prevented; feral and non-native nuisance species have been eliminated in suitable, occupied habitat; existing populations, within their historic range, are protected either through land acquisition or cooperative agreements; the coastal dune and coastal strand communities that provide habitat for the southeastern beach mouse are managed to prevent non-native species from re-establishing populations in suitable, occupied habitat; potential coastal dune and coastal strand habitats in Indian River and St. Lucie counties are restored or rehabilitated to provide habitat for the southeastern beach mouse; translocations of this subspecies have been conducted from Brevard County into suitable habitat in Indian River and St. Lucie counties; and the Indian River and St. Lucie County populations of southeastern beach mouse exhibit a stable age structure, maintain a 1:1 male:female ratio, and sustain a rate of increase (r) that is equal to or greater than 0.0 as a 3-year running average for 6 years.

Species-level Recovery Actions

S1. Determine the distribution and status of the southeastern beach mouse in South Florida.

S1.1. Conduct surveys for the southeastern beach mouse in suitable habitat throughout Indian River, St. Lucie, and Martin counties to determine its current distribution. Surveys should follow the live-trapping protocol for beach mice established by the GFC and FWS.

S1.2. Survey known populations at least once per year during winter/spring months (when populations are at their highest numbers), for a minimum of 5 years, in areas where beach mice are known to occur to assess the status of the population(s) and document fluctuations in total numbers.

S1.3. Maintain distribution data in GIS database. A GIS database will provide maps of the distribution of the southeastern beach mouse and allow for analyses of population and habitat trends.

S2. Protect and enhance existing populations of southeastern beach mice in South Florida.

S2.1. Work with Federal, State, and local agencies to protect known populations of the southeastern beach mouse, as well as occupied and unoccupied dune and coastal strand communities.

S2.2. Work with private landowners. Encourage landowners along the coasts of Indian River, St. Lucie, and Martin counties to manage their properties in ways compatible with the continued existence of healthy dune habitat and beach mice. The FWS should interact with these owners by providing technical advice or entering into cooperative agreements to effect beach mouse conservation.

S2.3. Use provisions of the ESA to protect beach mice. In South Florida, consultations pursuant to section 7 of the ESA will be required for most activities of the FWS, the COE, and the Federal Emergency Management Agency that affect southeastern beach mouse populations. Projects that may affect the conservation of beaches occupied by beach mice, such as jetty construction and beach renourishment, require Federal permits and therefore are subject to section 7 consultation under the ESA; these consultations should prevent further isolation of beach mouse populations to assure survival and recovery. The FWS should evaluate private development activities to determine if they will violate the take provisions of section 9 of the ESA. Take incidental to such activities can be permitted only under section 10(a) of the ESA, and requires the development of habitat conservation plans.

S2.4. Control/prevent establishment of non-native, domestic, or feral animals. Human visitation and residence in and near beach mouse habitat makes it likely that animals associated with man (primarily cats, dogs, black rats, and house mice) will become established. These animals threaten the survival of beach mice through predation or competition. To minimize these risks, the following tasks should be addressed:

S2.4.1. Discourage free-ranging cats and dogs. Develop and implement ordinances, regulations, covenants, deed restrictions, and other mechanisms to discourage the introduction and establishment of dogs and cats in beach mouse habitat.

S2.4.2. Control domestic or feral cats on public lands. Managers of public lands should remove domestic and feral cats from beach mouse habitat whenever their presence is detected.

S2.4.3. Discourage establishment of exotic rodents. Discourage the establishment and spread of exotic rodents by containment and prompt removal of garbage from residences and recreational areas, and by minimizing the deposit of materials (*e.g*. construction materials, riprap, or other debris) in beach mouse habitat that might provide shelter for exotic rodents. Rodent traps or poisons that might affect beach mice should not be used in beach mouse habitat.

S2.4.4. Establish a management program to eliminate fire ants from public lands where beach mice are known to occur.

S2.5. Re-establish populations of southeastern beach mouse in South Florida. Recovery of the southeastern beach mouse in Indian River and St. Lucie counties will require the re-establishment of populations within its historic range.

S2.5.1. **Identify recipient sites for translocating southeastern beach mice.** Recipient sites must be of suitable habitat within the historic range, of sufficient size, and protected. Beach mice and their sign should be absent from a recipient site as determined by surveys conducted in at least two seasons and for 2 years. Follow the live-trapping protocol established by the FWS and GFC to conduct surveys.

S2.5.2. **Restore or improve habitat** where necessary to make the recipient sites suitable for beach mice.

S2.5.3. **Identify suitable donor populations.** Determine population size and health of potential donor populations through surveys. Donor populations should either be large and stable enough to withstand removal of mice without adverse effect, or be classified as non-viable under current habitat conditions. The Brevard County populations of the southeastern beach mouse are currently the only potentially suitable donor populations.

S2.5.4. **Obtain stock for translocation**. Select the number, ages, and sex ratios of mice to be translocated, and the timing of the translocation. Select only healthy mice from a preselected donor site (see **S2.5.3.**), based on overall fitness, body measurements, and/or blood samples. Previous translocations of beach mice have involved trapping mice from donor sites at high population levels during fall and winter and releasing mice at a 1:1 sex ratio.

S2.5.5. **Release mice into new sites**. Release technique, whether “soft release” or “hard release,” should be mutually agreed upon by all parties involved with the translocation. Translocations should be done in the fall or winter to provide maximum opportunity for reproduction during the first year. Translocations should extend over 3 years to ensure an adequate founder population.

S2.5.6. **Perform exchanges of 2 to 3 healthy pairs of mice between founder and re-established populations** at 2 to 3 year intervals once populations meet the conditions set above. These small and infrequent exchanges of mice can help guard against loss of alleles in each population, and against genetic divergence of either population from the other.

S2.5.7. **Monitor introduced and donor populations** using live-trapping and tracking surveys to determine survival, reproductive success, and the intrinsic rate of increase to determine whether the introduction was successful. When the first translocated population is determined to be successful, based on demographic data, a translocation to a second area should begin.

S2.6. **Initiate captive propagation as necessary for survival and recovery of the southeastern beach mouse.** Captive propagation is used to re-establish or supplement wild populations for recovery, and should be used only when extinction of this subspecies is likely due to significantly low population numbers or habitat loss and degradation. A controlled propagation program must be integrated with other recovery actions.

S2.6.1. **Develop plan for captive propagation using the Department of Interior/Department of Commerce (DOI/DOC) Controlled Propagation Policy.** If it is necessary to establish a breeding colony to prevent extinction of this subspecies, follow the direction provided in the DOI/DOC Controlled Propagation Policy.

S2.6.2. Revise this recovery plan for the southeastern beach mouse to include the captive propagation plan. In accordance with DOI/DOC policy, the captive propagation plan produced from **S2.6.1** must be part of an approved recovery plan prior to its implementation.

S3. Conduct research on life history of the southeastern beach mouse.

S3.1. Conduct studies on basic biology of the southeastern beach mouse. Collect data on reproduction, adult and juvenile survival and mortality, age structure, longevity, movements, dispersal, home range size, food requirements, *etc.*

S3.2. Conduct risk assessment and population viability analyses on the southeastern beach mouse once basic biological information is collected. These modeling efforts will determine the minimum population size necessary to prevent extinction, the number of mice needed to ensure recovery, and the minimum number of distinct populations of beach mice needed to ensure persistence of the species. These data will also provide information needed to identify potential donor populations for translocation purposes. Results of these data need to be used in planning management strategies for the survival and recovery of this species.

S4. Monitor beach mouse populations to assure that further declines in range and numbers do not occur without recovery actions being taken. Collect data on gender, reproduction, adult and juvenile survival, and dispersal to determine population size, structure, and composition, as well as juvenile recruitment into the breeding population. Monitoring each population will also provide information on sites from which to select animals for reintroduction purposes.

S5. Increase public awareness about beach mice. Produce brochures, signs, and other materials to educate the public about the ecological role of beach mice in beach and dune communities, and the need to avoid foot traffic in and over dune habitat. The public should understand that continued existence of beach mice is an indication that healthy beach and dune systems are being maintained.

Habitat-level Recovery Actions

H1. Prevent degradation of existing beach mouse habitat. Coastal dunes are a dynamic ecosystem. When combined with the natural fluctuations in population numbers of beach mice, it is expected that population levels and habitat occupancy will be variable over time. These are important considerations when making decisions about habitat protection.

H1.1. Prevent direct destruction of habitat; specifically, further degradation and fragmentation of coastal dune habitats in Indian River, St. Lucie, and Martin counties to assure the survival and recovery of the southeastern beach mouse.

H1.1.1. Ensure that project activity (construction of roads, parking lots, buildings, and other structures) is set back behind primary dunes and outside of areas occupied by beach mice. At a minimum, new construction should always be located landward of the coastal construction control line.

H1.1.2. Manage human use of beaches to avoid damage to dunes and adjacent coastal strand habitats used by the mice**.** Prevent or eliminate human access to dunes in some areas, and provide dune crossovers (boardwalks) and signage at essential beach access points to avoid dune erosion and blowouts.

H1.1.3. Enforce regulations prohibiting use of motor or man-powered vehicles on beaches and dune habitat.

H1.1.4. **Ensure that beach renourishment and other projects avoid damaging beach mouse habitat.** Potential oil spill cleanups, or restoration of beaches following other natural or manmade catastrophes, must also be carried out in a way to minimize adverse effects on the dunes.

H1.2. **Acquire potential suitable habitat** through Federal, State or non-governmental conservation organization efforts as lands become available for purchase. Identifying suitable habitat patches within the matrix of remaining coastal dune to acquire and conserve is critical to the long-term viability of this species.

H1.3. **Discourage establishment of exotic plants.** Exotic plants are not currently a threat to the southeastern beach mouse, but coastal plant communities occupied by beach mice should be monitored for evidence of invasive vegetation.

H2. **Restore areas to suitable habitat.**

H2.1. **Restore severely eroded areas through the use of sand fences and/or revegetation with sea oats and other native dune vegetation.** In Indian River County, dune restoration should be initiated at Treasure Shores Park.

H2.2. **Implement management actions (*i.e.*, prescribed burns) that enhance habitat for beach mice.** These actions should be implemented in habitat in need of restoration where beach mice could naturally disperse, and in areas identified as potential reintroduction sites.

H3. **Conduct research on habitat requirements for the southeastern beach mouse.**

H3.1. **Identify the essential components** of what defines habitat for the southeastern beach mouse (*i.e.*, vegetative structure and composition, physical characteristics of the dune and coastal strand, spatial configuration, *etc*.).

H3.2. **Determine the minimum amount of suitable habitat needed** to support a viable population of southeastern beach mice, and the amount of habitat required to obtain recovery for a single population.

H3.3. **Identify the types of management actions that enhance habitat for beach mice.** For example, prescribed burns in an area that is in need of restoration may result in an increase in utilization by beach mice.

H4. **Monitor the status of beach mouse habitat.**

H4.1. **Identify all coastal areas in Indian River, St. Lucie, and Martin counties that currently provide or that could provide habitat for the southeastern beach mouse.** Maintain this information in a GIS database to document habitat trends.

H4.2. **Assess the effects of erosion or other causes of habitat loss in areas where beach mice occur** and implement restoration activities when warranted.

H4.3. **Ensure that occupied habitat and surrounding dune and coastal strand communities are maintained in suitable condition for beach mice.**

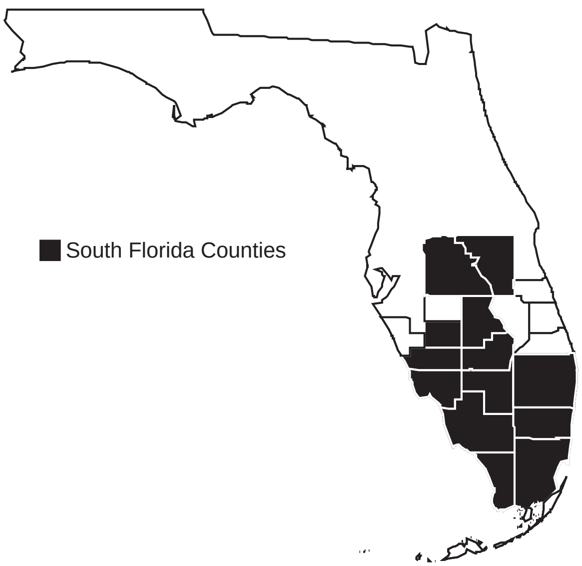
H5. **Increase public awareness about the coastal dune ecosystem.** The general public regularly uses beach areas in and adjacent to beach mouse habitat for recreational purposes. Inform the public of recreational practices that are compatible with the continued existence of beach mice. The Archie Carr Working Group could serve as a catalyst for public information and education materials.

Florida Panther

Puma concolor coryi

Federal Status:	**Endangered (March 11, 1967)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. County distribution of the Florida panther since 1981, based on radiotelemetry data.



The Florida panther, a subspecies of mountain lion, is one of the most endangered large mammals in the world. It is also Florida's state animal. A small population in South Florida,estimated to number between 30 and 50 adults (30 to 80 total individuals), represents the only known remaining wild population of an animal that once ranged throughout most of the southeastern United States from Arkansas and Louisiana eastward across Mississippi, Alabama, Georgia, Florida and parts of South Carolina and Tennessee. The panther presently occupies one of the least developed areas in the eastern United States; a contiguous system of large private ranches and public conservation lands in Broward, Collier, Glades, Hendry, Lee, Miami-Dade, Monroe, and Palm Beach counties totaling more than 809,400 ha.

Geographic isolation, habitat loss, population decline, and associated inbreeding have resulted in a significant loss of genetic variability and overall health of the Florida panther population. Natural gene exchange ceased when the panther became geographically isolated from other subspecies of *Puma concolor* about a century ago. Population viability projections have concluded that, under current demographic and genetic conditions, the panther would probably become extinct within two to four decades.

A genetic management program was implemented with the release of eight female Texas cougars (*Puma concolor stanleyana*) into South Florida in 1995 (refer to the Management section for a discussion of this program).

The survival and recovery of the Florida panther is dependent upon: (1) protection and enhancement of the extant population, associated habitats, and prey resources; (2) improving genetic health and population viability; and (3) re-establishing at least two additional populations within the historic range.

This account represents South Florida's contribution to the range-wide recovery plan for the Florida panther (FWS 1995); the range-wide recovery plan is currently under revision.

Description

The Florida panther is a medium-sized puma or mountain lion that is described as being relatively dark tawny in color, with short, stiff hair (Bangs 1899), and having longer legs and smaller feet (Cory 1896) than other subspecies. Adult male panthers reach a length of 2.15 m from their nose to the tip of their tail and may reach or exceed 68 kg in weight, but typically average around 54.5 kg. They stand approximately 60 to 70 cm at the shoulder. Female panthers are considerably smaller with an average weight of 34 kg and length of 1.85 m. The skull of the Florida panther has been described as having a broad, flat, frontal region, and broad, high-arched or upward-expanded nasals (Young and Goldman 1946).

The coat of an adult Florida panther is unspotted and typically rusty reddish-brown on the back, tawny on the sides, and pale gray underneath. The long cylindrical tail is relatively slender compared to some of the other subspecies of *Puma concolor* (Belden 1988).

Florida panther kittens are gray with dark brown or blackish spots and five bands around the tail. The spots gradually fade as the kittens grow older and are almost unnoticeable by the time they are six months old. At this age, their bright blue eyes slowly turn to the light-brown straw color of the adult (Belden 1988).

Three external characters are often observed in Florida panthers which are not found in combination in other subspecies of *Puma concolor.* These characters are: a right angle crook at the terminal end of the tail; a whorl of hair or "cowlick" in the middle of the back; and irregular, light flecking on the head, nape, and shoulders (Belden 1986). The light flecking may be a result of scarring from tick bites (Maehr 1992a, Wilkins 1994). The kinked tail and cowlicks are considered manifestations of inbreeding (Seal *et al*. 1994).

Taxonomy

The Florida panther was first described by Charles B. Cory in 1896 as *Felis concolor floridana*. The type specimen was collected by Cory in Sebastian, then considered a part of Brevard County (Hall and Kelson 1959). Bangs (1899), however, noted that *Felis floridana* had previously been used for a bobcat and, believing that the panther was restricted to peninsular Florida and could not intergrade with any other form, assigned it full specific status as *Felis coryi*. The taxonomic classification of the *Felis concolor* group was revised by Nelson and Goldman (1929), wherein the panther was reassigned subspecific status as *Felis concolor coryi.* This designation also incorporated *Felis arundivaga*, which had been classified by Hollister (1911) from specimens collected in Louisiana. Detailed descriptions of each of the subspecies are provided in Young and Goldman (1946) [30 subspecies], and Hall (1981) [27 subspecies]. The genus *Felis* was recently revised so all mountain lions, including the Florida panther, were placed in the genus *Puma* (Nowell and Jackson 1996).

Florida panther.
Original photograph by David Maehr.

Distribution

The only known, reproducing panther population is located in the Big Cypress Swamp/Everglades physiographic region of South Florida. The core of the breeding population is centered in Collier, Hendry and Miami-Dade counties. Radio-collared panthers have also been documented in Broward, DeSoto, Glades, Highlands, Lee, Monroe, Osceola, Palm Beach, and Polk counties (Figure 1). There are still large areas of privately owned land in Charlotte, Collier, Hendry,

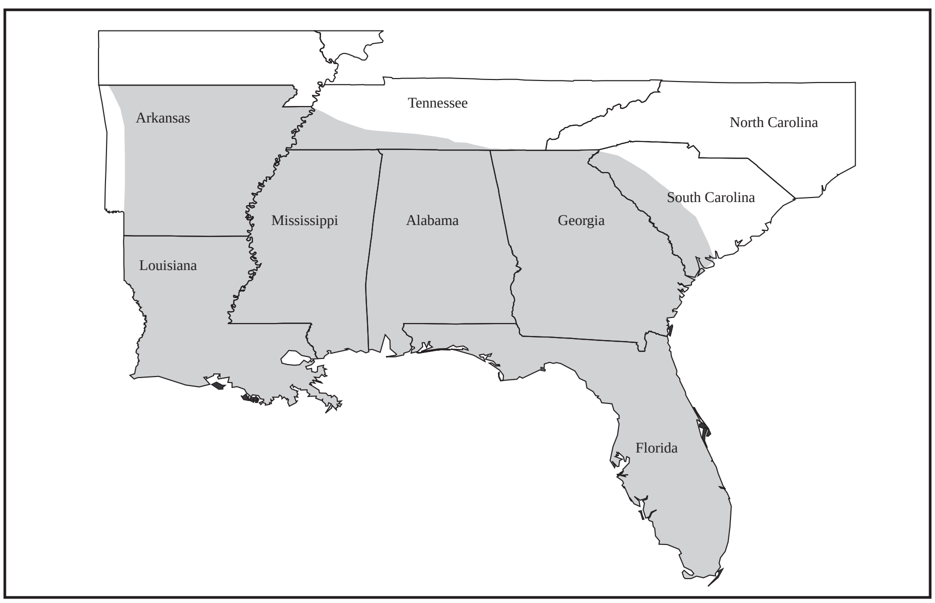


Figure 2. Historic distribution of the Florida panther (Young and Goldman 1946).

Lee, and Glades counties where uncollared individuals may reside (Maehr 1992b). Private lands account for approximately half the occupied panther range in South Florida (Maehr 1990b, Logan *et al*. 1993). This region is extremely reduced from the species' former range. The Florida panther once ranged from eastern Texas or western Louisiana and the lower Mississippi River valley east through the southeastern states (Figure 2), intergrading to the north with *F. c. couguar*, to the west with *F. c. stanleyana,* and to the northwest with *F. c. hippolestes* (Young and Goldman 1946).

Habitat

Early radiotelemetry investigations indicated that panther (n=6) use of mixed swamp forests and hammock forests was greater than expected in relation to the availability of these vegetative communities within the panthers' home range area (Belden *et al*. 1988). As investigations expanded onto private lands between 1985 and 1990, it was determined that panthers (n=26) preferred native, upland forests, especially hardwood hammocks and pine flatwoods, over wetlands and disturbed habitats (Maehr *et al.* 1991a). For pine flatwoods, which comprised about 12 percent of the habitat available to male Florida panthers (n=5) and female Florida panthers (n=5), mean habitat use between 1986 and 1994 averaged 33 and 32 percent respectively. For hardwood hammocks, which comprised about 13 percent of the habitat available, mean habitat use averaged 38 and 31 percent respectively (Maehr 1996). Hardwood hammocks provide important habitat for white-tailed deer (*Odocoileus virginianus*), an important panther prey species (Harlow 1959, Belden *et al.* 1988, Maehr 1990a, 1992a, Maehr *et al.* 1991a). Understory thickets of tall, almost impenetrable, saw palmetto (*Serenoa repens*) have been identified as the most important resting and denning cover for panthers (Maehr 1990a).

Agricultural and other disturbed habitats, freshwater marsh, thicket swamp, and mixed swamp are not preferred, and are either used in proportion to their availability or are avoided (Maehr 1990a). Panthers have not been found in pastures during daytime radiotelemetry flights but may travel through them at night (Maehr *et al.* 1991a, Maehr 1992a).

Male and female panther home range size is inversely related to habitat quality; the greater the extent of agricultural land and wetland habitats the larger the home range, and the greater the extent of mixed hardwood forests and dry pine forests the smaller the home range. High-quality habitat produces abundant prey and influences female panther reproductive success (Maehr 1992b, Maehr *et al.* 1989b).

The largest contiguous tract of panther habitat is in the Big Cypress Swamp/Everglades physiographic regions. Big Cypress National Preserve, Everglades NP, and Florida Panther NWR together comprise about 927,793 ha of native habitats--46 percent of which is forested. However upland forests, *e.g.* pine forests and hardwood hammocks, comprise only 8 percent of the total land area (Duever *et al*. 1986, FWS 1996, NPS 1998).

Behavior

Interactions between Florida panthers are infrequent. Most interactions occur between adult females and their kittens. Interactions between adult male and female panthers, lasting from 1 to 7 days, were second in frequency and usually resulted in pregnancy. Interactions between males were rare but often resulted in serious injury or death. Aggressive encounters between females have not been documented. "In the absence of unnatural mortality (*i.e.* road kills, illegal shooting, research accidents), aggression between males may be the most common form of male mortality and an important determinant of male spatial and recruitment patterns" (Maehr *et al.* 1991a).

Reproduction and Demography

The pattern of Florida panther distribution involves several males maintaining large, mutually exclusive home ranges containing several adult females and their dependent offspring. This spatial arrangement seems to be a prerequisite for successful reproduction (Maehr 1993).

Male Florida panthers are polygynous. Breeding activity peaks in fall and winter (Maehr 1992a). Parturition is distributed throughout the year with 81 percent of births occurring between March and July (July having the greatest number of births). Litter sizes range from one to four kittens, with a mean of 2.2 kittens surviving to at least 6 months. Intervals between litters range from 16 to 37 months (Land 1994).

Den sites are usually located in dense, understory vegetation, typically saw palmetto (Maehr 1990a) at distances greater than 1 km away from roads (Maehr 1996). Den sites are used for up to 2 months by female panthers and their litters from parturition to weaning. Female panthers losing their litters generally produce replacement litters. Five of seven females whose kittens were brought into the captive breeding program successfully reproduced an average of 10.4 months after the removal of the litter (Land 1994).

Female Florida panthers have bred as young as 18 months of age (Maehr *et al.* 1989a) and as late as 11 years of age. The mean age of denning females was 5.8 years (Land and Taylor 1998). The first sexual encounters for males occur at about 3 years of age (Maehr *et al.* 1991a) although a male in Everglades NP bred at 18 months (O. Bass, NPS, personal communication 1997). Dispersal of young typically occurs around 1.5 to 2 years of age, but may occur as early as one year of age (Maehr 1992a).

Infant mortality is thought to be relatively high with fewer than half of all pregnancies resulting in offspring that survive beyond 6 months of age (Roelke *et al.* 1993). The kitten survival rate between age 6 months and 1 year has been estimated at 0.895 (Land 1994). This is based on a sample of 15 radio-collared kittens monitored from 6 months to 1 year of age. Young panthers are considered recruited into the population when they have successfully reproduced (D. Jordan, FWS, personal communication 1997). Of 21 dependent kittens radio-collared and followed beyond independence, 71 percent of females (5 of 7) and 29 percent of males (4 of 14) have been recruited into the population. Females are readily recruited into the population as soon as they are capable of breeding (Maehr *et al.* 1991a). Males appear to have more difficulty being recruited. Without large areas of suitable habitat to accommodate dispersal, young males have few opportunities for recruitment as residents. As a result, the panthers' ability to increase and outbreed has been severely restricted. Successful male recruitment appears to depend on the death, or home range shift, of a resident adult male (Maehr *et al.* 1991a). Turnover in the breeding population is low; with documented mortality in radio-collared Florida panthers being greatest in subadult and non-resident males (Maehr *et al*. 1991b).

Florida panther mortality (n=67) averaged 3.5 deaths per year from 1978 through June 30, 1998. Male panthers accounted for 57.6 percent of mortality. Sub-adult panthers (0 to 3 years) of both sexes accounted for 45.5 percent of mortality. Specific causes of panther mortality include road kill (37.9 percent), intraspecific aggression (21.2 percent), disease and old age (18.2 percent), causes unknown (12.1 percent), shootings (9.1 percent), and research related (1.5 percent) (Land and Taylor 1998).These mortality figures only include panthers endemic to South Florida, and not the introduced Texas cougars.

Foraging

Food habit studies of Florida panthers indicate that feral hog (*Sus scrofa*) was the most commonly taken prey followed by white-tailed deer, raccoon (*Procyon lotor*), and nine-banded armadillo (*Dasypus novemcinctus*). Deer and hogs accounted for 85.7 percent of consumed biomass north of Interstate 75, and 66.1 percent south of Interstate 75 (Maehr *et al*. 1990a). No seasonal variation in diet was detected; however, panthers inhabiting an area of better soils north of Interstate 75 consumed more large prey. In addition, deer abundance was up to eight-fold greater north of Interstate 75 (McCown 1991). The estimated number of deer consumed per panther did not differ between the areas north and south of Interstate 75. Hog numbers were lower south of Interstate 75. Fewer large prey may, in part, explain the poorer physical condition, larger home ranges, and lower reproductive output of panthers residing south of Interstate 75. Hogs dominated the diet of panthers in the north in terms of both estimated biomass and numbers. In the south, deer accounted for the greatest estimated biomass consumed, whereas raccoons were the highest estimated number of consumed prey. Domestic livestock were found infrequently in scats or kills, although cattle were readily available (Maehr *et al.* 1990a).

Movements and Dispersal

Adult Florida panthers space themselves throughout available habitat in southwest Florida in a pattern similar to that of western cougars (Land 1994). The home range size of 26 radio-collared panthers monitored between 1985 and 1990 varied from 53 to 1,183 km^2, averaging 519 km^2 for resident males and 193 km^2 for resident females. Home ranges of resident adults were stable unless influenced by the death of other residents. Home-range overlap was extensive among resident females and limited among resident males (Maehr *et al.* 1991a).

There are no known differences in seasonal movements, wet and dry season habitat use, or effects of season on road crossing. There may be a response to fluctuations in water levels; however, the response is believed to be undetectable (Maehr 1989; Maehr *et al.* 1990b, 1991a).

A female panther was killed by automobile on S.R. 84 in 1986. Prior to, and during the early phases of, conversion from two-lane S.R. 84 to four-lane Interstate 75 only male panthers were detected crossing this roadway. The highway may have been a deterrent to female movements (Maehr *et al.* 1991a). Since the completion of Interstate 75 and associated wildlife crossings, numerous male panthers and a female panther have regularly crossed underneath the roadway (Lotz *et al.* 1996).

Western subspecies of *puma* have been documented crossing wide, swift-flowing rivers up to a mile in width (Seidensticker *et al*. 1973, Anderson 1983). The Caloosahatchee River, a narrow, channelized, blackwater river, should not be a significant barrier to panther movements, but the combination of the river, S.R. 80, and land uses along the river seems to have restricted panther dispersal northward (Maehr 1996). In 18 years of research only one radio-collared panther crossed the Caloosahatchee River. This dispersing subadult male crossed the river in April of 1998 enroute to Osceola County setting a dispersal record of 220 km in the process (Land and Taylor 1998). Dispersal distances average 58.7 km for subadult males and 16 km for a single subadult female. Mean dispersal age was 17.9 months (Maehr 1992a).

Activity levels for Florida panthers peak around sunrise and sunset (Maehr *et al.* 1990b). The lowest activity levels occur during the middle of the day. Female panthers at natal dens follow a similar pattern with less difference between high and low activity periods.

Relationship to Other Species

The Florida panther requires extensive, biotically diverse landscapes to survive. Large carnivores are considered critical in maintaining ecological integrity in many large forest systems (Terborgh 1988). Landscapes through which the panther ranges support a vast array of South Florida's rich faunal and floral diversity including the Florida black bear (*Ursus americanus*), Big Cypress fox squirrel (*Sciurus niger avicennia*), American swallow-tailed kite (*Elanoides forficatus*), hawks and owls, neotropical migratory birds, and endemic orchids and epiphytes (K. Dryden, GFC, personal communication 1996).

Deer, hog, and raccoon have already been mentioned as the most important prey species taken in terms of biomass and numbers (Maehr *et al*. 1990a). As a result of human-induced changes in habitat quantity and quality, it is possible that competition between key members of a faunal community may develop. However, comparisons of food habits, habitat use, and movements among bobcat (*Lynx rufus*), panther, and black bear revealed a low probability for competitive interactions (Maehr 1996).

Status and Trends

The State of Florida declared the panther a game species in 1950 and an endangered species in 1958. The FWS listed the panther as endangered in 1967 (32 FR 4001). Activities in the 1800s and early 1900s contributed to its need for listing.

The first bounty on Florida panthers was passed in 1832. Another Florida law passed in 1887 authorized a payment of $5.00 for panther scalps (Tinsley 1970). Agricultural land clearing in the southeast between 1850 and 1909 totaled 12.8 million ha. Lumbering reduced the original southern forest nearly 40 percent from 121.4 million ha to 72.0 million ha by 1919. A staggering 36.4 million ha of pine forests were considered cut-over by 1920 with one-third classified as restocked with sawable timber, one-third restocked with scrubby cordwood only, while one-third remained barren (Williams 1990). Meanwhile the white-tailed deer, primary prey of the panther, was reduced from a range-wide population of about 13 million in 1850, to under 1 million by 1900 (Halls 1984). Over a 100-year period, bounty hunting, land clearing, lumbering, and market hunting of deer contributed to the range-wide decline of the panther.

Of the 27 *Puma concolor* subspecies described in Hall (1981), the Florida panther is the only one remaining in the eastern U.S. The panther population in Florida numbered about 500 at the turn of the century (Seal *et al.* 1989). Kautz (1994) estimated that a loss of 1.74 million ha of forests in Florida between 1936 and 1987 was the equivalent of 35 to 70 male panther home ranges and 100 to 200 female panther home ranges. The Big Cypress population was estimated at 125 in 1969 (DOI 1969) and a South Florida population at 92 in 1972 (Schemnitz 1972). The Florida Panther Act, a State law enacted in 1978, made killing the panther a felony.

The uncertain status of the panther led to the establishment of a GFC Florida Panther Record Clearinghouse in the 1970s. Records were compiled prior to extensive field surveys and radiotelemetry research of remaining animals (Belden 1977). The first field surveys began in 1972. Radiotelemetry research began in 1981 and through 1983 was limited to Fakahatchee Strand State Preserve and Big Cypress National Preserve (Belden *et al.* 1988). The research program gradually expanded to include Everglades NP, Florida Panther NWR, Picayune Strand State Forest, Okaloacoochee Slough State Forest, the Corkscrew Regional Ecosystem Watershed, and private lands in Collier, Hendry, and Lee counties. A total of 72 panthers (41 male, 31 female) have been radio-collared since telemetry research began in 1981. As of June 30, 1998 there were 30 panthers (14 male, 16 female) being monitored.

Ten Florida panther kittens, five male and five female, were removed from the wild between February 1991 and August 1992 for captive breeding purposes. The kittens ranged in age from 10 days to 8 months and represented progeny of 11 different adult panthers. Two females died in captivity in 1992. One died after heart surgery in an attempt to correct an atrial septal heart defect and one died of unknown causes. Two males died of severe respiratory distress after being released to the wild in southern Big Cypress National Preserve in 1997. Six panthers remain in permanent captivity, one male and one female each, at White Oak Conservation Center in Yulee, FL, Lowry Park Zoo in Tampa, and at the Jacksonville Zoo (Land and Taylor 1998).

Threats

The Florida panther's existence is threatened by extinction processes. Population viability analysis projections indicate that under existing demographic and genetic conditions the panther will likely be extinct in 24 to 63 years (Seal *et al.* 1992). Environmental factors affecting the panther include: habitat loss and fragmentation, contaminants, prey availability, human-related disturbance and mortality, disease, and genetic erosion (Dunbar 1993). Any reference to mortalities associated with these threats refers only to the endemic South Florida population and not to the introduced western cougars.

Genetic and Physiological: Natural gene exchange between the Florida panther and three other subspecies ceased when the panther became geographically isolated, probably over a century ago (Seal *et al*. 1994). Isolation from *F. c. cougar*, *F. c. hippolestes*, and *F. c. stanleyana*, habitat loss, reduced population size, and inbreeding have resulted in loss of genetic variability and diminished health. Data on polymorphism and heterozygosity, when combined with multiple physiological abnormalities, suggest that the panther is experiencing inbreeding depression (Roelke *et al*. 1993, Barone *et al.* 1994). Inbreeding depression has been related to decreased semen quality, lowered fertility and neonatal survival, and congenital heart defects in a variety of domesticated and wild species (Lasley 1978, Ralls and Ballou 1982, Wildt *et al*. 1982, O'Brien *et al*. 1985, Roelke 1991). The panther exhibits many of these traits.

Congenital heart defects were documented in 11 Florida panthers in 1990 and 1991 (Roelke 1991). Some of these heart defects were severe enough to result in death. All eight panther kittens examined that year had heart murmurs, as well as 30 percent of the adults examined. Congenital heart defects are believed to result from inbreeding, and may interfere with survival and reproduction (Roelke 1991, Dunbar 1993, Barone *et al*. 1994).

The Florida panther exhibits poorer male reproductive characteristics than other populations of mountain lions in North America or Latin America (Barone *et al*. 1994). Of 16 panthers, more were unilaterally cryptorchid (43.8 percent vs. 3.9 percent), had lower testicular and semen volumes, poorer sperm progressive motility, and more morphologically abnormal sperm than did 51 individuals from other *Puma concolor* populations in Texas, Colorado, Latin America, and North American zoos (Wildt 1994).

Research indicates the extant Florida panther population is comprised of two genetic stocks. Panthers in Big Cypress Swamp descended from *F. c. coryi*. Panthers in the Everglades also descended from *F. c. coryi* but contain additional Latin American genetic markers (O'Brien *et al*. 1990) that probably originated from captive "Piper" stock released into the Everglades between 1956 and 1966 (Vanas 1976, Mounger 1991). The presence of Latin American genes may explain the lack of congenital heart defects in Everglades panthers. None of the Everglades panthers tested in one study were cryptorchid, whereas 64 percent of the Big Cypress panthers tested were cryptorchid (Barone *et al*. 1994).

Low heterozygosity levels indicate that the Florida panther has lost approximately half of its genetic diversity (Roelke 1990). The level of mDNA variation in the panther is the lowest reported in any similarly studied feline population, including leopards, cheetahs, and other *puma* subspecies. Electrophoretic analyses also indicate the panther has less variation than any other *puma* subspecies and is nearly as low as the level of allozyme variation reported in the two cheetah subspecies. Panther DNA fingerprint variation is nearly as low as the genetic variation in Asiatic lions from the Gir Forest Sanctuary in India (Roelke *et al.* 1993).

Disease: Disease is a threat to small, inbred populations (Roelke 1991, Barone *et al.* 1994, Seal *et al.* 1989). All Florida panthers undergo an examination to assess general health and physical condition at the time of capture. Panthers greater than 8 weeks of age are dewormed and vaccinated for feline viral rhinotracheitis (FVR), feline calicivirus (FCV), feline panleukopenia (FPV), and rabies. Biomedical samples collected include whole blood, skin biopsy, hair, and feces. Bacterial cultures are taken as needed. Panther kittens less than 6 weeks of age are also given injections of iron, vitamin B, and penicillin (Taylor 1997).

Six of 20 free-ranging Florida panthers (30 percent) captured from Everglades NP, Big Cypress National Preserve, and adjacent lands between 1986 and 1988 tested positive for feline immunodeficiency virus (FIV) (Barr *et al*. 1989). Five out of 19 panthers (26.3 percent) examined in 1992 (Roelke and Glass 1992) and one of 23 examined between July 1, 1996 and June 30, 1997 (Taylor 1997) tested postive for FIV. FIV has a long incubation period but leads to non-specific immunosuppression and death in domestic cats (Roelke 1991). Its significance to the panther is not known.

Other diseases, such as feline infectious peritonitis (FIP), feline leukemia virus (FeLV), *Cytauxzoon felis*, and *Bartonella henselae*, are present in varying degrees (Roelke 1991, Roelke and Glass 1992, Dunbar 1993).

Parasites found on 12 panthers examined between 1978 and 1983 included one protozoan, two trematodes, three cestodes, seven nematodes, six ticks, and one flea. The trematode *Alaria marcianae* and a hookworm *Ancylostoma pluridentatum* were the most prevalent and abundant (Forrester *et al.* 1985).

Mortality from shooting: Six Florida panther shootings, five fatal and one non-fatal, occurred between 1978 and 1986--an average of one every 2 years. These data do not include the more recent shootings of introduced Texas cougars; however, it should be noted that all subspecies of *Puma concolor* that occur in Florida are protected by a “similarity of appearance” provision in the Endangered Species Act.

Highways: Construction of highways in wildlife habitat may result in habitat fragmentation, direct mortality, direct habitat loss, displacement and avoidance, and associated human development (Ruediger 1998).

Rare carnivores are generally present only in locations with the lowest highway densities. Highways, and other human developments, tend to create boundaries for individuals and populations. Habitat fragmentation isolates small populations, subjecting them to demographic and stochastic factors (Ruediger 1998) that reduce their chances for survival and recovery.

Panthers consistently use large areas with few major highways (Maehr and Cox 1995). Belden and Hagedorn (1993) observed that Texas cougars, used in a population reintroduction study, established home ranges in an area with one-half the road density of the region in which the study was conducted. In particular, the study animals tended to avoid crossing more heavily traveled roads (*e.g.* primary and secondary hard-surface highways, and light-duty roads) in favor of more lightly traveled roads. Of 26 *puma* home ranges examined by Van Dyke *et al*. (1986), 22 (85 percent) included unimproved dirt roads, 15 (58 percent), included improved dirt roads, but only 6 (23 percent) included hard-surfaced roads. Female panthers rarely establish home ranges bisected by highways and maternal dens are located at distances one kilometer or greater away from highways (Maehr 1996).

Florida panther road mortality (n=24) between 1978 and June 30, 1998 averaged 1.2 panthers per year and was almost evenly divided between males (n=13) and females (n=11). Vehicle collisions resulting in the death of subadult panthers (0 to 3 years) of both sexes exceeds subadult mortality due to intraspecific aggression (23.4 versus 10.9 percent) and equals all other forms of subadult mortality combined (Land and Taylor 1998). Although the relative significance of highway deaths to other sources of mortality is not entirely known, it has been the most often documented source of mortality (Maehr 1989, Maehr *et al.* 1991b).

Florida panther road mortality and injury (n=30) between 1978 and June 30, 1998 was greatest in Collier County (76.7 percent), followed by Hendry County (10.0 percent), and Lee County (10.0 percent). During the same period panther mortality and injury was greatest on S.R. 29 (33.3 percent) and Alligator Alley (16.7 percent) in Collier County (Land and Taylor 1998). Nighttime speed limits were reduced on S.R. 29 and Alligator Alley in 1984 in an effort to minimize panther/vehicle collisions. Wildlife underpasses, first used by panthers in 1989 (Maehr 1992a), have greatly reduced risks in these problem areas (Foster and Humphrey 1995).

A 33 m (2 lane) and 100 m (4 lane) cleared right-of-way would consume, respectively, 1.9 and 5.7 percent of each section of land through which it passes (Ruediger 1998). Highways stimulate more land development than is generally recognized. Change occurs as far away as 3.2 km on either side of the highway. Thus for each kilometer a highway is extended, 644 ha are opened to new development (Wolf 1981).

Urbanization: The rapid and extensive loss of panther habitat is a result of Florida's flourishing human population, which has doubled nearly every 20 years since 1830. Only five percent of the state's residents lived in South Florida in 1900. Today 50 percent live there. Florida's population, fourth largest in the U.S., is expected to reach 17.8 million (127 persons per km^2) by 2010 (Floyd 1996).

The population of South Florida passed one million (130 persons per km^2) in 1950, three million (391 persons per km^2) in 1970, and six million (780 persons per km^2) in 1990. The population density of South Florida has exceeded the statewide average since 1960. South Florida's population is projected to reach 8.2 million (1,070 persons per km^2) by 2010 (Floyd 1996).

South Florida accounted for 49 percent of Florida's residential construction starts in 1995. Ft. Lauderdale, Miami, West Palm Beach-Boca Raton, Sarasota-Bradenton, Ft. Myers-Cape Coral, Ft. Pierce-Port St. Lucie, Lakeland-Winter Haven, Punta Gorda, and Naples, in descending order, accounted for 39 percent of Florida home sales in 1996. Ft. Lauderdale ranked third and Miami fourth statewide in total numbers of houses sold. Naples ranked second statewide in the percentage increase of houses sold (Floyd 1996).

Population growth and agricultural expansion in South Florida are compromising the ability of natural habitats to support a self-sustaining panther population. Continued expansion of the urbanized east coast, increasing growth on the west coast, and the spread of agricultural development in the interior have placed increasing pressures on forested tracts in Collier, Glades, Hendry, and Highlands counties (Maehr 1990b, Maehr 1992a, Maehr *et al*. 1991a).

Agriculture: Statewide between 1936 and 1987, cropland and rangeland increased 1.72 million ha or 30 percent, urban areas increased by 1.60 million ha or 538 percent, while herbaceous wetlands declined by 1.57 million ha or 56 percent and forests declined by 1.74 million ha or 21 percent.

Agricultural and urban development continues to replace and fragment panther habitat. Over 83 percent of the 648,000 ha of agricultural land in southwest Florida; *i.e.* Charlotte, Collier, Glades, Hendry, Lee and Sarasota counties, is categorized as rangeland. Between 1986 and 1990, row crop acreage increased by 3,640 ha or 21 percent, sugarcane increased by 6,475 ha or 21 percent, citrus increased by 21,850 ha or 75 percent, and rangeland--much of it suitable for panther occupation - decreased by 64,750 ha or 10 percent. Rangeland losses were about evenly divided between agricultural development (citrus, row crops, sugarcane) and urban development (Townsend 1991).

Occupied panther habitat is about evenly divided between public and private lands. If private land habitats are lost the existing public lands in South Florida are judged capable of supporting only 9 to 22 (Maehr 1990b) of the minimum 50 adult panthers needed to sustain a genetically viable population. Where current uses on private lands are compatible with panthers, owners should be economically encouraged to continue those practices (Maehr 1992a, 1992b).

Management

Early conservation efforts benefitting the Florida panther involved land protection and natural areas management. After nearly a decade of planning, Everglades NP was established in 1947. Corkscrew Swamp Sanctuary was established in 1954, when the National Audubon Society and The Nature Conservancy purchased remnant stands of old growth cypress from the Lee Tidewater Cypress Company and Collier Enterprises.

The Florida Legislature passed the Big Cypress Conservation Act of 1973, thus designating 347,228 ha of the 634,561 ha Big Cypress Watershed as an “Area of Critical State Concern (ACSC).” The Fakahatchee Strand State Preserve, established in 1974; the Big Cypress National Preserve, established in 1974 (P.L. 93-440); and the Florida Panther NWR, established in 1989 (the only public land established specifically to protect the panther), all lie within the Big Cypress ACSC. Today 24,282 ha remain in private ownership. Site alteration within the Big Cypress ACSC is limited to 10 percent of the land parcel. Impervious surfaces are limited to one-half of the site altered. Agricultural activities are exempt from these restrictions (Chapter 28-25, F.A.C.).

The Florida Panther Research and Management Trust Fund and the Florida Panther Technical Advisory Council were established by the Florida Legislature in 1983. Money from the trust fund is used to manage and protect the extant panther population and panther prey; to inform the public of panther recovery activities, and to reintroduce panthers into areas where habitat is suitable. These funds are obtained through donations and a portion of the severance tax on oil extracted in Collier County.

The Technical Advisory Council is comprised of two members that represent State or Federal agencies responsible for endangered species management, two members with academic expertise in the research and management of felines or large mammals, and one member from the public at large. Membership was expanded in 1997 to include two members representing landowners from that part of South Florida where panthers inhabit private lands. The purpose of the Technical Advisory Council is to advise the GFC on technical matters relevant to panther recovery, review and comment on research and management activities, and provide a public forum for technical review and the status of recovery efforts.

The Florida Panther Interagency Committee (FPIC), comprised of the FWS, NPS, GFC, and DEP, was established in 1986 to coordinate recovery of the Florida panther. A Habitat Preservation Plan (HPP), prepared in 1993 for the FPIC, identified 374,868 ha of occupied and potential habitat considered essential to maintaining a minimum viable population of 50 breeding adult panthers in South Florida. The HPP also identified habitat threats, and the means by which the habitat could be protected; *e.g.,* land acquisition, conservation easements, exchanges, donations, voluntary management agreements, landowner incentives, and landowner disincentives. Figure 3 shows the relationship of existing and proposed state land acquisition and conservation easement projects

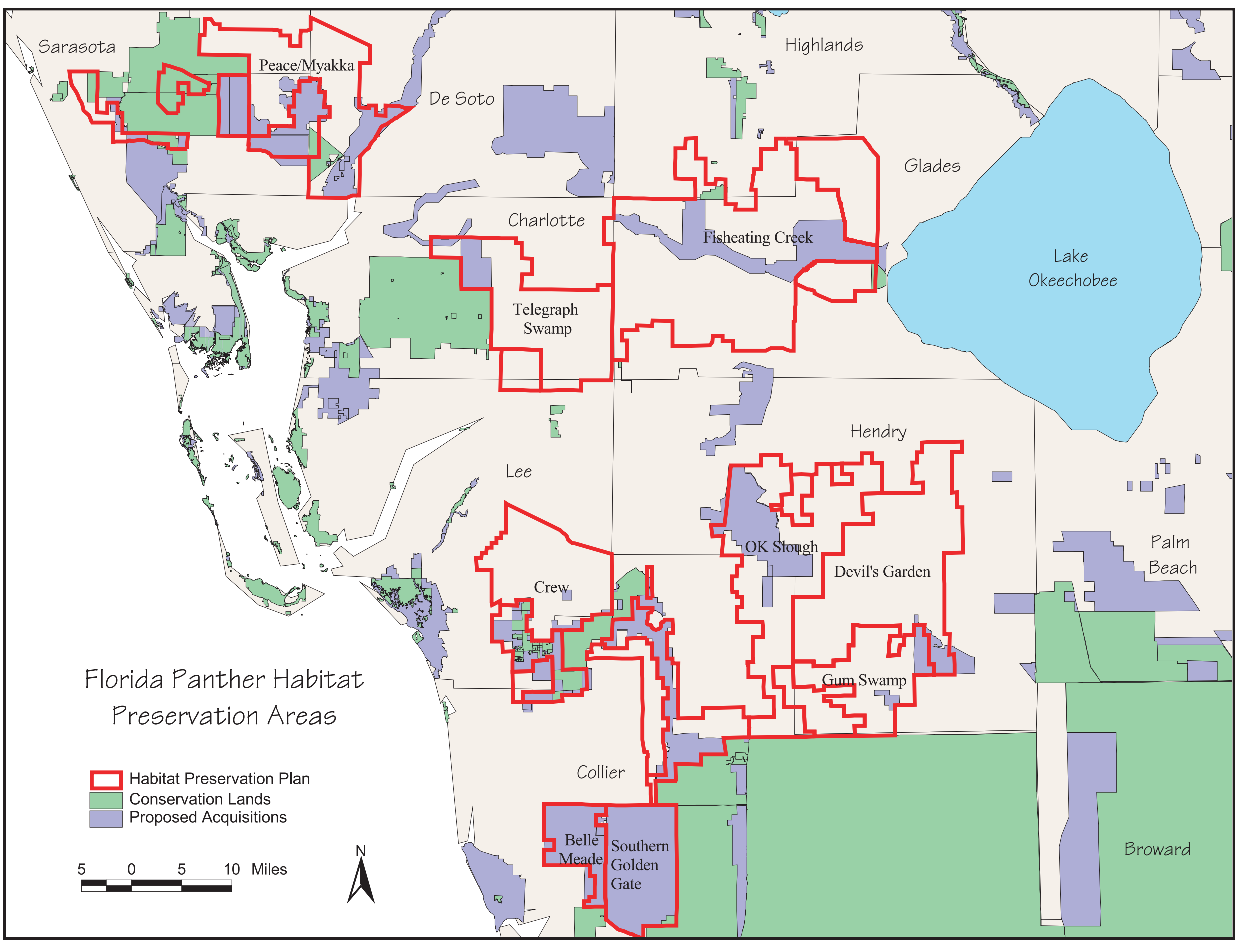


Figure 3. Florida panther habitat preservation areas.

to nine of the ecological units identified in the HPP (Logan *et al.* 1993).

Present-day conservation efforts include accelerating state acquisition of Picayune Strand SF with matching Federal funds. Okaloacoochee Slough SF, the first publicly owned conservation land in Hendry County, was purchased by the SFWMD in 1996. Lands were added to the Big Cypress National Preserve and Florida Panther NWR when the Arizona-Florida land exchange (P.L. 100-696) was finalized late in 1996. Caloosahatchee Ecoscape, a landscape corridor connecting panther habitat in Glades and Hendry counties, was added to the Conservation and Recreation Lands acquisition list in 1998. USDA/NRCS and FWS landowner incentive programs are suited to panther habitat protection and their full potential has yet to be realized. The State of Florida is promoting the use of conservation easements to protect panther habitat and easements are expected to play a larger role in Florida's land conservation efforts after 2000. Private landowners in South Florida have initiated a grassroots effort to link Federal estate tax reform with protection of endangered species habitat.

* * * * *

The survival and recovery of the Florida panther is dependent on: (1) protection and enhancement of the extant population, associated habitats, and prey resources; (2) improving genetic health and population viability; and (3) reestablishing at least two additional populations within the panther's historic range.

The first area of emphasis in Florida panther recovery is protection and enhancement of the extant population, its associated habitat, and its prey resources. Several State and Federal agencies manage within existing financial, legal, philosophical, and ecological constraints, public lands inhabited by the panther and its prey.

Panther habitat management on public lands consists primarily of prescribed fire and wildfire suppression in fire-adapted vegetation communities. Chemical, biological, and mechanical control of invasive exotic plants helps maintain and perpetuate preferred panther habitat types. In addition to prescribed fire and exotic plant control, management for panther prey, *e.g.* white-tailed deer and feral hog, consists of hunting restrictions and vehicle access restrictions.

Two-to-five year fire rotations and burn compartments less than 2,500 ha are recommended to increase habitat heterogeneity (Schortemeyer *et al.* 1991). However, fire prescriptions will vary based on fuel conditions, weather conditions, and historic fire frequency. Compartment size will vary based on site conditions, including the use of existing fire breaks or reluctance to establish new fire breaks that would reduce native habitats, fragment native habitats, and serve as vectors for the spread of exotic plants. For example, Florida Panther NWR uses existing swamp buggy trails and highways as burn compartment boundaries. The refuge is divided into 54 burn compartments that range in size from 121 to 445 ha. A range of 2,023 to 3,238 ha is burned annually depending on weather conditions. Best results have been obtained by burning 3 to 5 days following a light rain shower (<12.7 cm) and when dead fuel moistures (1 and 10 hour fuels) are 8 to 12 percent and live fuel moistures (1 and 10 hour fuels) are 134 to 168 percent (FWS 1996).

Food plots, clearings and feeders can be effective in local situations. Disturbed sites, particularly those invaded by willows, can produce good forage for deer. Establishment of oaks and palms on disturbed sites can significantly increase mast production in select areas (Schortemeyer *et al.* 1991).

Prey management has also been accomplished by regulating harvest. A variety of strategies have been used. Everglades NP, Fakahatchee Strand State Preserve, and Florida Panther NWR are closed to hunting. Portions of Big Cypress National Preserve are closed to hunting, open only for archery hunting, or open for a limited general gun season. Use of hunting quotas and off road vehicle (ORV) access permits have reduced or redistributed hunting pressures. Use of dogs for hunting is prohibited. A five-inch antler rule reduced the harvest of does and fawns. Big Cypress National Preserve and all private lands south of Interstate 75 are excluded from the doe season (Schortemeyer *et al.* 1991).

Overall, management activities directly benefitting the panther and panther prey are limited to upland habitats which comprise only 8 percent of the total land area in Big Cypress National Preserve, Everglades NP, and Florida Panther NWR.

Private landowners should be encouraged to continue or initiate land management practices beneficial to the Florida panther. Landowner incentive programs can be used to provide technical and financial assistance for prescribed fire, exotic vegetation control, rotational grazing, fencing, tree planting, *etc*. Given that 60 to 80 percent of panther radio-locations occur in pine flatwoods and hardwood hammocks (Maehr 1996) landowners should be encouraged to restore pine flatwoods and protect hardwood hammocks from over-grazing.

The Immokalee Rise physiographic region includes all of Hendry County and parts of Collier, Glades, and Lee counties, *i.e.* the core of occupied panther habitat. Pine flatwoods in this area declined 88 percent from 153,928 ha in 1900 to 17,970 ha in 1989. Pine flatwoods have also been severely fragmented and today are comprised of thousands of patches less than 50 ha in size (Mazzotti *et al.* 1992). Pine flatwoods have been replaced by pasture, row crops, and citrus.

Restoration of pine flatwoods will not be easy. Few landowners in South Florida are located within the critical radius of a railhead in Palmdale, Florida--the only route by which timber from South Florida can be hauled to North Florida mills for processing and distribution. Consequently there is little incentive to replant timber in South Florida once it matures and is harvested. One possible long-term solution is development of local outlets for "value-added" pine timber products. An alternative, short-term solution is to pay landowners to replant and maintain sufficient stands of pine flatwoods to increase panther distribution and densities.

Hardwood hammocks have increased (probably due to land drainage) from 6,703 ha in 1900 to 9,516 ha in 1989 but have never comprised more than 2 percent of the vegetative cover in the Immokalee Rise physiographic region (Mazzotti *et al.* 1992). Given the high level of panther use and scarcity as a cover type it is important that hardwood hammocks be maintained in conditions attractive to panthers and panther prey. Hardwood hammocks are sometimes manipulated by landowners to increase understory browse for cattle. In extreme cases over-grazing has reduced the hammock understory to bare dirt. Landowner incentive programs should be used to establish rotational grazing programs to reduce grazing pressure on the hammocks and to fence cattle from the hammocks where appropriate.

The second area of emphasis in Florida panther recovery is genetic health and population viability.

A program to address these concerns through the restoration of gene flow was initiated in 1995. The rationale and details for the program, as well as morphological and genetic criteria used to monitor and measure success, are found in the FWS document entitled "Final Environmental Assessment - Genetic Restoration of the Florida Panther" and the associated genetic restoration and management plan (FWS 1994).

The level of introgression required to reverse the deleterious effects of inbreeding is estimated at 20 percent, or 6 to 10 Texas cougars (*F. c. stanleyana*), based on the current population estimate of 30 to 50 breeding adult panthers. Each of the Texas cougars released needs to produce at least two offspring that survive and are recruited as breeders. One additional Texas cougar will be translocated into South Florida every 6 years thereafter. This should restore genetic variability in the panther without significant alteration to its basic genetic makeup which may be adapted to local environmental conditions (Seal *et al.* 1994).

Unrelated animals were selected from various locations throughout Texas, screened in the field for cowlicks and kinked tails, and screened in quarantine for atrial septal heart defects and disease. Females 2 to 4 years of age were selected because they were considered more likely to remain near release sites, less likely to be adversely affected, and could be more easily assimilated into the extant panther population (Seal *et al.* 1992).

The extent of introgression will be assessed by several factors: pedigree analysis based on Florida and Texas founder contributions, analysis of molecular genetic markers, and analysis of morphological characters that differentiate the two subspecies (Seal *et al.* 1992).

Genetic management began with the release of eight female Texas cougars in 1995. Two each were released in Fakahatchee Strand State Preserve, northern Big Cypress National Preserve, southern Big Cypress National Preserve (Figure 4), and Everglades NP.

As of July 1, 1998 six of the eight female Texas cougars remained alive. One was killed in a vehicle collision in Hendry County September 1, 1995. The second was found shot in a Collier County citrus grove April 18, 1998. Five of the six female Texas cougars remaining alive have produced eight litters of first generation (F_1) intercross kittens--eight female and four male (Land and Taylor 1998). An F_1 female produced the first litter of F_2 kittens (one female, two male) in September 1998. A population viability analysis workshop will assess the progress of the genetic management program.

The third area of emphasis in Florida panther recovery is to establish two additional populations within the historic range of the panther (FWS 1987, FWS 1995). Population establishment involves site selection and use of surrogate animals for site evaluation (Jordan 1994, Belden and Hagedorn 1993, Belden and McCown 1994). Between 1988 and 1995, 26 Texas cougars were released near Okefenokee NWR and Osceola NF. Six animals were born and raised in captivity. Twenty were captured in western Texas and translocated to Florida, 17 of which were released into the wild shortly after arrival. The remaining three were part of a study to develop captive breeding techniques and were held in captivity for 2 to 8 years prior to release (Belden *et al*. 1989, Belden and McCown 1996).

The study animals, monitored by radiotelemetry at least 3 days per week, established overlapping home ranges, made kills of large prey at predicted frequencies, and generally adapted well to their new environment (Belden *et al*. 1989). Captive-raised animals tended to establish home ranges more quickly, and were more likely to associate with other study animals than were wild-caught animals. Captive-raised animals, particularly males, were more likely to be seen

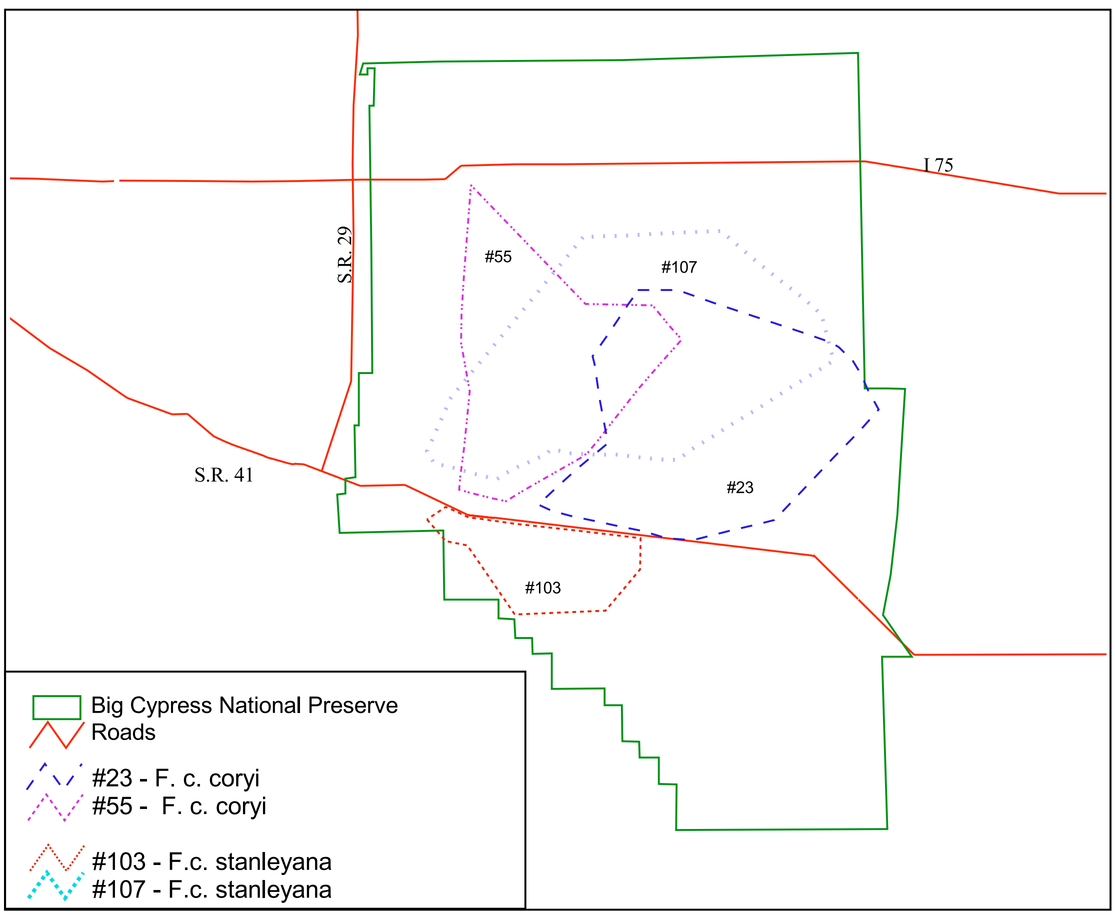


Figure 4. Home ranges of collared *F. concolor* in portions of Big Cypress National

by humans and were the primary cause of negative attitudes toward the study. The mean distance from the release site to the home range center and the mean home range size were significantly greater for the wild-caught males than captive-held males, and captive or wild-caught females (Belden and McCown 1996).

One of two plans for population re-establishment discussed by Belden and McCown (1996) involves the release of four to five wild-caught female Florida panthers into a select area. Once they established home ranges a captive-raised male would be introduced only long enough to breed the females. This plan has the advantages of requiring fewer panthers from the South Florida population and of allowing more control over where re-establishment occurs. Wild-caught females with kittens could also be used.

Studies have concluded that Florida panther reintroduction is biologically feasible (Belden and Hagedorn 1993, Belden and McCown 1996). Habitat and prey available in north Florida and south Georgia are sufficient to support a viable panther population. However, complex social issues must be addressed prior to population reestablishment (Belden and McCown 1996). A study is currently underway to identify these issues and ways to manage them.

Literature Cited

Anderson, A.E. 1983. A critical review of literature on puma (*Felis concolor*). Special report No. 54. Colorado Division of Wildlife, Wildlife Research Section; Denver, Colorado.

Bangs, O. 1899. The Florida puma. Proceedings of the Biological Society of Washington. 13:15-17.

Barone, M.A., M.E. Roelke, J. Howard, J.L. Brown, A.E. Anderson, and D.E. Wildt. 1994. Reproductive characteristics of male Florida panthers: Comparative studies from Florida, Texas, Colorado, Latin America, and North American zoos. Journal of Mammalogy 75(1):150-162.

Barr, M.C., P.P. Calle, M.E. Roelke, and F.W. Scott. 1989. Feline immunodeficiency virus infection in nondomestic felids. Journal of Zoo and Wildlife Medicine 20(3):265-272.

Bass, O.L. 1997. Comments on draft species account. July 1997.

Belden, R.C. 1977. If you see a panther. Florida Wildlife. September-October 1977.

Belden, R.C. 1986. Florida panther recovery plan implementation - A 1983 progress report. Pages 159-172 *in* S.D. Miller and D.D. Everett eds., Cats of the world: biology, conservation and management. Proceedings of the second international cat symposium. Caesare Kleberg Wildlife Research Institute; Kingsville, Texas.

Belden, R.C. 1988. The Florida panther. Pages 515-532 *in* Audubon Wildlife Report 1988/1989. National Audubon Society; New York, New York.

Belden, R.C. and B.W. Hagedorn. 1993. Feasibility of translocating panthers into northeast Florida. Journal of Wildlife Management 57(2):388-397.

Belden, R.C., W.B. Frankenberger, R.T. McBride, and S.T. Schwikert. 1988. Panther habitat use in southern Florida. Journal of Wildlife Management 52(4):660-663.

Belden, R.C., B.W. Hagedorn, and W.B. Frankenberger. 1989. Florida panther captive breeding/reintroduction feasibility. Annual performance report, July 1, 1988 to June 30, 1989. Study no. 7507, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Belden, R.C., and J.W. McCown. 1994. Florida panther captive breeding/reintroduction feasibility. Annual performance report, July 1, 1993 to June 30, 1994, study no. 7507, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Belden, R.C., and J.W. McCown. 1996. Florida panther reintroduction feasibility study. Final report, July 1, 1992 to June 30, 1995. Study no. 7507, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Cory, C.B. 1896. Hunting and fishing in Florida. Estes and Lauriat; Boston, Massachusetts.

Dryden, K. 1996. Comments on draft species account. October 18, 1996.

Duever, M.J., J.E. Carlson, J.F. Meeder, L.C. Duever, L.H. Gunderson, L.A. Riopelle, T.R. Alexander, R.L. Myers, and D.P. Spangler. 1986. The Big Cypress National Preserve. Research report no. 8 of the National Audubon Society. National Audubon Society; New York, New York.

Dunbar, M.R. 1993. Florida panther biomedical investigation. Annual performance report, July 1, 1992 to June 30, 1993. Study no. 7506, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Floyd, S.S. 1996. Florida county rankings 1996. Bureau of Economic and Business Research, Warrington College of Business Administration, University of Florida; Gainesville, Florida.

Forrester, D.J., J.A. Conti, and R.C. Belden. 1985. Parasites of the Florida panther (*Felis concolor coryi*). Proceedings Helminthological Society, Washington, D. C. 52(1):95-97.

Foster, M.L., and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23(1):95-100.

Hall, E.R. and K.R. Kelson. 1959. The mammals of North America. Volume II. The Ronald Press Company; New York, New York.

Hall, E.R. 1981. The mammals of North America. Volume II; John Wiley and Sons; New York, New York.

Halls, Lowell K., ed. 1984.White-tailed deer, ecology and management. The Wildlife Management Institute; Washington, D.C.

Harlow, R.F. 1959. An evaluation of white-tailed deer habitat in Florida. Florida Game and Fresh Water Fish Commission technical bulletin 5:1-64; Tallahassee, Florida.

Hollister, N. 1911. The Louisiana puma. Proceedings of the Biological Society of Washington 24:175-178.

Jordan, D.B. 1994. Final preliminary analysis of some potential Florida panther population reestablishment sites. U.S. Fish and Wildlife Service; Jacksonville, Florida.

Jordan, D.B. 1997. Comments on draft species account, December 24, 1997.

Kautz, R. 1994. Historical trends within the range of the Florida panther. Pages 285-296 *in:* D.B. Jordan, ed., Proceedings of the Florida panther conference. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Land, E.D. 1994. Response of the wild Florida panther population to removals for captive breeding. Final report, study no. 7571. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Land, E.D. and K. Taylor. 1998. Florida panther genetic restoration and management. Annual report, study number 7508. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Lasley, M.F.W. 1978. Genetics of livestock improvement. Third edition Prentice-Hall; Englewood Cliffs, New Jersey.

Logan, T.J., A.C. Eller, Jr., R. Morrell, D. Ruffner, and J. Sewell. 1993. Florida panther habitat preservation plan South Florida population. Prepared for the Florida Panther Interagency Committee; Tallahassee, Florida.

Lotz, M.A., E.D. Land, and K.G. Johnson. 1996. Evaluation of State Road 29 wildlife crossings. Final report, study no. 7583. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Maehr, D.S. 1989. Florida panther road mortality prevention. Final performance report, study no. 7502. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Maehr, D.S. 1990a. Florida panther movements, social organization, and habitat utilization. Final performance report, study no. 7502. Florida Game and Fresh Water Fish Commission, Tallahassee, Florida.

Maehr, D.S. 1990b. The Florida panther and private lands. Conservation Biology 4(2):167-170.

Maehr, D.S. 1992a. Florida panther. Pages 176-189 *in* S.R. Humphrey, ed., Rare and endangered biota of Florida. Volume I: mammals. University Press of Florida; Gainesville, Florida.

Maehr, D.S. 1992b. Florida panther distribution and conservation strategy. Final report, study no. 7572. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Maehr, D.S. 1993. Response to the wild Florida panther population to removals for captive breeding. Final report, study no. 7571. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Maehr, D.S. 1996. Comparative ecology of bobcat, black bear, and Florida panther in south Florida. Ph.D. dissertation, University of Florida, Gainesville, Florida.

Maehr, D.S. 1997. Telephone communication. January 2, 1997.

Maehr, D.S. and J. A. Cox. 1995. Landscape features and panthers in Florida. Conservation Biology 9(5):1008-1019.

Maehr, D.S., J.C. Roof, E.D. Land, and J.W. McCown. 1989a. First reproduction of a panther (*Felis concolor coryi*) in Southwest Florida, U.S.A. Mammalia 25:37-38.

Maehr, D.S., E.D. Land, J.C. Roof, and J.W. McCown. 1989b. Early maternal behavior in the Florida panther (*Felis concolor coryi*). American Midland Naturalist 122:34-43.

Maehr, D.S., R.C. Belden, E.D. Land, and L. Wilkins. 1990a. Food habits of panthers in southwest Florida. Journal of Wildlife Management 54:420-423.

Maehr, D.S., E.D. Land, J.C. Roof, and J.W. McCown. 1990b. Day beds, natal dens, and activity of Florida panthers. Proceedings of the annual conference of southeast fish and wildlife agencies 44:310-318.

Maehr, D.S., E.D. Land, and J.C. Roof. 1991a. Social ecology of Florida panthers. National Geographic Research and Exploration 7(4):414-431.

Maehr, D.S., E.D. Land, and M.E. Roelke. 1991b. Mortality patterns of panthers in southwest Florida. Proceedings of the annual conference of the southeastern association of fish and wildlife agencies 45:201-207.

Mazzotti, F.J., L.A. Brandt, L.G. Pearlstine, W.M. Kitchens, T.A. Obreza, F.C. Depkin, N.E. Morris, and C.E. Arnold. 1992. An evaluation of the regional effects of new citrus development on the ecological integrity of wildlife resources in southwest Florida. Final report. South Florida Water Management District; West Palm Beach, Florida.

McCown, J.W. 1991. Big Cypress deer/panther relationships: deer herd health and reproduction. Final report, study number 7508. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Mounger, J. 1991. Piper cubs from Piper stock. Florida Wildlife Rehabilitators Association.

National Park Service [NPS]. 1998. GRASS GIS classification of 1987 Landsat satellite image acquired from Florida DOT.

Nelson, E.W., and E.A. Goldman. 1929. List of the pumas with three described as new. Journal of Mammalogy 10:345-350.

Nowell, K., and P. Jackson. 1996. Status survey and conservation action plan: Wild cats. International Union for Conservation of Nature and Natural Resources. Burlington Press; Cambridge, U.K.

O'Brien, S.J., M.E. Roelke, L. Marker, A. Newman, C.A. Winkler, D. Meltzer, L. Colly, J.F. Evermann, M. Bush, and D.E. Wildt. 1985. Genetic basis for species vulnerability in the cheetah. Science 227:1428-1434.

O'Brien, S.J., M.E. Roelke, N. Yuhki, K.W. Richards, W.E. Johnson, W.L. Franklin, A.E. Anderson, O.L. Bass, Jr., R.C. Belden, and J.S. Martenson. 1990. Genetic introgression within the Florida panther, *Felis concolor coryi*. National Geographic Research 6(4):485-494.

Ralls, K., and J. Ballou. 1982. Effects of inbreeding on infant mortality in captive primates. International Journal of Primatology 3:491-505.

Roelke, M.E. 1990. Florida panther biomedical investigations. Final performance report, July 1, 1986 to June 30, 1990, study no. 7506. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Roelke, M.E. 1991. Florida panther biomedical investigation. Annual performance report, July 1, 1990 to June 30, 1991, study no. 7506. Florida Game and Fresh Water Fish Commission, Tallahassee, Florida.

Roelke, M.E., and C.M. Glass. 1992. Florida panther biomedical investigation. Annual performance report, endangered species project E-1 11-E-7 7506. Florida Game and Fresh Water Fish Commission, Tallahassee, Florida.

Roelke, M.E., J.S. Martenson, and S.J. O'Brien. 1993. The consequences of demographic reduction and genetic depletion in the endangered Florida panther. Current Biology 3:340-350.

Ruediger, B. 1998. Rare carnivores and highways moving into the 21st century. Pages 10-16 *in* Evink, G.L., P. Garrett, and J. Berry, eds. Proceedings of the international conference on wildlife ecology and transportation. FL-ER-69-98, Florida Department of Transportation, Tallahassee, Florida.

Schemnitz, S.D. 1972. Distribution and abundance of alligator, bear, deer, and panther in the Everglades region of Florida. Florida Game and Fresh Water Fish Commission; Ft. Lauderdale, Florida.

Schortemeyer, J.L., D.S. Maehr, J.W. McCown, E.D. Land, and P.D. Manor. 1991. Prey management for the Florida panther: a unique role for wildlife managers. Transactions 56th North American Wildlife & Natural Resources Conference.

Seal, U.S., R.C. Lacy, and workshop participants. 1989. Florida panther viability analysis and species survival plan. Report to the U.S. Fish and Wildlife Service, by the Conservation Breeding Specialist Group, Species Survival Commission, IUCN; Apple Valley, Minnesota.

Seal, U.S., R.C. Lacy, and workshop participants. 1992. Genetic management strategies and population viability of the Florida panther. Report to the U.S. Fish and Wildlife Service, by the Conservation Breeding Specialist Group, Species Survival Commission, IUCN; Apple Valley, Minnesota.

Seal, U.S., and workshop participants. 1994. A plan for genetic restoration and management of the Florida panther (*Felis concolor coryi*). Report to the Florida Game and Fresh Water Fish Commission, by the Conservation Breeding Specialist Group, Species Survival Commission, IUCN; Apple Valley, Minnesota.

Seidensticker, J.C., IV, M.G. Hornocker, W.V. Wiles, and J.P. Messick. 1973. Mountain lion social organization in the Idaho Primative Area. Wildlife Monographs 35:1-60.

Taylor, Sharon. 1997. Florida panther biomedical investigations. Annual report, study no. 7506. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Terborgh, J. 1988. The big things that run the world-a sequel to E. O. Wilson. Conservation Biology 2:402-403.

Tinsley, J.B. 1970. The Florida panther. Great Outdoors Publishing Company; St. Petersburg, Florida.

Townsend, D. 1991. An economic overview of the agricultural expansion in southwest Florida. Unpublished report on file at South Florida Field Office; Vero Beach, Florida.

U.S. Department of the Interior [DOI]. 1969. Environmental impact statement of the Big Cypress Swamp jetport. Washington, D.C.

U.S. Fish and Wildlife Service [FWS]. 1987. Florida panther (*Felis concolor coryi*) recovery plan. Prepared by the Florida panther interagency committee for the U.S. Fish and Wildlife Service; Atlanta, Georgia.

U.S. Fish and Wildlife Service [FWS]. 1994. Final environmental assessment - genetic restoration of the Florida panther; Atlanta, Georgia.

U.S. Fish and Wildlife Service. [FWS]. 1995. Second revision Florida panther recovery plan; Atlanta, Georgia.

U.S. Fish and Wildlife Service [FWS]. 1996. Florida Panther NWR and Ten Thousand Islands NWR; Naples, Florida. Annual Narrative Report, Calendar Year 1996. Atlanta, Georgia.

Van Dyke, F.G., R.H. Brocke, and H.G. Shaw. 1986. Use of road track counts as indices of mountain lion presence. Journal Wildlife Management. 50:102-109.

Vanas, J. 1976. The Florida panther in the Big Cypress Swamp and the role of Everglades Wonder Gardens in the past and future captive breeding programs. *In* P.C.H. Pritchard, ed., Proceedings of the Florida panther conference. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Wildt, D.E. 1994. Endangered species spermatozoa: Diversity, research and conservation. Pages 1-24 *in:* A. Bartke, ed., Function of somatic cells in the testes. Springer-Verlag; New York.

Wildt, D.E., E.J. Baas, P.K. Chakraborty, T. L. Wolfle, and A. P. Stewart. 1982. Influence of inbreeding on reproductive performance, ejaculate quality and testicular volume in the dog. Theriogenology 17:445-452.

Wilkins, L. 1994. Practical cats: Comparing *coryi* to other cougars: An analysis of variation in the Florida panther, *Felis concolor coryi*. Pages 14-41 *in:* D.B Jordan, ed., Proceedings of the Florida panther conference. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Williams, M. 1990. Americans & their forests, a historical geography. Cambridge University Press; New York, New York.

Wolf, P. 1981. Land in America: its value, use and control. Pantheon Books; New York.

Young, S.P. and E.A. Goldman. 1946. The puma-mysterious American cat. The American Wildlife Institute; Washington, D.C.

Recovery for the Florida Panther

Felis concolor coryi

Recovery Objective: Establish three viable populations within the historic range**.**

South Florida Contribution: The narrative in this multi-species recovery plan is being prepared in advance of the range-wide Florida panther recovery plan revision which will be undergoing complete revision beginning in late 1997. Therefore, recovery tasks identified in this plan should be considered tentative and subject to change based on the results of the range-wide recovery plan revision. The multi-species plan will focus on the South Florida population, while recognizing that full recovery of this species is dependent upon the establishment of additional populations within the historic range of the species. The FWS will ensure the two plans complement one another in effecting recovery of the Florida panther.

Recovery Criteria

The present range-wide recovery objective for the Florida panther is to achieve three viable, self-sustaining populations within the historic range of the animal. First priority will be to secure the population in South Florida. A viable population level will be determined when enough data are available to develop a panther population model. An essential criteria for recovery of the panther needs to ensure 95 percent probability of persistence of the South Florida population over a minimum of 100 years. Re-established populations may require separate population goals. Population objectives will generally be based on the size of the respective areas, prey base, and other ecological factors important to panthers.

This narrative will only address the existing population in South Florida. The range-wide recovery plan revision will incorporate the needs in South Florida with population re-establishment and the many other tasks deemed necessary to recover the panther.

Species-level Recovery Actions

S1. **Refine the current distribution of the South Florida panther population**. Delineate areas inhabited or frequented by panthers. Radio-collared panthers have been documented in 12 of 19 counties in South Florida. The breeding population is centered in Collier, Hendry, and Miami-Dade counties. Uncollared panthers may still reside on private lands in Charlotte, Collier, Hendry, Lee, and Glades counties.

S1.1. **Conduct field surveys on all newly acquired public lands.** As State or Federal conservation lands are added to the public trust field surveys should be conducted to determine the presence or absence of Florida panthers. Uncollared panthers encountered should be added to the research population.

S1.2. **Conduct field surveys on private lands to document panther presence**. Potential sites would include areas identified in the HPP, other areas comprising panther habitat, and areas associated with reliable reports of panther observation/sign. Special emphasis should be placed on developing cooperative partnerships with private landowners for access. Private landowners currently involved in telemetry research studies should be commended for their participation. As in **S1.1**, uncollared panthers encountered should be added to the research population.

S2. Protect and enhance the South Florida panther population.

S2.1. Enhance the panther population through genetic and demographic management. Plans for genetic and demographic management should anticipate the circumstance under which translocation would be appropriate, and should distinguish the advantages and disadvantages of using males, females, pregnant females, animals of various ages, soft- and hard-release techniques, *etc*.

S2.1.1. Translocate animals for genetic management. Eight female western cougars (*F. c. stanleyana*) were translocated from Texas to Florida for genetic introgression in 1995. The approved genetics management plan calls for the translocation of one female western cougar about every 6 years thereafter. Animals selected for translocation must be screened in the field for cowlicks and kinked tails and screened in quarantine for atrial septal heart defects or disease using established protocols.

S2.1.2. Formulate plan for humane disposition of surplus animals. Female western cougars may need to be removed once F1 kitten recruitment goals (two per female) are met. A female western cougar/male F1 kitten pairing (backcross) is undesirable. Contraception, translocation, and removal are techniques by which undesirable pairings can be prevented. Develop a protocol for removal of these surplus animals from the population and attach it to the recovery plan as an appendix.

S2.2. Translocate animals for demographic management. It may be necessary, on occasion, to translocate panthers or intercross progeny to minimize or prevent undesirable pairings, to balance gender representation, and to fill home range vacancies in marginal habitat (*i.e*. southern Big Cypress).

S2.3. Reformulate plan for captive propagation of Florida panthers. Ten kittens, representing 11 adult panthers, were removed from South Florida during 1991 and 1992. Two died in captivity in 1992. Two died after being released to the wild in 1997. The other six panthers remain in permanent captivity. A population re-establishment study showed that there were advantages to using wild-caught versus captive-raised animals. Wild-caught western cougars are being used for genetic management rather than captive-raised animals. Consequently, the role of captive propagation in panther recovery would seem diminished. However, the fate of panthers remaining in captivity, and the role of captive propagation for education, genetic management, demographic management, or population re-establishment has not been determined. These issues need to be addressed.

S2.4. Identify causes of injury and mortality. Florida panther mortality (n=67) averaged 3.5 deaths per year from 1978 through June 30, 1998. Specific causes of panther mortality include: road kill (37.9 percent), intraspecific aggression (21.2 percent), disease and old age (18.2 percent), causes unknown (12.1 percent), shootings (9.1 percent), and capture related (1.5 percent). Other than disease, only those causes of panther injury or mortality attributable to humans can be minimized.

S2.4.1. Continue to minimize injury and mortality from panther/vehicle collisions. Florida panther injury and mortality (n=30) from vehicle collisions averaged 1.5 per year between 1978 and June 30, 1998. Panther/vehicle collisions were greatest in Collier County (76.7 percent), Hendry County (10 percent), and Lee County (10 percent); and on S.R. 29 (33.3 percent) and Alligator Alley (16.7 percent) in Collier County. Reduced nighttime speed limits are in effect, and enforced, on S.R. 29. Underpasses and fencing have eliminated panther mortality on Alligator Alley and certain stretches of S.R. 29. Panther/vehicle collisions continue on other rural roads.

S2.4.1.1. Complete installation of underpasses on S.R. 29. Four of six underpasses have been installed concurrent with the widening and realignment of S.R. 29. Two underpasses remain to be constructed in the Sunniland, Florida vicinity.

S2.4.1.2. Establish an underpass on S.R. 80 east of LaBelle, Florida. The Caloosahatchee Ecoscape was added to the Conservation and Recreation Lands acquisition list in 1998 and serves as the last remaining link between panther habitat in Glades County and Hendry County. S.R. 80, which runs from Ft. Myers to West Palm Beach, bisects the project, is heavily traveled, and likely to be four-laned. An underpass or underpassses will be required to maintain this important landscape link.

S2.4.1.3. Identify and prioritize other underpass needs in South Florida. Panther/vehicle collisions continue on rural two-lane roads in eastern Collier County, Hendry County, and in rapidly developing eastern Lee County. Underpass needs should be identified prior to future road maintenance or improvement projects on appropriate roads in South Florida counties. It is more efficient to construct wildlife underpasses concurrent with road improvements.

S2.4.2. Minimize the risk of disease outbreaks. Disease is a threat to small, inbred populations. All Florida panthers undergo an examination to assess general health and physical condition at the time of capture. Panthers greater than 8 weeks of age are dewormed and vaccinated for feline viral rhinotracheitis (FVR), feline calicivirus (FCV), feline panleukopenia (FPV), and rabies. Biomedical samples collected include whole blood, skin biopsy, hair, and feces. Bacterial cultures are taken as needed. Panther kittens less than 6 weeks of age are also given injections of iron, vitamin B, and penicillin. This protocol should continue--subject to periodic review, and amendment as needed.

S2.4.3. Minimize the risk of shootings. Education, self-policing among hunters, and regulation are the tools by which shootings are minimized. All free-ranging puma in the southeastern U.S. are protected by a “similarity of appearance” provision in the ESA.

S2.4.4. Minimize the risk of capture-related mortality. The only capture-related panther mortality occurred in 1983. Captures are confined to cooler months (November through March) to minimize heat stress. Crash bags and safety nets are used to cushion the impact of panthers that fall from the tree after immobilization. Anesthetic drugs have been changed and doses reduced through experience to minimize adverse reactions to the drugs. Advances in pharmacology have also made anesthesia safer.

S2.5. **Enforce available protective measures.** Implement local, State and Federal regulations and guidelines to protect Florida panthers and their habitat.

S2.5.1. **Initiate section 7 consultation when applicable.** All Federal agencies must consult with the FWS on any of their activities (authorized, funded, or carried out) that might adversely affect Florida panther populations. Such activities include (among others) land clearing, road construction, and military training exercises.

S2.5.2. **Implement on-site minimization, habitat compensation, and mitigation on private lands through section 10 when needed.** Where adverse effects cannot be avoided, measures must be taken to minimize on-site disturbance, and compensate or mitigate for the impacts that remain. The FWS generally recommends that areas used as habitat compensation be located in the vicinity of the affected habitat, where appropriate, and avoid further fragmentation and isolation of existing habitat.

S3. Continue Florida panther life history and ecology research.

S3.1. **Conduct research on biology, ecology, and population demographics**. Although considerable work has been done on the biology and ecology of the Florida panther, biological studies should continue to increase information on population viability, and relationship of demographic factors to habitat quality and availability.

S3.2. **Conduct risk assessment and population viability analyses** to determine the probability of persistence of panthers in South Florida, using current demographic data. Conduct periodic workshops to update population viability projections.

S3.3. **Continue research on effects of mortality on the Florida panther.**

S3.3.1. **Assess the current state of knowledge of the effects of environmental contaminants on the Florida panther.** Compile the latest available information from published and unpublished literature, and from scientists, to determine the direction for future research.

S3.3.2. **Continue to research effects of environmental contaminants that could be affecting the Florida panther.** Other environmental contaminants, such as endocrine disruptive chemicals, should be researched to assess any possible effects to the Florida panther.

S3.3.3. **Continue to gather and evaluate data on feline-associated viruses, parasites and other potentially debilitating agents**. Management recommendations should follow guidelines resulting from these data.

S3.3.4. **Develop health indicator matrix**. Presence or absence of disease and contaminants (estrogen mimics, mercury) for each animal would be indicated in the matrix. An index of health would be established by noting the number of animals affected by disease or contaminants, the extent to which the animal is affected, the age, sex, and breeding condition of the animal, and comparing that to a desired index.

S3.3.6. **Conduct research to determine the effects of road density and development** (human density) on white-tailed deer and feral hog distribution and abundance.

S4. Monitor the South Florida panther population.

4.1. Continue and expand the radio-telemetry/monitoring program. The radiotelemetry/monitoring program within the core population area has been underway since 1981. Continue to track locations of collared panthers, and maintain all data on a GIS database. Expand the program by radio-instrumenting individuals in under-studied segments of the population and monitoring outside of the core area (*i.e.* CREW, Okaloacoochee Slough area, areas north of the Caloosahatchee River, *etc*.).

4.2. Continue to monitor translocated animals and offspring. All western cougars used for genetic introgression are radio-collared and monitored. All intercross kittens will be implanted with transponder identification chips, radio-collared prior to dispersal, and monitored. Four F1 kittens implanted with transponder identification chips have dispersed without being radio-collared. These animals, now old enough to breed, will be collared when encountered. DNA analysis will be required to establish the identity of F2 kittens sired or reared by the four uncollared F1 kittens.

S5. Refine statewide education and outreach programs for Florida panther. A 1995 public opinion survey indicates that Floridians are remarkably positive in their opinions and attitudes toward panther conservation (92 percent support, 2 percent oppose). The challenge now is to turn this support into tangible conservation efforts. Educators need to identify specific ways Floridians can become involved in panther protection. The action items should be simple and need to be effectively and constantly communicated to the public.

S5.1. Emphasize basic facts about the Florida panther in outreach materials. Awareness of the panther among respondents of the 1995 survey was high (90 percent) but knowledge levels were limited. Surprisingly, only 44 percent of the people aware of panthers in Florida knew that the panthers were confined to South Florida and only 14 percent knew that there were less than 50 remaining. Public relations efforts and materials must continue to reflect these basic facts.

S5.2. Tailor outreach efforts and materials to non-residents. Tourism, which brings about 40 million people to Florida annually, was not a focus of the 1995 survey. Agencies are only now beginning to understand the relationship between tourism, development, and wildlife conservation. Another way to increase panther awareness levels and support is to tailor outreach efforts and materials to tourists.

S5.3. Publicize Florida panther website. A website has been developed by Florida State University and the Florida Advisory Council on Environmental Education with funding derived from the sale of panther license plates. Education and outreach materials should include the web address (www.panther.state.fl.us).

S5.4. Establish South Florida education and outreach programs for Florida panther. Informing the public about the life history of the panther, land management practices that benefit the panther, and interagency efforts to prevent the extinction of the panther are important components of the panther recovery program. Listed below are tasks specific to South Florida as identified in the Florida Panther National Wildlife Refuge

Comprehensive Conservation Plan.

S5.4.1. **Develop multi-agency visitor center.** Use high-quality, conventional exhibits and progressive interactive media displays to inform public. The center will serve as an outdoor classroom in the Big Cypress Watershed for students in Collier County, Hendry County, Lee County, and all of South Florida.

S5.4.2. **Hire three new personnel at Florida Panther National Wildlife Refuge.** A media specialist is needed to coordinate news events, press releases, and information transfer to local, State, and national news outlets. A public use specialist is needed to coordinate visitor center activities, refuge interpretive displays, school outreach, and refuge volunteer activities. An administrative assistant is needed to support the media specialist and public use specialist.

S5.4.3. **Increase membership of "Friends of the Panther Refuge" support group.** The target is to have 100 members. The group will assist with education programs on and off the refuge. Quarterly evaluations will assess the effectiveness of the group's support efforts.

S5.4.4. **Collaborate with partners to support outreach activities.** Partners include but are not limited to local, State, and national non-profit organizations, and State and Federal agencies. Participate with partners in at least two events per year (National Wildlife Refuge Week, International Migratory Bird Day, Earth Day, *etc*.).

S5.4.5. **Develop lesson plans for local school teachers and community organizations.** The lesson plans should focus on the panther, public land management, South Florida ecosystem issues and restoration efforts. An annual workshop will be held for teachers from school districts in Collier County, Hendry County, Lee County, and all of South Florida.

S6. **Continue to participate in the Florida Panther Recovery Program.** .

S6.1. **Reconstitute the Florida Panther Interagency Committee.** The Florida Panther Interagency Committee (FPIC), established in 1986 to coordinate panther recovery efforts, is comprised of the FWS, NPS, GFC, and DEP. However, other State and Federal agencies and tribal governments have much to contribute to panther recovery. Consideration should be given to expanding FPIC membership.

S6.2. **Convene periodic meetings of the Florida Panther Recovery Team.** The Florida Panther Recovery Team should convene periodically to discuss interagency relations, ongoing research, research results, new literature relevant to panther recovery, and to assess panther recovery program accomplishments and needs.

S6.3. **Convene periodic meetings of the Florida panther Technical Advisory Council.** The Florida Panther Technical Advisory Council should continue to convene biannually.

S6.4. **Update and revise the range-wide Florida panther recovery plan.** The range-wide recovery plan, first approved in 1981, then revised in 1987 and 1995, is currently undergoing its third revision, which should be complete in 2000. The range-wide plan details the status of the recovery program and the myriad of tasks necessary for panther recovery. The plan should be updated and revised every 5 years. Progress reports on recovery plan implementation should be published annually.

S6.5. Convene periodic conferences for recovery program partners and general public. The Florida Audubon Society sponsored the first Florida Panther Conference in Orlando, Florida in 1978. A second conference sponsored by Florida Defenders of the Environment was held in Gainesville, Florida in 1986. A third conference sponsored by the Florida Panther Interagency Committee was held in Ft. Myers, Florida in 1994. The conferences have all focused on the issues of, and progress towards, panther recovery. Conferences held about once a decade for recovery program partners and the general public seem appropriate.

Habitat-level Recovery Actions

H1. Preserve and protect Florida panther habitat. The Florida Panther Habitat Preservation Plan (HPP) identified 374,868 ha of occupied and potential habitat considered essential to maintaining a minimum viable population of 50 breeding adult panthers in South Florida. Fifty-seven percent of these lands are classified as Priority 1 (highest quality and/or most frequently used) and 43 percent as Priority 2 (lower quality and/or less frequently used). The HPP also identified habitat threats, and the means by which habitat could be protected: land acquisition, conservation easements, exchanges, donations, voluntary management agreements, landowner incentives, and landowner disincentives.

H1.1. Complete acquisition projects comprised of Priority 1 and Priority 2 habitat. Nearly 190,000 ha of priority panther habitat have been proposed for State (75 percent) or Federal (25 percent) acquisition. Thirty-three percent of these lands have been preserved using fee-simple acquisition and conservation easements. The remainder should be preserved in a timely manner.

H1.2. Initiate new acquisition projects comprised of Priority 1 and Priority 2 habitat. The FWS has initiated a proposal to expand the Florida Panther NWR in Collier County and Hendry County by about 150,000 ha. Other proposals are being developed. Appropriate agencies should continue to identify landowners interested in panther recovery from whom land and conservation easements may be purchased.

H1.3. Complete public protection of Big Cypress Area of Critical State Concern. The Big Cypress Conservation Act of 1973 designated 347,228 ha of the 634,561 ha Big Cypress Watershed as an Area of Critical State Concern (ACSC). Today, 93 percent of the ACSC is in public ownership. The 7 percent remaining in private ownership, all Priority 1 habitat, extends from Florida Panther NWR north to Okaloacoochee Slough SF, serves as a large mammal corridor between Collier County and Hendry County, and should be protected.

H1.4. Establish, restore, and maintain important corridors. Corridors are necessary for population expansion and for facilitating gene flow between subpopulations. The Caloosahatchee Ecoscape, added to the CARL acquisition list in 1998, is a 4,047 ha corridor connecting panther habitat in Glades County and Hendry County. Camp Keais strand links Florida Panther NWR with the CREW. A recent 20,695 ha conservation easement acquired by the SWFWMD could link panther habitat in DeSoto County and Glades County. The Florida Greenways Coordinating Council adopted in 1998 a five-year implementation plan for a statewide system of greenways and trails that could benefit the panther long-term.

H2. Use landowner incentive programs to conserve, restore, and manage panther habitat. The USDA-NRCS and FWS administer several landowner incentive programs capable of preserving Priority 1 and Priority 2 panther habitat on farms and ranches in South Florida. Each of the programs is briefly discussed below. Some examples of how the program can be used for panther recovery are given.

H2.1. Environmental Conservation Acreage Reserve Program. The Environmental Conservation Acreage Reserve Program (ECARP) encompasses the Conservation Reserve Program, Wetlands Reserve Program, and the Environmental Quality Incentives Program. The purpose of these programs is to help farmers and ranchers conserve and enhance soil, water, and related natural resources, including grazing land, wetlands, and wildlife habitat. Program objectives are achieved primarily through short-term or perpetual retirement of marginal agricultural land and changes in land management practices.

H2.1.1. Conservation Reserve Program. The Conservation Reserve Program (CRP) makes annual rental payments and pays 50 percent of the cost of eligible conservation practices implemented by the landowner. Two types of CRP are recognized.

The **Traditional CRP** allows irregular, periodic enrollment of large acreages and can quickly provide measurable benefits to wildlife species requiring expanses of contiguous habitat. For example, traditional CRP should be used to establish tracts of pine flatwoods 250 ha or greater to reverse a historic pine flatwoods decline of 88 percent in central South Florida. Forest tracts 250 ha or larger are a constituent element of occupied panther range and pine flatwoods can account for about 30 percent of individual panther radio-locations.

The **Continuous CRP** allows year-round enrollment of small acreages with an emphasis on strip-type water quality practices. The continuous CRP should be used to plant pine or hardwood buffers around isolated cypress domes or along cypress strands to provide cover for panthers, cover for panther prey, and to increase average forest patch size in a given area, thus reversing fragmentation. Trees planted in strips of sufficient width along ditches, canals, interior access roads or similar landscape features could serve as cover for panther prey and provide nominal travel corridors for the panther.

H2.1.2. Wetlands Reserve Program. The Wetlands Reserve Program (WRP) pays farmers and ranchers to restore former and degraded wetlands. Restoration of forested wetlands would reverse forest declines and would be somewhat beneficial to the panther given its preference for forested habitats. Wetland restoration would also benefit panther prey, which can be found feeding in, or around the edge of, herbaceous wetlands. The options available include the following: (1) permanent easements, where the easement payment is generally 100 percent of the agricultural value or a predetermined area cap, and NRCS pays 100 percent of the restoration costs; (2) 30-year easements, where the easement payment is generally 75 percent of the agricultural value or a predetermined area cap, and NRCS pays 75 percent of the restoration costs; and (3) restoration cost-share agreements, where there is no easement payment but NRCS pays 75 percent of the restoration costs. The minimum duration for the agreement is 10 years.

H2.1.3. **Environmental Quality Incentives Program.** The Environmental Quality Incentives Program (EQIP) provides educational, technical, and financial assistance to help farmers and ranchers comply with State and Federal environmental laws. Fifty percent of the annual appropriation is allocated to livestock-related natural resource concerns and cattlemen owning land inhabited by the panther are ideal applicants. This program can be used to fence hardwood hammocks that have been degraded by mechanical manipulation or overgrazing. Hardwood hammocks can account for 30 to 40 percent of individual panther radio-locations and are the most productive white-tailed deer habitat.

H2.2. **Wildlife Habitat Incentives Program.** The Wildlife Habitat Incentives Program (WHIP) helps farmers and ranchers to plan and pay for improvements that benefit threatened and endangered upland and wetland species. NRCS will pay up to 75 percent of the cost of implementing the conservation practice. A minimum 10-year contract is required. Annual food plots are not eligible. The program was designed to promote habitat management compatible with active agricultural operations and can be used to develop, restore, or enhance many habitat types. All of the examples given above could be accomplished using this program. Use of prescribed fire to manage pine flatwoods and to stimulate the growth of understory browse for deer is also possible.

H2.3. **FWS Partners for Fish and Wildlife program.** The Partners for Fish and Wildlife (PFW) program provides technical and financial assistance to private landowners to restore and enhance fish and wildlife habitat on their property. The FWS will pay up to 100 percent of the cost of habitat restoration projects and up to 50 percent of habitat improvement projects. The funding is limited to $10,000 per landowner per year and the minimum duration of a PFW contract is 10 years. The PFW program can work in conjunction with any of the USDA-NRCS programs to help implement the conservation practices discussed above.

H3. **Optimize habitat management techniques for panther and prey.** Optimal management of habitat suitable for panther and prey on public and private lands is second only to habitat preservation. Prescribed fire should be used to maintain fire-adapted vegetation communities and provide browse for white-tailed deer. Chemical, biological, and mechanical control methods can eradicate invasive exotic plants. Hunting and access restrictions can be used to manage prey and minimize human activities that might disturb panthers. Research and education are key to optimizing habitat management for panther and prey.

H3.1. **Continue research on panther, panther prey, and habitat relationships.** The USGS-BRD, University of Tennessee is conducting a study on the response of panthers to prescribed fire and a study on panther movements in response to recreational hunting. The University of Florida, Institute of Food and Agricultural Sciences, Southwest Florida Research Center is conducting a deer forage study. Staff at Florida Panther NWR are conducting experiments on food plots for white-tailed deer. Other studies are underway or being planned. Land management programs will be refined as research results dictate.

H3.1.1. Determine properties best suited for habitat restoration using landowner incentive programs. Using most recent low-level aerial photography and land ownership data available, determine which ownerships best fit the ideal for panther habitat.

H3.1.2. Host annual seminar for South Florida land managers. The seminar will provide an interactive forum for farmers, ranchers, and public land managers to discuss management techniques, current research, research needs, public/private partnerships, and other topics pertinent to panther habitat management and panther recovery.

H4. Develop and implement a habitat monitoring program. Data exist for habitat changes in the Immokalee Rise physiographic region from 1900 through 1989. Low-level aerial photography should be acquired every 10 years to ascertain positive and negative changes in habitat quantity. The analysis should focus on upland and wetland forest fragmentation, *i.e.* gaps between forest patches, forest patch size and abundance per patch size, *etc*.

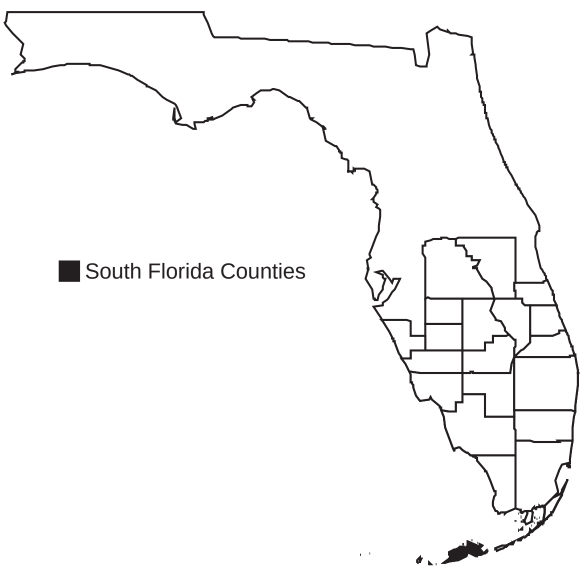
H5. Publicize habitat management techniques and research results to increase public awareness. Publish a periodic newsletter, via print and the internet, on panther habitat management issues and relevant research results. The newsletter should be sent via direct mail to all South Florida land managers (public and private) and distributed through local county extension and USDA-NRCS offices to landowners.

Lower Keys Rabbit

Sylvilagus palustris hefneri

Federal Status:	**Endangered (June 21, 1990)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. Distribution of the Lower Keys rabbit; this species is endemic only to the Florida Keys.



The Lower Keys rabbit (commonly known as the Lower Keys marsh rabbit) is endemic to the Lower Florida Keys. The narrow geographic range of this species causes it to be more susceptible to extinction. Habitat destruction and fragmentation associated with residential and commercial construction activities over the past 20 years is responsible for the Lower Keys marsh rabbit's endangered status.

This account represents a revision of the existing recovery plan for the Lower Keys marsh rabbit (FWS 1994).

Description

Lower Keys rabbits are small-to-medium sized marsh rabbits, with short, dark brown fur and a greyish-white belly. Their feet are small and their tails are dark brown and inconspicuous. Male and female marsh rabbits do not appear to differ measurably in size or color. Lower Keys marsh rabbits are about 320 to 380 mm in length and weigh between 1,000 and 1,400 g. Their hind feet range from 65 to 80 mm and their ears range from 45 to 62 mm in length (E. Forys, Eckerd College, personal communication 1996).

This marsh rabbit differs from mainland (*S. p. palustris*) and Upper Keys marsh rabbits (*S. p. paludicola*) in several cranial characteristics (Lazell 1984). The Lower Keys marsh rabbit has a shorter molariform tooth row, higher and more convex frontonasal profile, broader cranium, and elongated dentary symphysis. They are also different in the extent and ornateness of the dorsal skull sculpture. The Lower Keys rabbit is the smallest of the three marsh rabbit subspecies and is distinguished from other marsh rabbits by its dark fur.

Taxonomy

A separate species of marsh rabbit (*S. palustris*) in the Lower Florida Keys was first noted by Schwartz (1952) with additional sightings and scat records by Layne (1974).

This species was originally included as a range extension of *S. palustris paludicola* by Hall (1981) based on Layne's findings, although Hall did not examine the specimens. The Lower Keys rabbit (*S. p. hefneri*) was recognized as a distinct subspecies by Lazell (1984) based on an examination of specimens collected from Lower Sugarloaf Key, Monroe County, Florida. *Sylvilagus palustris hefneri* is the most recently described of the three subspecies of marsh rabbit. The new subspecies was named in honor of Hugh M. Hefner in recognitition of the financial support received by his corporation. The common name given for this species in the most current FWS list of threatened and endangered wildlife (CFR 17.11) is Lower Keys rabbit. Because it is more commonly called the Lower Keys marsh rabbit in other sources, this common name is also used throughout the account.

Distribution

Marsh rabbits are found throughout southeastern North America. *Sylvilagus p. palustris* is found from southeastern Virginia south to the Georgia-Florida border. *Sylvilagus p. paludicola* is found from the Georgia-Florida border south to the Upper Keys. Populations of marsh rabbits probably inhabited the areas of what is known today as the Lower Keys during the Wurm glacial maximum about 40,000-12,000 YBP (Lazell 1984). Since that time, sea level has continued to rise, stranding those species in the Lower Keys approximately 10,000 YBP. The isolation of these species and the unique ecological characteristics of the Keys were responsible for the marsh rabbit's speciation. Today, *Sylvilagus palustris hefneri* is confined to the oolitic and oolitic-coraline composite Lower Keys (Figure 1).

Lower Keys marsh rabbits were first reported from Key West by dePourtales (1877). The Lower Keys marsh rabbit's original range extended from Big Pine Key to Key West (Layne 1974, Hall 1981) encompassing a linear distance of about 48 km. Historically, Lower Keys marsh rabbits probably occurred on all of the Lower Keys that supported suitable habitat but did not occur east of the Seven-mile bridge where it is replaced by *S. p. paludicola*.

In 1995, a comprehensive survey for Lower Keys marsh rabbits located 81 areas, comprising a total of 317 ha, that provided suitable habitat for the Lower Keys marsh rabbit (Forys *et al*. 1996). Lower Keys marsh rabbits have been recorded at 50 of these 81 areas. The majority of these areas of suitable habitat are smaller than 3 ha and the total amount of habitat occupied by the Lower Keys marsh rabbit is about 253 ha (Forys *et al*. 1996). Lower Keys marsh rabbits have been found on only a few of the larger Lower Keys (specifically, Boca Chica, Saddlebunch, Sugarloaf, and Big Pine Keys) and the small islands near these Keys. There is a large gap in the distribution of Lower Keys marsh rabbits from Cudjoe Key to the Torch Keys.

Habitat

In general, other subspecies of *S. palustris* are typically found in saltmarsh areas of slightly higher elevation, such as ridges or islands (Ivey 1959). They also are found along fresh water bordered by hammocks and flatwoods.

Lower Keys rabbit.
Original photograph courtesy of U.S. Fish and Wildlife Service.

Normally, marsh rabbits are restricted to relatively undisturbed wetlands (Padgett 1989).

The Lower Keys marsh rabbit is habitat specific, depending upon a transition zone of grasses and sedges for feeding, shelter, and nesting. This species primarily occurs in the grassy marshes and prairies of the Lower Keys; which are transitional areas similar in form and species composition to communities interspersed throughout mangrove forests of mainland Florida (Forys and Humphrey 1994). These wetland communities lie in the middle of the salinity gradient in the Lower Keys. Major vegetative species include grasses (*Monanthochloe littoralis*, *Fimbristylis castaneasea*); succulent herbs (*Borrichia frutescens, Batis maritima, Salicornia virginica*); sedges (*Cyperus* spp.); and sparse tree cover (*Conocarpus erectus* and *Pithecellobium guadalupense*).

Lower Keys marsh rabbits also use marshes at the fresh water end of this salinity gradient. Fresh water marsh areas are dominated by sedges like sawgrass (*Cladium jamiacense*), with succulent herbs like seashore dropseed (*Sporobolus virginicus*) and grasses like cordgrass (*Spartina* spp.). Fresh water marshes are found in depressions in the interior of only a few islands, primarily in the Lower Keys. During the wet season these areas can accumulate standing water.

Marsh rabbits also use coastal beach berm habitat, which is a relatively rare habitat consisting of a vegetated high ridge of storm-deposited sand and shell. Coastal berms are vegetated with over 84 plant species, including blolly (*Guapira discolor*), gumbo limbo (*Bursera simaruba*), poisonwood (*Metopium toxiferum*), seagrape (*Coccoloba uvifera*), and Spanish stopper (*Eugenia foetida*) (Kruer 1992). Coastal berm habitat in the Lower Keys is often disturbed and is found on Money, Ohio, and Porpoise keys, Cook's Island, the north edge of Pye Key, Key Lois, West Content Key and several islands in the Great White Heron NWR, Lower Sugarloaf, Saddlehill, and the

BocaChica/Geiger Key area. Many of these are in private ownership (Kruer 1992). Of these areas, Lower Keys marsh rabbits are known from Long Beach on Big Pine Key and Sugarloaf Beach on the Saddlebunch Keys, but may also occur in other areas.

Freshwater marsh and coastal berm habitats are relatively rare in the Keys. Both fresh and saltwater marshes are limited in the Keys, since mangroves occupy coastal areas and interior fresh water habitat is scarce.

Lower Keys marsh rabbits prefer areas with high amounts of clump grass, ground cover, and *Borrichia frutescens* present, areas closer to other existing marsh rabbit populations, and areas close to large bodies of water (Forys and Humphrey 1994). These marsh rabbits spend most of their time in the mid-marsh (*Borrichia frutescens*) and high-marsh (*Spartina* spp. and *Fimbristylis castanea*), both of which are used for cover and foraging, while most nesting occurs in the high-marsh area (Forys and Humphrey 1994). Lower Keys marsh rabbits occasionally use low shrub marshes and mangrove communities (red mangrove--*Rhizophora mangle*, black mangrove--*Avicennia germinans*, white mangrove--*Laguncularia racemosa*, and buttonwood--*Conocarpus erectus*) for feeding and as a corridor between patches of transitional habitats. In brackish habitats, the two plant species that are most important to the Lower Keys marsh rabbit for cover and nesting are cordgrass (*Spartina spartinae*) and saltmarsh fimbristylis (*Fimbristylis castanea*), both of which are thick, abundant grasses. In freshwater wetlands, the Lower Keys marsh rabbit may use sawgrass for the same purpose. Not much is known on how marsh rabbits use vegetation in coastal berm areas (Kruer 1992, Forys and Humphrey 1994).

Behavior

Dispersal and Home Range

Adult Lower Keys marsh rabbits of the same sex do not have overlapping home ranges, and may display territorial behavior if another adult enters their home range. The home ranges of these marsh rabbits average 0.32 ha. Adult marsh rabbits have permanent home ranges, while male subadults tend to disperse. Adults of both sexes have similar home range sizes, although the size varies widely among individuals. This individual variability may be due to differences in habitat quality, population density, or the status of an individual in a social hierarchy. Juvenile Lower Keys marsh rabbits appear to use a home range near their nest site.

Lower Keys marsh rabbits usually travel through a variety of habitats between their natal and permanent home ranges, including areas with dense ground cover, mangroves, upland hardwood hammocks, and vegetation between the road shoulder and the water (Forys and Humphrey 1994). Marsh rabbits are good swimmers and will swim when pursued (Ivey 1959, Padgett 1989). Dispersing marsh rabbits suffer high mortalities, particularly when there is a lack of habitat between populations or when there are roads to cross. Dispersing Lower Keys marsh rabbits travel up to two kilometers from their nests, expanding their home ranges with time.

Population Structure

The Lower Keys marsh rabbit, with its small body size, short life span, high reproductive output, and high habitat specificity, exhibits classic metapopulation community dynamics (Forys 1995). There are 40 subpopulations of rabbits that occur in small disjunct patches of habitat on four keys. Rabbits living in these habitat patches are socially isolated from other patches but interact through dispersal (Forys and Humphrey 1996). Distance among habitats is important because the ability of rabbits to recolonize vacant habitat patches depends upon the presence of habitat corridors. These habitat patches occur in a highly fragmented mosaic of native and disturbed habitat, with few contiguous areas of native habitat greater than 5 ha (Forys 1995). Random population fluctuation is evident in marsh rabbit populations; several populations were so small and contained so few individuals of the same sex that they eventually became extirpated (Forys 1995). The Lower Keys marsh rabbit population is estimated to contain approximately 100 to 300 individuals.

Reproduction

Both sexes of marsh rabbits (*S. palustris*) begin to sexually mature at about nine months of age. At this time, the majority of the males disperse. Sexually-maturing females do not appear to disperse. Similar to other subspecies of marsh rabbits, the Lower Keys marsh rabbit is polygamous and breeds year round. Initial results from a study of 24 rabbits from 5 populations indicates that all females breed and only a portion of the males breed (FWS 1994).

Lower Keys marsh rabbits do not display an apparent seasonal breeding pattern (FWS 1994). However, the highest proportion of females with litters occurs in March and September; the lowest proportion in April and December. The average number of litters produced during the wet and dry seasons do not differ significantly. Other species of marsh rabbits breed year round, but seasonal patterns are more evident (Tomkins 1935, Blair 1936, Holler and Conaway 1979). In South Florida, other marsh rabbit pregnancy rates are usually lower from September through December and higher from February through June (Holler and Conaway 1979). Higher anestrous or infertile periods are also evident from mid-October through mid-March, although anestrous females are present in every month. A large enough proportion of fertile males are able to breed year round. During a breeding season, marsh rabbit males become ready to breed just prior to females, whose breeding may be induced by male behavior. The number of fertile males decreases one month prior to female pregnancy.

Some female marsh rabbits in South Florida may be continuously pregnant and could potentially produce 10-12 litters per year, although this high rate of productivity is rare since some females fail to breed each month (Holler and Conaway 1979). Usually, 75 percent of female marsh rabbits in South Florida are pregnant during the height of the breeding season. Although no estimate is available for Lower Keys marsh rabbits, the average gestation period of marsh rabbits from mainland Florida ranges from 30 to 37 days with an average of 6.92 to 5.68 litters per year, respectively (Holler and Conaway 1979).

The Lower Keys marsh rabbit may be less fecund than other marsh rabbits (FWS 1994). An average of 3.7 litters per year has been reported for Lower Keys marsh rabbits, which is a lower fecundity rate than southern Florida marsh rabbits' 5.7 litters per year (Holler and Conaway 1979). Some marsh rabbits experience total litter resorption that can affect their reproductive output. The loss of these ovulated ova can be related to maternal physiological changes in response to stressful events like overcrowding (Conaway and Wight 1962). It is not yet known if such stresses cause total litter resorption in Lower Keys marsh rabbits, but with the continual loss of habitat, marsh rabbits may experience similar problems.

A population viability analysis (PVA) conducted for the Lower Keys marsh rabbit predicted that this species will go extinct in the next 20 to 30 years under current conditions (Forys 1995). Although the PVA did not evaluate the effects of any increases in the threats, the FWS expects that such increases would only accelerate the extinction of the Lower Keys marsh rabbit. When different management scenarios were included in the model, the persistence of the Lower Keys marsh rabbit was extended to 50 years if all predation by cats was removed (Forys and Humphrey 1996). Persistence was not extended appreciably if all road mortality was removed or reintroductions into vacant patches were conducted. The PVA did not assess whether habitat restoration, introductions into occupied habitats, or a combination of management activities would change persistence rates. Considering the desperate condition of the Lower Keys marsh rabbit, the continued degradation of its habitat and predation by cats are likely to push this subspecies of marsh rabbit towards extinction.

Foraging

Marsh rabbits and other species of rabbits feed throughout the year on a variety of vegetation. Marsh rabbits do show a preference for particular species, but this is not based on seasonal changes. The climate and vegetation in the Lower Keys are relatively stable coinciding with the marsh rabbits invariant diet (Forys and Humphrey 1994).

Marsh rabbits eat vegetation in proportion to its abundance. The most important food species for the Lower Keys marsh rabbit appears to be *Borrichia frutescens*, which is common in the mid-saltmarsh area. The marsh rabbit spends most of its time feeding in the mid- and high- marsh areas (Forys and Humphrey 1994). Rabbits have been seen foraging on a variety of grass, sedge, shrub and tree species, but have not been seen eating tree leaves or bark. Lower Keys marsh rabbits feed on at least 19 different plant species, representing 14 families (FWS 1994). The most abundant species in the rabbit's diet include *Sporobolus virginicus, Salicornia virginica, Spartina spartinae, Borrichia frutescens, Rhizophora mangle* and *Laguncularia racemosa* (Forys and Humphrey 1994). Dietary habits are not affected by sex or season.

Based on their distribution, Lower Keys marsh rabbits appear to need little fresh water to survive. In a study of several mammals from the Lower Florida Keys, the Lower Keys marsh rabbit was found to have one of the highest capacities to concentrate urine (Dunson and Lazell 1982). Although further study is warranted, Lower Keys marsh rabbits may be able to survive solely on dew and brackish water. Lower Keys marsh rabbits probably cannot use seawater to meet their need for water; even black rats, the most salt tolerant mammal in the study, could not maintain its body mass on seawater.

Relationship to Other Species

Many endemic species, like those in the Lower Keys, have evolved in an environment with reduced levels of competition, predation, and disease, and are thus more susceptible to extinction (Primack 1993). Endemic species are also more vulnerable to extinction due to loss of habitat (Gilpin and Soule 1986) and must balance a dynamic equilibrium between the processes of immigration and extinction in order to survive (MacArthur and Wilson 1963, 1967). This equilibrium is contingent upon the habitat itself, *i.e.*, size and isolation, and upon the ability of the species present to disperse and reproduce. The survival of endemic species and other species in the Lower Keys, including the marsh rabbit, is dependent upon the integrity and health of their habitat.

Many of the endemic species in the Lower Keys depend upon similar or adjacent habitats. The Lower Keys marsh rabbit occupies habitat that overlaps with that of other listed endemic species, such as the endangered Key deer (*Odocoileus virginianus clavium*), Key tree-cactus *(Pilosocereus robinii)*, and silver rice rat *(Oryzomys palustris natator*). Marsh rabbits and silver rice rats utilize similar vegetation in salt marshes (*e.g.*, *Sporobolus virginicus*), transitional areas (*e.g.*, *Conocarpus erectus*), and freshwater marshes (*e.g.*, *Cladium jamaicense*). Coastal berm areas on Long Beach and Sugarloaf Beach are used by marsh rabbits, as well as by Key deer who use these same areas for bedding and fawning (Folk *et al*. 1990). Sugarloaf Beach is also used as nesting habitat by threatened Atlantic loggerhead (*Caretta caretta*) and endangered green (*Chelonia mydas mydas*) sea turtles. The state-listed threatened white-crowned pigeon (*Columba leucocephala*) and other bird species also feed along coastal berm areas and within forested marsh areas (Strong and Bancroft 1994).

Status and Trends

The Lower Keys marsh rabbit was listed as a federally endangered species on June 21, 1990 (55 FR 25591). The marsh rabbit was listed because of habitat loss and fragmentation, predation by cats, and road mortalities caused by automobiles; critical habitat was not designated. The rabbit was also listed as endangered by the State of Florida in 1989 (F.A.C. 39-27). Although once abundant on many of the Lower Keys including Key West, habitat destruction has limited this marsh rabbit to small populations on a few keys such as Boca Chica, Saddlebunch/Sugarloaf, and Big Pine Key (FWS 1994). Current population estimates range between 100 and 300 rabbits in the Lower Florida Keys. The current status of the Lower Keys marsh rabbit is considered to be declining (FWS 1994). In 1991, there was a high of 300 individuals and by 1993, the population decreased to only 100 individuals (Forys and Humphrey 1994). The marsh rabbit population was higher before 1991. Approximately one-third of the total Lower Keys marsh rabbit habitat is owned by the Department of Defense, one-third is part of the FWS' National Key Deer Refuge and Great White Heron NWR, and the remaining one-third is privately owned.

The Lower Keys marsh rabbit is vulnerable to habitat alteration, contaminants, vehicular traffic, dumping, poaching, domestic animals, feral hogs, fire ants, and exotic vegetation. These threats have resulted in a decrease in the number of populations; a decline in the individuals in those populations; the isolation of populations; an increase in road mortalities; the increase in feral cat-caused mortality; and the loss of foraging, sheltering, and nesting habitat. All of these threats have disrupted the equilibrium between the Lower Keys marsh rabbit's environment and its survival.

The Lower Keys marsh rabbit occurs in small, disjunct populations whose survival depends on the emigration and dispersal of individuals. In order to persist, the immigration rates of the Lower Keys marsh rabbit have to be equal to or greater than the death rates. This subspecies is thought to be less fecund than others, making it more susceptible to demographic and stochastic events (Forys 1995). Direct mortality and disruption of dispersal have reduced reproductive potential. With the lower potential for interchange between subpopulations, the probability of persistence has been decreased substantially.

This marsh rabbit is habitat specific, depending upon a transition zone of grasses and sedges for feeding, shelter, and nesting. Without these important habitat elements, the survival of the Lower Keys marsh rabbit is drastically reduced. Currently, the habitat consists of a mosaic of small native and disturbed habitat patches. In the 2 years between the study (1988-1990) for the Lower Keys marsh rabbit's listing (Howe 1988) and the actual listing, four of the 15 original sites used in the listing were destroyed. Today, the majority of the sites that remain are isolated by urbanized areas, and population interchange seems unlikely. Few of the contiguous areas remaining are greater than 5 ha (Forys *et al*. 1996). Currently, only 81 patches (317 ha) of Lower Keys marsh rabbit habitat remain, of these, 39 percent is privately owned and may be vulnerable to urbanization. Only 50 (253 ha) of these 81 patches currently have rabbits present (Forys *et al*. 1996).

The primary cause of the Lower Keys marsh rabbit's decline is habitat loss. In the past 20 years, more than half the area of suitable Lower Keys marsh rabbit habitat has been destroyed for construction of residential housing, commercial facilities, utility lines, roads, or other infrastructure in the Lower Keys. Most of the remaining suitable habitat has been degraded by exotic invasive plants, repeated mowing, dumping of trash, and off-road vehicle use. Urbanization has fragmented the sites occupied by the marsh rabbits and has eliminated many of the corridors that allow marsh rabbits to move from one site to another. In larger, urbanized areas where the vegetation has been mowed, dispersing marsh rabbits have no cover from predation. In general, residential and commercial activities in the Keys have affected the Lower Keys marsh rabbit by: increasing the number of residences, increasing habitat alteration (destruction, fragmentation, degradation), increasing species mortality, interfering with reproduction, and decreasing the water quality. These actions have appreciably reduced the likelihood of this species' survival and recovery in the wild.

Because the Lower Keys marsh rabbit exhibits classic metapopulation dynamics, it relies on the recolonization of vacant habitat patches for survival

(Forys *et al*. 1996). Subpopulations in habitat patches are vulnerable to extinction, but vacant habitat patches have the potential to be recolonized by dispersing rabbits. Those sites that are not occupied are just as vulnerable as occupied sites and are important for future dispersal and recovery. The potential for recolonization has been decreased or eliminated because of habitat loss or fragmentation at both occupied and unoccupied sites.

Habitat alteration has become the largest effect that prevents this species from returning to its natural state. Continued habitat fragmentation hinders the probability of successful recolonization due to the isolated nature of the habitat, increased road mortality, and cat-caused deaths. Urbanization has isolated subpopulations, and interchange between the majority of the sites is unlikely. Adult territories (of the same sex) do not overlap; therefore the Lower Keys marsh rabbit may be forced to have smaller territories if habitat is continually fragmented. If urbanization proceeds, habitat will continue to be fragmented and dispersal and migration will be hindered. The minimum habitat size considered suitable to support the Lower Keys marsh rabbit is based on the minimum home range size of 0.3 ha. The destruction and fragmentation of habitat may result in habitat patches that are too small to support subpopulations of the Lower Keys marsh rabbit. For example, five occupied habitat patches located on isolated islands without cat predation were determined not large enough to support viable populations of this species long term (Forys *et al*. 1996).

Although habitat loss is responsible for the original decline of the Lower Keys marsh rabbit, high mortality from cats may be the greatest current threat to the persistence of the Lower Keys marsh rabbit (Forys 1996). A detailed study of cat diets in the Keys has not been conducted, but rabbits were the largest component of feral cat diets in several studies that have been conducted elsewhere (Jones and Coman 1981, Liberg 1985). Even though the exact extent cannot be determined, the number of cats present in the Lower Keys has increased over the past 20 years with the increase in the residential population. Cats are responsible for both juvenile and adult mortality (Forys 1995). Lower Keys marsh rabbits appear to be equally susceptible to cat predation, regardless of gender or age. Currently, 14 occupied patches have domestic and feral cats present.

As urbanization has increased over the past 20 years, construction of new roads, or the improvement of existing roads, has been necessary to accommodate more vehicles. The construction of roads results in two main threats to the Lower Keys marsh rabbit: interference with dispersal is and increased road mortality. Vehicular traffic interferes with dispersal and may prevent essential interchange between subpopulations (Forys *et al*.1996). Dispersing males are the most vulnerable to road mortality. Dispersal is needed for repopulating sites where rabbits have been extirpated. Since only a portion of the males breed during the year, the loss of these males may lower the likelihood of mating and hence decrease the reproductive potential. The threat of roads and traffic has increased in significance because of the magnitude of habitat fragmentation: the size of the remaining habitat fragments forces more adult males to disperse in order to establish territories, putting them at a greater risk of being killed by cars.

A significant portion of the remaining population of Lower Keys marsh rabbits is found on Naval Air Station (NAS), Boca Chica. Four Lower Keys marsh rabbit road kills had been reported on NAS property between 1992 and 1994 (Forys and Humphrey 1994). This represents only those animals that have been recovered; it is reasonable to assume that others were never recorded (undetected in roadside vegetation or carried off by scavengers). Most Lower Keys marsh rabbits are killed by vehicles during the rabbit's most active period between dusk and dawn. Off-road vehicular activities also affect the Lower Keys marsh rabbit through habitat degradation and direct mortality. At least one animal has been killed by an off-road vehicle on NAS property. The amount of road mortality has not been determined for other areas in the Keys, but marsh rabbits may experience the same mortality as on NAS (Forys and Humphrey 1994).

The Lower Keys marsh rabbit may be exposed to pesticides used in marsh habitat. They may also come in contact with poisons used to control black rats. These contaminants can either be ingested while foraging on plants or drinking water. In a 1993 Biological Opinion, the FWS investigated the effects of vertebrate control agents on endangered and threatened species and determined that several chemicals (*e.g.*, Pival) would jeopardize the continued existence of the Lower Keys marsh rabbit (FWS 1993). Chemicals--such as Pival--a rodenticide used to kill rats, are lethal if ingested. The FWS also concluded that if development in the Keys continues to increase, the potential for these animals to come in contact with such chemicals also increases, as does the potential for their extinction. Based on these findings, the FWS believes the continued use of such chemicals will result in the deaths of Lower Keys marsh rabbits. Given that the majority of occupied habitat is adjacent to urbanized areas, and that urbanization continues to expand into their habitat, then it can reasonably be predicted that the use of such chemicals has had a negative impact upon the Lower Keys marsh rabbit that may prevent its recovery.

Other human-related effects include contamination, dumping, poaching, feral hogs, and fire ants. Increased nutrients from septic tanks and fertilizers degrade water quality in habitat of the Lower Keys marsh rabbit. Illegal dumping deteriorates habitat and allows the invasion of exotic plants and animals to occur. Feral hogs destroy Lower Keys marsh rabbit habitat while foraging, but the extent of impact has not been analyzed. Fire ants have been increasing in marsh habitat and pose a threat to newborns. These human-induced effects have threatened the Lower Keys marsh rabbit over the past 20 years, but to a lesser degree than habitat loss and feral cat predation.

Since the status of the Lower Keys marsh rabbit is declining, urbanization is predicted to have adverse effects that are likely to drive this species to extinction because of its narrow range and distribution, habitat specificity, classic metapopulation community dynamics which rely on dispersal, and low recovery potential. The Lower Keys marsh rabbit is a very sensitive species that is naturally vulnerable to stochastic and deterministic events. Increasing human impacts to natural occurring events only reduces the marsh rabbit's likelihood of survival.

Management

To alleviate negative effects on the marsh rabbit at NAS, the FWS consulted with the Navy in 1993 concerning marsh rabbit road mortalities and mowing activities on the base. Several actions have been initiated by the Navy in an attempt to reduce these effects, including the posting of “no mowing” signs in important rabbit habitat, fencing of some rabbit habitat to prevent illegal vehicle traffic, removal of some exotics, and the elimination of the feral cat population on the installation. These cooperative efforts have not only minimized impacts on the rabbit but also provided additional protection. The Lower Keys marsh rabbit and its habitat are also protected on National Key Deer Refuge and Great White Heron NWR. In addition, the two tracts on Sugarloaf Key where the marsh rabbit occurs are in the process of being transferred to National Key Deer Refuge to provide additional protection.

In April 1996, the Recovery Team met to discuss the status of listed species in the Keys and ways to improve that status. Four main recovery objectives were determined as priority actions necessary to prevent the extinction of the Lower Keys marsh rabbit. These include the acquisition of suitable habitat with an upland buffer, control of predation by feral and domestic cats, monitoring of existing populations, and trial reintroduction of rabbits to unoccupied suitable habitat.

Recently, the FWS consulted on how the administration of the National Flood Insurance Program by the Federal Emergency Management Agency (FEMA) affects threatened and endangered species in Monroe County. The Lower Keys marsh rabbit was one of 10 species that was determined to be affected by FEMA’s actions. Prior to this consultation, FEMA did not address listed species issues as required by section 7 of the ESA. FEMA’s responsibilities to consult arise from a sequence of events that begins before a structure is designed and ends with habitat destruction or modification for the construction of residential or commercial structures. Although FEMA is not the only entity involved in this sequence of events, it still has the obligation, as a federal agency, to ensure its actions do not jeopardize the continued existence of a listed species like the Lower Keys marsh rabbit. The FWS concluded that the continued administration of the National Flood Insurance Program by FEMA in the Keys, with its effects on land use planning and zoning and incentives for landowners, was likely to jeopardize the continued existence of the Lower Keys marsh rabbit. As a reasonable and prudent alternative to alleviate jeopardy, FEMA committed to implement procedures to ensure their actions do not jeopardize the marsh rabbit.

Research to better understand the life history parameters of the Lower Keys marsh rabbit conducted over the past few years by the GFC and FWS have been useful in developing more effective conservation measures. In addition, the population viability analysis conducted on the marsh rabbit not only predicted this species will go extinct in the next 20 to 30 years but also resulted in the development of management scenarios to help prevent extinction (Forys 1995).

In conjunction with the GFC, the FWS recently produced Geographic Information System (GIS) maps of suitable Lower Keys marsh rabbit habitat to assist in making better management decisions. Areas in private ownership that are either occupied or unoccupied by rabbits are the most vulnerable to loss. Currently there are 44 suitable habitat patches in private ownership, encompassing approximately 222 ha. The FWS believes all remaining occupied and unoccupied suitable habitat should be protected in order to ensure the continued existence of the Lower Keys marsh rabbit. In addition, the FWS recommends that a 500 m buffer zone be placed around these areas since adjacent areas are also vulnerable to urbanization. The necessity for a protected buffer is based on the likelihood that human influences will encroach upon and impact the Lower Keys marsh rabbit. The distance of 500 m is based on the use of upland areas by this species and the estimated range of domestic cats. Upland and wetland buffers are important habitat because they provide connectivity between subpopulations and minimize secondary impacts such as road and cat mortality.

The Lower Keys marsh rabbit's recovery potential is quite low due to the lack of available habitat and increased mortality due to cats and vehicular traffic. This recovery potential is increased if active management actions of populations and habitats are taken (Forys *et al*. 1996). Since urbanization has affected both occupied and unoccupied sites over the past 20 years, not only is survival affected, but the opportunity for natural or managed recovery has been precluded in some areas.

Literature Cited

Blair, W.F. 1936. The Florida marsh rabbit. Journal of Mammalogy 17:197-207.

Conaway, C.H., and H.M. Wight. 1962. Onset of reproductive season and first pregnancy of the season cottontails. Journal of Wildlife Management 26:278-290.

dePourtales, L.F. 1877. Hints on the origin of the flora and fauna of the Florida Keys. American Naturalist 11:137-144.

Dunson, W.A., and J.D. Lazell. 1982. Urinary concentrating capacity of *Rattus rattus* and other mammals from the Lower Florida Keys. Comparative Biochemistry and Physiology 71A:17-21.

Folk, M.J., W.D. Klimstra, C.R. Kruer and M.L Folk. 1990. Special Report: Key deer accessibility to all of Big Pine. Cooperative Wildlife Research Laboratory, S. Illinois University; Carbondale, Illinois.

Forys, E.A. 1995. Metapopulations of marsh rabbits: a population viability analysis of the Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*). PhD. Thesis, University of Florida; Gainesville, Florida.

Forys, E.A. 1996. Multi-Species Recovery Team meeting, April 1996.

Forys, E.A., P.A. Frank, and R.S. Kautz. 1996. Recovery Actions for the Lower Keys marsh rabbit, silver rice rat, and Stock Island tree snail. Unpublished report to Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Forys, E.A., and S.R. Humphrey. 1994. Biology of the Lower Keys marsh rabbit at Navy lands in the Lower Florida Keys. Semi-annual performance report no. 3 in files of the Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Gilpin, M.E., and M.E. Soule. 1986. Minimum viable populations: the processes of species extinctions. Pages 13-34 *in* M.E. Soule, ed. Conservation Biology: The science of scarcity and diversity. Sinauer Associates Incorporated; Sunderland, Massachussetts.

Hall, E.R. 1981. The mammals of North America. Wiley and Sons; New York, New York.

Holler, N.R., and C.H. Conaway. 1979. Reproduction of the marsh rabbit (*Sylvilagus palustris*) in South Florida. Journal of Mammalogy 60(4):769-777.

Howe, S.E. 1988. Lower Keys marsh rabbit status survey. Report to the U.S. Fish and Wildlife Service; Jacksonville, Florida.

Ivey, R.D. 1959. The mammals of Palm Valley, Florida. Journal of Mammalogy 40:585-591.

Jones, E. and B.J. Coman. 1981. Ecology of the feral cat, *Felis catus* (L.), in south-eastern Australia. Australian Wildlife Research 8:537-547.

Kruer, C.R. 1992. An assessment of Florida's remaining coastal upland communities: Florida Keys. Prepared for Florida Natural Areas Inventory; Tallahassee, Florida.

Layne, J.N. 1974. The land mammals of South Florida. Memoirs of the Miami Geologic Society 2:386-413.

Lazell, J.D., Jr. 1984. A new marsh rabbit (*Sylvilagus palustris*) from Florida's Lower Keys. Journal of Mammalogy 65(1):26-33.

Liberg, O. 1985. Food habits and prey impact by feral and house-based domestic cats in a rural area in southern Sweden. Journal of Mammalogy 65:424-432.

MacArthur, R.H., and E.O. Wilson. 1963. An equilibrium theory of insular zoogeography. Evolution 17: 373:387.

MacArthur. R.H., and E.O. Wilson. 1967. The theory of island biogeography. Princeton University Press; Princeton, New Jersey.

Padgett, T.M. 1989. A range extension of the marsh rabbit, *Sylvilagus palustri*s, from southeastern Virginia. Virginia Journal of Science 40(3):177.

Primack, R.B. 1993. Essentials of conservation biology. Sinauer Associates, Incorporated; Sunderland, Massachussetts.

Schwartz, N.C. 1952. Land mammals of southern Florida and the Upper Florida Keys. Unpublished PhD. Dissertation, University of Michigan; Ann Arbor, Michigan.

Strong, A.M., and G.T. Bancroft. 1994. Postfledging dispersal of white-crowned pigeons: implications for conservation of deciduous seasonal forests in the Florida Keys. Conservation Biology 8(3):770-779.

Tomkins, I.R. 1935. The marsh rabbit: an incomplete life history. Journal of Mammalogy 16:201-205.

U.S. Fish and Wildlife Service [FWS]. 1993. U.S. Fish and Wildlife Service Biological Opinion: Effects of 16 vertebrate control agents on threatened and endangered species. On file at the Vero Beach Field Office; Vero Beach, Florida.

U.S. Fish and Wildlife Service [FWS]. 1994. Recovery Plan for the Lower Keys marsh rabbit. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Recovery for the Lower Keys Rabbit

Sylvilagus palustris hefneri

Recovery Objective: RECLASSIFY to threatened

Recovery Criteria

Information from recent surveys and a GIS analysis indicates that the Lower Keys marsh rabbit population has experienced local extirpations and is vulnerable to extinction as a result of habitat loss and fragmentation, and other anthropogenic factors. The nature of these disturbances isolates rabbit populations and limits the reproductive potential and survival of the marsh rabbit. Consequently, the objective is to reclassify the Lower Keys marsh rabbit from *endangered* to *threatened* by protecting and managing its habitat in the Lower Keys, reducing mortality from cat predation, and increasing the size of its population. This objective will be achieved when further loss, fragmentation, or degradation of suitable marsh rabbit habitat has been prevented; native and non-native nuisance species have been reduced by 80 percent; all suitable habitat on priority acquisition lists is protected either through land acquisition or cooperative agreements; potential habitat on these protected lands are restored or rehabilitated to provide habitat for the Lower Keys marsh rabbit; and stable populations of the Lower Keys marsh rabbit are distributed on at least five Keys connected to U.S. Highway 1 and three backcountry islands in the Lower Keys. These populations will be considered demographically stable when they exhibit a stable age structure and have a rate of increase (*r*) equal to or greater than 0.0 as a 3-year running average for 6years.

Species-level Recovery Actions

S1. **Determine the distribution and status of the Lower Keys marsh rabbit.** Surveys conducted by the GFC in 1995 have provided the majority of information known, but some areas still need surveying. Conduct surveys to determine the distribution and status of marsh rabbits.

S1.1. **Conduct additional surveys to refine marsh rabbit distribution.** Conduct necessary aerial and ground surveys for the presence of marsh rabbits and suitable habitat. Conduct surveys at the northern extent of the range (Big Pine area and the backcountry islands in the Big Pine Complex--*e.g.*, Little Pine Island, Johnson Keys) and the southern extent of the range (Saddlebunch area) to finalize distribution and range map. Conduct surveys along U.S. Highway 1 on Saddlebunch Key.

S1.2. **Conduct presence/absence surveys in areas of unoccupied habitat.** A recent status survey examined potential habitat available and documented the presence or absence of marsh rabbits (Forys et al. 1996 op. cit.). Conduct additional presence-absence surveys in different seasons over a period of 3 years to confirm use or non-use of unoccupied habitat patches.

S1.3. Investigate components of both occupied and unoccupied marsh rabbit habitat and determine why rabbits are present or absent.

S1.4. Maintain and improve the GIS database for marsh rabbit information. Compile and maintain marsh rabbit distribution information through the FWS and GFC Geographic Information System (GIS) databases.

S2. Protect and enhance existing populations.

S2.1. Assign a biologist responsibility for implementing recovery actions for the threatened or endangered species of the Lower Keys. Recovery actions implemented to recover the marsh rabbit will benefit other threatened or endangered species in the Lower Florida Keys, including the Key deer, Keys tree cactus, silver rice rat, and Stock Island tree snail. The number of actions that will be necessary to recover threatened or endangered species in the Middle and Lower Florida Keys will require the attention of a biologist or similarly-trained professional who is dedicated to specifically addressing the recovery needs of these species.

S2.2. Conduct marsh rabbit reintroductions from natural wild populations.

S2.2.1. Develop a standard protocol for conducting, monitoring, and evaluating all reintroduction, translocation, and supplementation efforts of Lower Keys marsh rabbits using the IUCN/SSC Guidelines for Reintroductions. Develop criteria that determine the type of release to be conducted, evaluate and select release site, identify source and health of release stock, develop and monitor short-and long-term success indicators, and develop a policy on intervention. Ensure release sites are free of threats, especially cats, prior to any release of rabbits.

S2.2.2. Reintroduce marsh rabbits on Water Key. FWS manages 20 ha of suitable habitat on Water Key which is within the historic range that once supported rabbits and can currently support about 22-130 individuals. Conduct a direct release of 10 adults to this area from five stable nearby populations. Radio collar and tag adults and monitor three times each week for the first two months, then once a month for the next year. Conduct pellet counts to estimate the number of adults and juveniles.

S2.2.3. Conduct reintroduction of marsh rabbits to other areas. Direct release and monitor rabbits on federally owned or managed land on the Torch Keys (e.g., Buccaneer Beach Estate), Little Pine Island, remote backcountry islands, and the Naval Air Station.

S2.3. Utilize federal regulatory mechanisms for protection. Conduct section 7 consultations on federal activities. Federal agencies whose actions may affect the rabbit include: COE, FEMA, Federal Housing Administration, and the Rural Electrification Administration. Determine jeopardy thresholds for the marsh rabbit. Estimate and evaluate the type of federal activities over the next 20 years that are likely to cause jeopardy and determine threshold levels for the total population. Coordinate with FWS Law Enforcement to prevent take under section 9. Identify what activities could result in take of marsh rabbits, such as habitat loss, cat predation, mowing, vehicular traffic, and poaching.

S2.4. Provide information about marsh rabbits to federal, state, county, and city agencies. Distribute information regarding the presence of marsh rabbits, their protection under the ESA, and ways to minimize impacts. Non-federal agencies that may influence the marsh rabbit include DEP, Department of Community Affairs, GFC, FDACS, Monroe County Mosquito Control, Florida Keys Aqueduct Authority, and Monroe County Government.

S2.5. Minimize and eliminate disturbance or mortality to the Lower Keys marsh rabbit.

S2.5.1. Control or eliminate free-roaming cat populations near rabbit habitat. Free-roaming cats are abundant in the Lower Keys and are a major threat to juvenile and adult marsh rabbit survival. Establish a program throughout the Lower Keys to control free roaming cats. Establish a program to license domestic cats, implement leash laws, eliminate cat-feeding stations, implement spay and neuter program, increase awareness through educational material, test diseases, and remove nuisance feral cats.

S2.5.1.1. Continue coordination efforts with NAS, Key West to eliminate free roaming cats from that federal facility.

S2.5.1.2. Reduce impacts by free roaming cats. Develop deed restrictions to prohibit free roaming cats in rabbit sensitive areas. Develop and enforce deed restrictions that minimize the effects of free-roaming cats on Lower Keys marsh rabbits.

S2.5.2. Control raccoon predation. Raccoon populations are unnaturally high in some areas of the Lower Keys. Raccoons are capable of killing both adult and juvenile rabbits. Eliminate supplemental food sources--outdoor cat feeding stations and open dumpsters--to reduce raccoon populations.

S2.5.3. Minimize marsh rabbit road mortality. Much of the rabbit habitat left is bisected by roads, making it necessary for animals to cross. Marsh rabbits are most active from dusk until dawn and are more susceptible to road mortality during this time.

S2.5.3.1. Install chatter strips at known rabbit crossing areas on NAS, Key West and Monroe County roads, where feasible. Conduct follow-up monitoring to evaluate effectiveness.

S2.5.3.2. Implement slower speed zones and increase enforcement of existing zones to decrease rabbit roadkills. A reduction in the nighttime speed limit to 15 mph may decrease the number of road kills both on NAS, Key West and County roads. Conduct follow up monitoring to evaluate the effectiveness.

S2.5.4. Control poaching. Marsh rabbits are vulnerable to hunting and poaching. Enforce regulations to prohibit and prevent poaching of marsh rabbits.

S2.6. Establish captive propagation protocols and plans. Guidelines and protocol should be established to guide captive propagation efforts, when necessary. Any captive propagation efforts should be conducted in the Lower Keys in as similar to natural conditions as possible, continued only when necessary, and all propagation efforts should be strictly monitored. DOI guidance should be followed.

S3. Conduct research on the life history and population ecology of the marsh rabbit. Essential baseline information on the life history of marsh rabbits has been gathered in the last three to 5 years *(e.g.*, Forys and Humphrey 1994, Forys 1995, Forys *et al*. 1996 *op. cit.*). In order to develop reclassification criteria for the marsh rabbit, some additional information is still needed.

S3.1. Determine if the total population size is large enough to prevent functional extinction and genetic extinction. The population is estimated to be between 100 and 300 individuals, but is below carrying capacity based on the amount of unoccupied available habitat. Test the predictions of the PVA by obtaining long-term information on population abundance and metapopulation occupancy (Forys 1995 *op. cit.*). Test the PVA's major assumption that population growth is not currently density dependent.

S3.2. Examine effects on the persistence of the Lower Keys marsh rabbit. Ascertain what aspect of this species ecology makes it most vulnerable to extinction (e.g., predation, lack of food, inability to find mate). Cats, black rats, raccoons, fire ants, or other animals compete with or prey on the marsh rabbit. Examine how these competitors and predators are affecting each of the subpopulations and their effects on the marsh rabbit's overall persistence.

S3.3. Determine the effective population size. Inbreeding does not appear to threaten the marsh rabbit because of its present genetic variation (Forys 1995 *op. cit.*), but because there are single sex populations that have been extirpated, it is important to determine if the population size is effective in preventing inbreeding depression.

S3.4. Determine the number of subpopulations necessary to maintain a stable or increasing population. There are 40 subpopulations of rabbits that occur in small disjunct patches of habitat in the Lower Keys. The marsh rabbit appears to exhibit classic metapopulation structure and some movement and exchange between populations is responsible for its persistence (Forys and Humphrey 1994 *op. cit.*). Increases in habitat fragmentation will decrease the rabbit's ability to recolonize different habitat.

S3.4.1. Identify subpopulations vulnerable to extinction. Rabbit populations have recently been extirpated from Geiger Key, separating the Boca Chica population from the Sugarloaf/Saddlebunch population. Identify additional subpopulations vulnerable to habitat fragmentation, lost corridors, and reduced dispersal, and focus recovery actions on these sites.

S3.4.2. Determine the necessary number of subpopulations and level of exchange that will enable the rabbit to persist for 100 years.

S3.5. Conduct an experimental marsh rabbit reintroduction and evaluate its effectiveness in increasing the rabbits' persistence. Determine factors for a stable population structure (e.g., sex ratio, age structure, group size). Investigate these parameters to determine what constitutes a stable population structure. Mortality appears high in each sex and age class (FWS 1994 *op. cit.*), but a healthy age structure and sex ratio is not known.

S4. Monitor Lower Keys marsh rabbit populations.

S4.1. Conduct long-term monitoring. Monitor the status of the rabbit using established pellet counting methods (Forys and Humphrey 1994). Monitor presence/absence and degree of abundance yearly until the rabbit is recovered.

S4.2. Develop methods to monitor demographic parameters. Monitor sex ratios, age class structure, survivorship, home range size, age of dispersal, and dispersal distance of the rabbit.

S5. Increase public awareness and instill stewardship. Develop informational materials and host public workshops to increase awareness about marsh rabbits and instill a sense of stewardship for the protection of this endangered species.

S5.1. Prepare informational material for the general public. Distribute materials at visitor information centers and local chambers of commerce.

S5.2. Develop and implement a free-roaming cat control program. Conduct workshops to inform residents about the necessity of controlling cat predation on marsh rabbits through licensing programs, leash laws, and spay and neuter programs.

S5.3. Continue to inform military and civilian personnel at NAS. Inform personnel about the marsh rabbit's presence, its protection under the ESA, and ways to minimize impacts on it.

S6. Establish reclassification and delisting criteria. Develop measurable reclassification criteria based on factors that result in a stable or increasing population, including total population size, number of subpopulations, sex ratio, age structure, habitat condition and availability, and level of threats. Evaluate and monitor the marsh rabbit's status in relation to reclassification criteria.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Habitat loss is one of the main reasons for the Lower Keys marsh rabbit's decline. Habitat protection and management is paramount to the marsh rabbit's survival. Habitat degradation or loss can decrease the number of rabbits an area can support, contributing to the overall probability of extinction.

H1.1. Acquire marsh rabbit habitat. Acquire habitat essential to the rabbit's survival. Develop an acquisition plan based on habitat under greatest threat, while taking into consideration the need for reserve design (*e.g.*, corridors, core areas). About one third of all marsh rabbit habitat is privately owned.

H1.1.1. Continue Federal acquisition efforts. Continue to acquire habitat within the National Key Deer Refuge and Great White Heron NWR boundaries.

H1.1.2. Support State acquisition efforts. Continue to support the acquisition of state lands by programs such as Florida's Conservation and Recreation Lands (CARL) program.

H1.1.3. Support and encourage land acquisition by non-governmental agencies. Habitat not listed for federal, state, or county acquisition may become available for private purchase and management by such organizations as The Nature Conservancy and Florida Keys Land Trust.

H1.2. Protect and manage marsh rabbit habitat. Most marsh rabbit sites are less than 5 ha in size and are near high concentrations of people. Protect and manage these areas to prevent negative impacts on the rabbit.

H1.2.1. Protect marsh rabbits on private lands. Protect marsh rabbit populations on private land through acquisition, conservation easements or agreements, and education of land owners. Develop agreements or coordinate section 10 permits between the FWS and private land owners to minimize impacts such as feral cats, mowing, and exotics. For example, coordinate with Long Beach Estate Fish Camp to minimize the impact of feral cats and increase exotic control along the nature trail.

H1.2.2. Protect marsh rabbits on public lands. Manage public lands for exotics, off-road vehicles, dumping, feral cats and other predators, and vehicular traffic. Identify and minimize other causes of rabbit injury or mortality on public lands.

H1.2.3. Coordinate with Federal, State and Monroe County agencies and private entities to develop management actions to protect marsh rabbit habitat. Coordinate with these entities to ensure proposed construction activities that result in land clearing or alteration do not impact the marsh rabbit and its habitat.

H1.2.4. Protect important corridors. Several marsh rabbit populations are linked by corridors of low marsh and mangroves. Protect these areas by coordinating with the appropriate permitting offices to avoid any negative impact on the rabbit.

H1.2.5. Remove invasive exotic vegetation. Australian pine, Brazilian pepper, and *Colubrina asiatica* thrive in transition zone habitat. Australian pine needles kill undergrowth, destroying the rabbit's food, shelter and nesting sites. Brazilian pepper competes with native trees and grasses as does the viney *Colubrina*. These exotics are most abundant on the NAS and privately owned land. A list of exotic removal priority areas has been given to the Navy (Forys and Humphrey 1994). Continue efforts to remove exotic plants in Lower Keys marsh rabbit habitat.

H1.2.6. Prevent habitat areas from being mowed. Grass mowing temporarily destroys shelter, nesting sites, food and may kill young in the nest. Coordinate with NAS, Key West, and private land owners to reduce the impact of mowing on the Lower Keys marsh rabbit.

H1.2.7. Fence or barricade areas where off-road vehicle (ORV) use and/or dumping is a threat. Areas along roads are often used by ORVs and as dumps. Dumping and ORV use destroys habitat. Other methods have been attempted to deter ORV use, but fences 0.3 m off the ground appear to be the best method to prevent illegal vehicle use and yet allow rabbit and other species' movements. In areas that are also used by Key deer, alternative methods should be explored.

H1.2.8. Continue cooperative management at NAS, Key West. NAS has minimized their impacts on the Lower Keys marsh rabbit through management actions. Continue protection efforts such as controlled mowing, exotic removal, habitat restoration, and cat control.

H2. Restore and create marsh rabbit habitat. Several rabbit habitat sites, especially the transition zone, have been scarified by ORV's, covered with refuse, or disturbed by previous land use. Restored, these areas could support more marsh rabbits and decrease the chance of the rabbit's extinction.

H2.1. Restore natural tidal flow and hydrology by placing culverts or removing fill. The Big Pine Slough Restoration project will restore tidal flow that will benefit rabbits. Continue hydrological restoration efforts in other areas of marsh rabbit habitat.

H2.2. Manage mosquito ditches so they do not impact rabbit habitat. The Coupon Bight Buffer Preserve is proposing to manage mosquito ditches in a way that protects marsh rabbits. Implement this type of mosquito ditch management in other areas of marsh rabbit habitat.

H2.3. Improve water quality in fresh water sources and create additional fresh water sources. Restoration efforts on Shepard Tract will remove about 1 m of fill and establish deep water pockets which will benefit the marsh rabbit. Improve water quality in other fresh water areas.

H2.4. Enhance Lower Keys marsh rabbit habitat. Remove overstory vegetation in transitional areas in order to promote understory. Rabbit habitat in areas that have been overgrown can be enhanced by encouraging the growth of understory vegetation.

H2.5. Improve habitat by planting or encouraging native plant species. Plant native vegetation in areas that have been scarified or degraded.

H2.6. Create habitat by filling and restoring areas that have been dredged or altered. Mulch areas or regrade roads to restore and create habitat. Several areas are suitable for this type of restoration, such as habitat on the Torch Keys.

H3. Conduct research on marsh rabbit habitat and how it affects the rabbit's distribution and abundance. The decline of the marsh rabbit is attributed to the loss or degradation of its habitat. Understanding the relationships between the rabbit and its habitat will allow for better management of this species.

H3.1. Investigate how rabbits use different habitat components for survival (e.g., food, shelter, nesting, traveling).

H3.1.1. Conduct radiotelemetry on other subpopulations. Determine how rabbits, on Big Pine Key and other areas, utilize components of their habitat and which components are most limiting.

H3.1.2. Investigate the effect of habitat change. Determine how the rabbit's distribution and abundance is affected by increased habitat fragmentation, degradation, and hydrological changes.

H3.2. Determine an index of habitat fragmentation. The marsh rabbit inhabits a patchy landscape with very few contiguous habitat patches greater than 5 ha. Marsh rabbits have been able to survive because of the ability to disperse between populations.

H3.2.1. Investigate movement patterns and the spatial use of habitat to identify important core areas and corridors.

H3.2.2. Determine home range and minimum area required. Determine if home range estimates reflect the norm for the total population. Compare size of home range in fresh water habitat versus salt marsh habitat.

H3.2.3. **Determine if the amount and configuration of habitat is sufficient to support a stable or increasing population of Lower Keys marsh rabbits.**

H4. **Monitor the status of marsh rabbit habitat and examine ecological processes.** Conduct yearly monitoring evaluations of the marsh rabbit's habitat. Overlay habitat quality with GIS mapping of habitat locations, including what patches are being altered or lost each year. Use GIS to update the loss or change of habitat from residential or commercial construction.

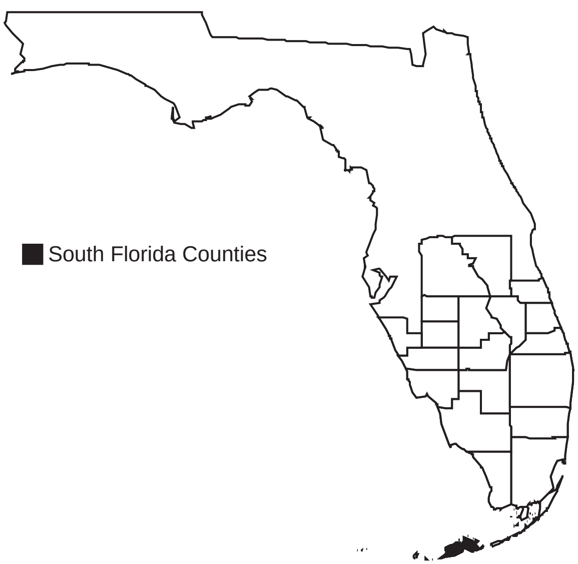
H5. **Increase public awareness of Lower Keys marsh rabbit habitat and instill stewardship.** Conduct workshops with the public to inform private land owners on appropriate management practices to preserve marsh rabbit habitat. Encourage private land owners to remove exotics, maintain natural hydrology, refrain from mowing rabbit habitat, and restore disturbed areas. Prepare literature with information regarding the Lower Keys marsh rabbit's habitat and ways to protect it.

Rice Rat

Oryzomys palustris natator

Federal Status:	**Endangered (April 30, 1991)**
Critical Habitat:	**Designated (Sept. 1993)**
Florida Status:	**Endangered**
Recovery Plan Status:	**Original (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. Distribution of the silver rice rat; this species is endemic only to the Florida Keys .



The rice rat, or silver rice rat as it is commonly called, is a small wetland rodent adapted to the unique island habitats of the Lower Keys, Florida. The silver rice rat differs from the more common marsh rice rat by its rarity, larger body size, lower fecundity, and larger home range size. Populations of these rice rats are found at extremely low densities on 12 islands in the Lower Keys and were listed as endangered primarily because their wetland habitat had been destroyed by residential and commercial construction activities. With a small population size and restricted geographic range, rice rats in the Florida Keys are greatly impacted by loss of habitat. Dredge and fill activities and other habitat alterations reduce the likelihood this species can persist.

This account represents the recovery plan for the rice rat in the Florida Keys.

Description

The rice rat in the Lower Keys, also known as the silver rice rat, was described as a full species (Spitzer and Lazell 1978) based on two specimens trapped in a freshwater marsh on Cudjoe Key in 1973.

This rice rat externally resembles other marsh rice rats in general form, being a medium-sized, semi-aquatic, generalized rat. However, the silver rice rat is distinct in having no tufts of digital bristles projecting beyond the ends of the median claws in the hind foot, by silver-gray pelage coloring laterally, and by a narrow, delicate skull with elongate nasal bones (Spitzer and Lazell 1978). Mitchell (1996) found adult weights of field-caught silver rice rats range between 14 to 136 g with males weighing generally more than females, while Forys *et al.* (1996) found weights ranging between 21 to 158 g, with the average weight of males not being statistically different than females, which is similar to findings for adult

Oryzomys palustris in Mississippi (Wolfe 1985). Adult silver rice rats tend to be larger than *Oryzomys palustris* in Virginia (Forys *et al.* 1996). External measurements (mm) of the holotype specimen (USNM 514995), an adult female, are: total length 251, tail 121, hind foot 32, ear 17 (Spitzer and Lazell 1978).

Taxonomy

Rice rats (*Oryzomys*) are New World rodents occurring from the southeastern U.S. to Mexico southward through Central America to northern South America and on some islands in the Galapagos and Caribbean. *Oryzomys* is in the order Rodentia and family Muridae with more than five subgenera and a dozen subspecies existing in North and Central America. The marsh rice rat (*Oryzomys palustris*) was first discovered by Bachman and described by Harlan in 1837, with a further taxonomic revision by Goldman in 1918 (Humphrey and Setzer 1989).

The silver rice rat was first described as a separate species by Spitzer and Lazell (1978) and named for its silvery color. The type specimen was collected in 1973 from a freshwater marsh on Cudjoe Key, Monroe County, Florida. The silver rice rat is similar to the *Oryzomys palustris* group with respect to some cranial characteristics, but is considered distinct based on its lack of digital bristle tufts projecting beyond the ends of median claws on the hind foot, large, wide sphenopalatine vacuities, long slender nasal bones, narrow skull, and silver-grey pelage (Goodyear 1991). Besides the distinct differences in skull characters and pelage, the silver rice rat is also different in morphological and color distinctions and ecological and behavioral differences (Goodyear 1991).

The taxonomic validity of this rice rat as a full species has been questioned and debated within the scientific community (Barbour and Humphrey 1982, Goodyear and Lazell 1986, Humphrey and Setzer 1989, Goodyear 1991, Humphrey 1992). The silver rice rat (*O. palustris natator* = *Oryzomys argentatus*) has been considered by some as an insular form of the more widely distributed marsh rice rat (Humphrey and Barbour 1979, Barbour and Humphrey 1982, Wolfe 1982, Humphrey and Setzer 1989, Humphrey 1992), while others view it as a separate species (Spitzer and Lazell 1978, Goodyear and Lazell 1986, Goodyear 1991). The current taxonomic status of the silver rice rat remains unresolved. For purposes of this account, however, the current FWS list of endangered and threatened wildlife and plants (50 CFR 17.11 and 17.12) considers it as *O. palustris natator*. A detailed discussion of the history of silver rice rat taxonomy and listing actions is provided in the Federal Register (FWS 1991, 1993).

Distribution

The silver rice rat is known to occur on 12 islands (Figure 1) in the Lower Keys: Little Pine, Howe, Water, Middle Torch, Big Torch, Summerland, Raccoon, Johnston, Cudjoe, Upper Sugarloaf, Lower Sugarloaf, and

Rice rat. *Original photograph by Beth Forys.*

Saddlebunch Keys (Vessey *et al.* 1976, Goodyear 1984, 1987; Wolfe 1986, 1987 Goodyear 1992, Forys *et al.* 1996, Mitchell 1996). Populations are widely distributed and occur at extremely low densities. Based on the availability of suitable habitat and proximity to existing populations, the silver rice rat may also occur on several other islands in the Lower Keys, including but not limited to Big Pine, No Name, Cudjoe, Little Torch, Ramrod, and Boca Chica Keys, although recent survey efforts have failed to detect their presence (Forys *et al.* 1996, Mitchell 1996).

Rice rats were not found on Big Pine Key and Boca Chica Key despite the availability of large areas of apparently suitable habitat (Goodyear 1987, Wolfe 1987). Because of the semi-aquatic habits of the silver rice rat, the extensive areas it traverses, and fluctuations in small mammal populations, it is reasonable to assume that Boca Chica Key and Big Pine Key could be colonized from existing populations on adjacent islands, and that they may support populations of silver rice rats at least periodically. Black rats and raccoons on both Boca Chica Key and Big Pine Key could be factors in the absence of silver rice rats from these islands (Goodyear 1983). Islands such as the Contents, Muds, Sawyer, and the Snipe Keys are large pristine islands but do not contain the three vegetative communities used by rice rats nor sufficient freshwater sources (Goodyear 1987, Forys *et al.* 1996, Mitchell 1996). Silver rice rats are not found in the Middle or Upper Keys presumably because of the lack of suitable habitat (Goodyear 1987).

Habitat

The first two silver rice rats captured on Cudjoe Key were in a freshwater marsh vegetated mainly with sawgrass and cattails (Spitzer and Lazell 1978). Since those original captures, however, silver rice rats were not found again in freshwater marshes until 1996 (Mitchell 1996), but instead were only found in salt marsh habitats (Goodyear 1987). In a recent radio telemetry and capture study, silver rice rats were found using freshwater wetlands (freshwater marsh, hardwoods, and pinelands) that are adjacent to saltmarshes on Cudjoe and Big Torch Key (Mitchell 1996). Freshwater marshes are primarily a Lower Keys habitat found in depressions in the interior of only a few islands and are dominated by sawgrass (*Cladium jamiacense*), seashore dropseed (*Sporobolus virginicus*), and cordgrass (*Spartina* spp.). During the wet season these areas can accumulate standing water. Silver rice rats depend on both freshwater wetlands and saline wetland habitat, especially large areas of adjacent or contiguous habitat.

Silver rice rats typically use three zones that are delineated by their salinity and topography: (1) low intertidal areas, (2) salt marsh flooded by spring or storm tides, and (3) buttonwood transitional areas that are slightly more elevated and only flooded by storm tides (Goodyear 1987). The low intertidal area is comprised primarily of red and black mangroves with white mangroves, buttonwoods, woody glasswort, saltwort, and Key grass found on higher elevated areas. These areas are used by silver rice rats mainly during nocturnal activity periods and also for foraging, moving between habitats, and nesting. The low salt marsh area consists of the grasses *Distichilis* and *Sporobolus*, interspersed with sea ox-eye, white and black mangrove, and buttonwood, in addition to depression areas that contain saltwort, black mangrove, and glasswort. Silver rice rats use this zone mainly for foraging and nesting. The buttonwood transitional salt marsh area is at a higher elevation than other salt marsh habitats, contains a denser coverage of *Distichilis*, *Sporobolus*, and sea ox-eye, and is used for foraging and nesting (Goodyear 1987).

In general, rice rats use mangrove habitats primarily for foraging, while higher-elevation salt marshes are used for nesting and foraging (Forys *et al.* 1996). Silver rice rats tend to use various vegetation zones during different seasons: during the dry season (March-April and December-January) they use low marsh more, while in the wet season, mid- and higher-elevation salt marsh habitats are used more (Forys *et al.* 1996). *Oryzomys palustris* in the Everglades displays a fugitive behavior of moving from one patch of habitat to another in response to seasonal fluctuations in water levels (Smith and Vrieze 1979). Silver rice rats may also exhibit such an adaptive behavior in response to seasonal changes in water levels or food availability. Silver rice rats occur at comparable densities in both scrub and fringe mangrove communities, although microhabitat data suggests that this species spends most of its time in red and black mangroves (Forys *et al.* 1996).

The rice rat requires large, contiguous areas of mangrove and salt marsh habitats to sustain viable populations. Forys *et al.* (1996) trapped individual rice rats in areas of very sparse residential development, and suggested that marshes in proximity to human impacts are still capable of supporting silver rice rats. However, development in or immediately adjacent to silver rice rat habitat could adversely affect the survival and recovery of the species. These areas include all mangrove habitat within 1 km of known silver rice rat habitat. The 1 km distance would serve as a buffer from the majority of adverse effects resulting from residential and commercial construction projects.

The amount of silver rice rat habitat available is based on the vegetation type included. There are approximately 3,575 ha of fringe and scrub mangrove habitat with silver rice rats present, with a total amount of 5,542 ha of habitat available (occupied and unoccupied) (Forys *et al.* 1996). When other vegetation types (*e.g.*, freshwater marsh, hardwoods, pinelands and saltmarsh) used by the silver rice rat are included, the amount of occupied habitat is 5,644 ha (Mitchell 1996).

Critical Habitat

Critical habitat for the silver rice rat includes areas containing contiguous mangrove swamps, salt marsh flats, and buttonwood transition vegetation. These vegetational types, as well as cattail marshes, contain the primary constituent elements in critical habitat types (50 CFR 17.95).

The major constituent elements of this critical habitat that require special management considerations or protection are: mangrove swamps containing red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and buttonwood (*Conocarpus erectus*); salt marshes, swales, and adjacent transitional wetlands containing saltwort (*Batis maritima*), perennial glasswort (*Salicornia virginica*), saltgrass (*Distichlis spicata*), sea ox-eye (*Borrichia frutescens*), Key grass (*Monanthochloe littoralis*), and coastal dropseed (*Sporobolus virginicus*); and freshwater marshes containing cattails (*Typha domingensis*), sawgrass (*Cladium jamaicense*), and cordgrass (*Spartina* spp.).

The original critical habitat proposal included nine keys totaling 4,075 ha on the following islands: Little Pine Key, Water Keys (north of Big Torch, but not the Water Key west of Little Pine Key), Big Torch Key, Middle Torch Key, Raccoon Key, Summerland Key north of U.S. Highway 1, Cudjoe Key, Johnston Key, and the Saddlebunch Keys south of U.S. Highway 1, but not including lands in Township 67S, Range 27E, Section 8, and the northern 1/5 of Section 17. All lands and waters above mean low tide are included in this designation. Approximately 2,026 ha of the proposed critical habitat was within NWR boundaries. After a scientific and economic analysis, the FWS concluded there was no justification for excluding areas from the proposed critical habitat based on economic reasons, although two areas should be excluded from critical habitat designation because they no longer supported significant silver rice rat habitat. These two areas included 418 ha with 186 ha on Summerland Key and 232 ha on Cudjoe Key. Both areas are located south of U.S. Highway 1, are extensively urbanized, and hence have little remaining suitable habitat left for the silver rice rat.

Behavior

Silver rice rats are primarily nocturnal and have large home ranges. Spitzer (1983) estimated the home range of a male silver rice rat on Summerland Key to be 23 ha. This animal regularly traveled long distances during a single activity; in one night it traveled 1 km. Forys *et al.* (1996) observed rice rats undertaking movements of 325 m in one day. In a recent telemetry study, Mitchell (1996) found home ranges of 2.0 to 8.5 ha for females and 3.4 to 11.0

ha for males, which is much larger than *O. palustris* ranges of 0.33 for females and 0.25 ha for males in the Everglades (Birkenholz 1963). Overall, there is no estimate on the average dispersal distance for silver rice rats; however, their home range size is estimated to be much larger than is known for other rice rats by 5 to 10 times as large (Spitzer 1983, Mitchell 1996). The need for a large home range may be a behavioral response to a limited supply of food or freshwater resources (Forys *et al.* 1996).

Five types of locomotory movements are evident in silver rice rats: walking, running, swimming, climbing, and jumping (Spitzer 1983). Silver rice rats frequently climb through vegetation and use their tails for additional support when climbing, but rarely do they climb higher than one meter above the ground (Spitzer 1983, Mitchell 1996). Silver rice rats dive and swim on the surface and underwater and swim more frequently and faster than cotton rats (*Sigmodon hispidus*). Self-grooming behaviors to maintain the water repellent nature of their pelage are displayed by *Oryzomys palustris* (Wolfe 1982) and are believed to be done by silver rice rats as well.

Reproduction

Silver rice rats are found at extremely low densities throughout their range: 2.29/ha for silver rice rat compared to 18.07/ha for *O. palustris* in the Everglades and are significantly lower than for marsh rice rats elsewhere (Smith and Vrieze 1979, Wolfe 1985, Forys *et al*. 1996). The largest populations of silver rice rats occur on Big Torch, Cudjoe, and Raccoon Keys (Forys *et al*. 1996, Mitchell 1996). Population variations between years were evident in *O. palustris* in Mississippi (Wolfe 1985), but not in Everglades rice rat populations (Smith and Vrieze 1979). Yearly population trends are not known for the silver rice rat, but populations of *O. palustris* have been found to be lower in the early spring (2 to 5 per ha) with a gradual increase to peak levels in late autumn and early winter (13 to 25 per ha) (Wolfe 1985). Silver rice rats appear to have a fairly high survivorship as compared to *O. palustris* (Forys *et al*. 1996).

Like some *O. palustris* in lower latitudes, reproduction in silver rice rats can occur throughout the year and is influenced by a variety of ecological factors (Wolfe 1982). Climatic conditions and photoperiod in the Lower Keys are less variable than in higher latitudes and may not restrict rice rats to one litter a year. Rather, the milder conditions may allow rice rats to produce several litters each year (Edmonds and Stetson 1993). A reproductive peak in silver rice rats occurs after the wet season, from September to October (Forys *et al*. 1996), although Spitzer (1983) trapped a pregnant female silver rice rat during winter. Similar to *O. palustris*, the gestation period for silver rice rats is 21 to 28 days, with litter size ranging three to five. The number of litters produced each year is not known for silver rice rats.

Forys *et al*. (1996) found that juvenile rice rats comprised only 14 percent of the total number of individuals captured in their study. This number is significantly lower than results from studies of *O. palustris* in Mississippi and Louisiana (Negus *et al*. 1961, Wolfe 1985). The number of juveniles present in the population is usually higher where higher numbers of females are present (Mitchell 1996). Although survivorship of silver rice rats in the Florida Keys was found to be relatively high, the low proportion of juveniles in this population is indicative of a low reproductive rate which may in turn, be limited by the availability of food and freshwater resources (Forys *et al*. 1996).

A sex ratio at weaning of 1:1 has been reported for *O. palustris* (Wolfe 1982). Other studies have documented a ratio of 272 males:215 females in Mississippi (Wolfe 1985) and 23 males:16 females in a central Florida population (Birkenholz 1963). Wolfe (1985) attributed the higher number of males to a lower survival rate for females or decreased trappability of adult females, especially when they are pregnant or caring for their young. Forys *et al*. (1996) documented a ratio of 66 males:19 females in silver rice rat populations caught during grid trapping, as did Mitchell (1996) during line trappings (68 percent were male). Social behavior is not apparent, but copulatory behavior of the silver rice rat is similar to *O. palustris*.

Silver rice rats construct simple spherical nests that are 15 cm in diameter consisting primarily of *Distichilis* or *Sporobolus* grasses, although other materials such as buttonwood, mangrove, or saltwort may also be used in nest construction (Spitzer 1983). Nests are usually built on the ground or slightly elevated in grasses. Spitzer (1983) found that a single male silver rice rat on Summerland Key alternately used 16 different nest sites, often quite distant from each other, over a one-month period.

Foraging

The congener, *O. palustris* is predominantly omnivorous, but preferably carnivorous, feeding mainly on insects, snails, and crabs, and occasionally on clams, fishes, baby turtles, carcasses of muskrats, deer mice, sparrows, and eggs and young of marsh wrens (Negus *et al.* 1961, see Wolfe 1982 for review). These marsh rice rats also eat seeds and parts from plants such as *Spartina* spp., *Tripsacum* spp. and *Elymus* spp. (Wolfe 1982).

Similarly, silver rice rats prefer to eat animal material but in general, they are omnivorous (Spitzer 1983, Goodyear 1992). Silver rice rats forage along the edges of flooded areas or in recently flooded areas on a variety of animal and plant material, including invertebrates such as isopods (*Ligia* sp.), snails (*Melampus* sp. and *Cerithidea* sp.), and crabs (*Uca* sp.) and seeds of saltwort, coconut palm (*Cocos nucifera*), and buttonwood, *Rhizophora propagules*, and germinating *Avicennia* seedlings (Spitzer 1983). Silver rice rats do not appear to hoard food, but food has been found in their nests suggesting they may carry the food back to eat in their nest (Wolfe 1982, Spitzer 1983).

Seasonal variation in food consumption has not been documented for the silver rice rat, but is evident in the foraging habits of *O. palustris* (Negus *et al*. 1961); the dietary habits of silver rice rats are not expected to be affected as much since seasonal changes are not as dramatic in the Lower Keys as they are in higher latitudes. The availability of freshwater is important to the survival of silver rice rats since they cannot effectively concentrate urine to meet their metabolic needs (Dunson and Lazell 1982, Goodyear 1987). They depend on several sources of fresh water including freshwater lenses, water droplets on vegetation, and pools of water collected in tree holes (Spitzer 1983, Goodyear 1987).

Relationship To Other Species

Species that live in island habitats like the silver rice rat are more susceptible to the negative effects of habitat loss, predation, competition, diseases, and natural catastrophes and therefore are more vulnerable to extinction (MacArthur and Wilson 1963, 1967). The integrity of the silver rice rat's habitat is important to its continued existence and to the other species that share its habitat. A balance between the needs of these species is essential for maintaining the relationships of these species and ensuring the survival of the silver rice rat. The Lower Keys marsh rabbit (*Sylvilagus palustris hefneri*) and silver rice rat utilize similar vegetation in salt marshes (*e.g. Sporobolus virginicus*), transitional areas *(e.g., Conocarpus erectus*), and freshwater marshes (*e.g*., *Cladium jamaicense*). Silver rice rats also use many of the same habitats as the endangered Key deer (*Odocoileus virginianus clavium*).

Silver rice rats coexist with several other small mammals, which may be potential competitors, such as the black rat (*Rattus rattus*) and Key cotton rat (*Sigmodon hispidus exsputus*). The abundance of these rodents may influence the relative abundance of the silver rice rat (Kincaid and Cameron 1982, Wolfe 1982, Forys *et al.* 1996, Mitchell 1996). Both the silver rice rat and black rat have similar food items and habitat preferences. *Oryzomys palustris* diet overlaps with sympatric populations of hispid cotton rat (*Sigmodon hispidus*) and fulvous harvest mouse (*Reithrodontomys fulvescens*). There is evidence of habitat distinction between these species because each species uses different subhabitats to feed in during different times of the year (Kincaid and Cameron 1982, Goodyear 1992).

Rhesus monkeys or macaques (*Cercopithecus mulattus*) on Raccoon Key heavily forage on the vegetation (especially mangrove foliage) and degrade silver rice rat habitat. Owls, hawks, snakes, raccoons, and foxes are known predators on *O. palustris* (Wolfe 1982), and are also believed to be predators of the silver rice rat (Spitzer 1983). Feral cats and red fire ants (*Solenopsis invicta*) are also considered to be a threat to the silver rice rat (Forys *et al.* 1996).

Several parasites, such as trematodes, mites, helminths, and ticks have been reported on the congener *O. palustris* (Layne 1967, Kinsella 1974, Wolfe 1982) and probably occur on the silver rice rat as well. The effects of these parasites on their host is not well known, but is believed to be minimal, except during high periods of environmental stress where they may negatively influence the host more.

Status and Trends

Federal protection for the silver rice rat first became an issue in 1980, when the FWS was petitioned by the Center for Action on Endangered Species to list this species as endangered and provide it full protection under the Endangered Species Act. Between 1982 and 1988, the FWS published annual reports stating that a listing proposal for the silver rice rat was "warranted but precluded" by other listing actions of higher priority. During this time, the FWS considered the silver rice rat a full species. In 1988, the FWS announced it was no longer considering the silver rice rat for protection under the ESA based on a 1986 report that rebutted the animal's identity as a separate species. In response to that, the Sierra Club Legal Defense Fund, Inc., filed a lawsuit challenging the FWS's decision not to proceed with listing the silver rice rat and stated the FWS did not consider listing the silver rice rat as a "distinct vertebrate population." The silver rice rat was then placed in the "warranted but precluded" category and a review period for listing this species as a vertebrate population was announced. After additional review and research, the FWS announced its proposal to list the silver rice rat as an endangered species in 1990.

The silver rice rat was listed as an endangered species on April 30, 1991 (56 Federal Register 19814). At that time, the silver rice rat was extirpated from one key where it formerly occurred and was believed to be extirpated from two additional keys. The silver rice rat was listed as endangered because its wetland habitat had been destroyed by residential and commercial construction; because of predation, competition, and habitat modification from various introduced mammals and because its low populations make it more susceptible to reduced genetic variability. In the final rule listing the silver rice rat as an endangered species, the FWS determined that critical habitat designation was not prudent. A reexamination of potential threats to the silver rice rat led the FWS to conclude the illicit takings arising from publication of critical habitat would not be so serious as to render designation of critical habitat imprudent. Critical habitat was then designated on September 30, 1993. Some areas have been excluded from critical habitat designation based on comments received on the proposed rule.

The silver rice rat has a narrow geographic range and a small local population size, both of which make it more vulnerable to extinction. After its discovery, surveys conducted the following 5 years failed to find any additional specimens in freshwater wetlands--the type locality. Surveys conducted in 1978-79 also failed to find any silver rice rats and this species was believed to be extirpated in the type locality and on nearby islands (Barbour and Humphrey 1982). Shortly after that study was completed, the identity of specimens collected in 1976 on Raccoon Key was examined and confirmed to be silver rice rats (Barbour and Humphrey 1982, Wolfe 1987), indicating this species was not extinct and occurred on islands not previously recorded. At the time of their Federal listing in 1991, silver rice rats were known to exist on eight islands including Little Pine, Water, Big Torch, Middle Torch, Raccoon, Summerland, Johnston, and Saddlebunch Keys. During 1987-88, Goodyear (1993) captured rice rats on Big Torch, Middle Torch, Saddlebunch, and Summerland Keys. In addition to the original eight islands, the most recent status reports from 1996 report four other islands also support populations of silver rice rats including Howe, Cudjoe, Upper Sugarloaf, and Lower Sugarloaf Keys (Forys *et al.* 1996, Mitchell 1996). It was not until 1996 that silver rice rats were located again in the type locality of freshwater marshes. Both adults and juveniles were surveyed in freshwater marshes on Cudjoe and Big Torch keys (Mitchell 1996). Silver rice rats have not been found on No Name, Big Pine or Ramrod keys although suitable habitat is present (Forys *et al.* 1996, Mitchell 1996).

In general, islands located on the periphery of the silver rice rat's range do not support populations although suitable habitat is present, whereas islands in the middle or interior of the range all support populations (Forys *et al.* 1996). Populations on the periphery of a species' range are considered more susceptible to perturbations because they are less stable and also tend to have lower numbers.

Considering the limited range, habitat specificity, and low population density of the silver rice rat, it is unlikely that this species or its habitat was ever extremely abundant in the Lower keys, at least in recent times. Silver rice rats occur at extremely low densities on most islands sampled, with the exceptions of Raccoon and Johnston Keys, where populations occur at densities more typical of rice rats from mainland locations. Population trends can only be inferred from the limited trapping data available from Raccoon, Saddlebunch, Middle Torch, Big Torch, and Summerland keys collected by various researchers over the years (Vessey *et al.* 1976; Goodyear 1987, 1993; Wolfe 1986, 1987). Based on these surveys, silver rice rat population levels remained at low numbers throughout the period 1981-1987 on those islands where repeat trapping was conducted.

Populations have decreased at four of five saline wetland sites originally surveyed in the 1980s: Johnston, Middle Torch, Saddlebunch, and Summerland keys (Mitchell 1996). In 1984, Johnston Key had 0.83 individuals per ha and by 1996 the population declined to zero. Estimated population sizes for silver rice rats from nine islands range from 0 to 16 individuals present, with an average of approximately five per island (Mitchell 1996).

Threats

Residential and commercial activities, recent habitat loss, and the introduction or increase of non-native predators and competitors have been the contributing factors to the endangered status of the rice rat (Forys *et al*. 1996). Limited food or freshwater resources may also be contributing to the rarity of the rice rat. Rice rats have very large home ranges, which may indicate a low supply of food or water and the need to travel further distances to find these important resources. As a result of limited resources, silver rice rats are believed to have a low reproductive rate as evident from the low number of juveniles in population studies (Forys *et al*. 1996).

The main threat to the silver rice rat is degradation and loss of habitat due to urbanization. Construction activities typically result in the direct loss of habitat as well as secondary effects that extend into surrounding habitats. Related secondary effects include habitat fragmentation and an increase in the densities of black rats and domestic cats. Cats are predators of silver rice rats and there is evidence of interspecific competition between silver rice rats and black rats (Goodyear 1992, Forys *et al*. 1996).

Secondary threats resulting from human encroachment on silver rice rat habitat have been difficult to quantify because of the low population densities of this species throughout the Lower Keys. These threats include predation and competition from domestic and exotic animals, contaminants, and dumping. Domestic cats are abundant throughout the Lower Keys, and forage in the higher-elevation salt marsh habitats also used by the silver rice rat. Because rodents are often the most abundant items in a domestic cat's diet (Eberhard 1954, Churcher and Lawton 1989), the potential for domestic cats to prey upon silver rice rats is high. Given the low densities of silver rice rats throughout the Lower Keys, any increase in cat predation would pose a direct effect on the species' survival.

Human habitation and solid waste accumulation encourages establishment of black rats. Goodyear (1993) has shown that silver rice rats and black rats exhibit extensive niche overlap, and that islands with high densities of black rats support few silver rice rats. Goodyear's data suggest that black rats may outcompete silver rice rats for food and habitat resources; in areas of suitable habitat, the occurrence of black rats may preclude the survival of silver rice rats. Black rats may also prey upon newborn silver rice rats. Pesticides used to control black rats also pose a threat to the silver rice rat (FWS 1993). Exotic fire ants have been documented to cause declines in populations of small mammals in Texas (Killion *et al*. 1990, Killion and Grant 1993) and may cause direct mortality of juvenile silver rice rats.

In some areas, the natural hydrologic cycles of silver rice rat wetland habitat has been altered by the construction of fill roads, borrow pits, and mosquito ditches. As a result, the vegetative communities change and disrupt behaviors such as nesting, movement, and foraging. These alterations also encourage invasion by exotic vegetation, which may reduce habitat quality.

The small, isolated, and widely distributed populations of silver rice rats are also vulnerable to extinction through random demographic fluctuations, loss of genetic variability caused by small population size, and stochastic environmental events (*e.g.,* hurricanes).

Management

The types of habitat (primarily salt marsh and mangrove wetlands) silver rice rats use require Federal, State, and Monroe County permits in order to conduct residential or commercial construction. Although Federal and State regulations provide for the consideration of impacts of dredge and fill operations on endangered species, permits nevertheless are issued for construction in silver rice rat habitat on a regular basis. Additional protection for this species is provided through the designation and preservation of critical habitat. Critical habitat only affects Federal agency actions and does not apply to private, local, or State government activities that are not subject to Federal authorization or funding.

Federal agencies affected by the designation of silver rice rat critical habitat include the FWS' National Key Deer Refuge (NKDR), COE, and FEMA (58 FR 46031). Seven of the nine keys in designated critical habitat are within the NKDR boundaries. Although the NKDR is primarily managed for Key deer, the habitat requirements and biological needs of the species do not conflict. Silver rice rat habitat on NKDR and Great White Heron NWR is being managed by refuge staff.

In addition, the two tracts on Sugarloaf Key where the species occurs is in the process of being transferred to the NKDR to provide additional protection. Both the permitting program of the COE and the administration of flood insurance by FEMA are affected by the silver rice rat's critical habitat designation. All Federal agencies are required to insure that their actions do not result in the destruction or adverse modification of critical habitat for the silver rice rat. Permitting actions that may affect the silver rice rat or areas within silver rice rat critical habitat require section 7 consultation with the FWS. Federal, State, and county agencies are currently working with Charles River Lab to minimize adverse effects at Raccoon Key, which may comprise the largest population of silver rice rats.

The persistence of the silver rice rat is dependent upon the amount of suitable habitat available. Some silver rice rats have been found to use areas with some residential construction nearby (Forys *et al.* 1996), but their long term persistence in these disturbed areas in not known. Much of the remaining wetland habitat suitable for rice rats is protected under local, State, and Federal law, but total protection in all areas is not assured. The presence of contiguous habitat has been suggested to be capable of supporting higher densities of *O. palustris,* and silver rice rats also require large areas of habitat (an average of 5.4 ha^2 of habitat required per rat) to persist. With the current limited amount of suitable habitat available, it is important to retain the integrity of the larger contiguous wetlands and prevent further fragmentation and destruction.

The GFC surveyed and monitored for silver rice rats in all occupied and unoccupied habitat. Suitable rice rat habitat includes habitat as identified in the survey by GFC (Forys *et al*. 1996) with a 500 m buffer around occupied habitat and all habitat on Raccoon and Water keys. At least 2,643 ha of suitable rat habitat are in private ownership and have the potential to be destroyed by construction activities. In a recent study of the population dynamics of the silver rice rat in suitable habitat throughout the Lower Keys, Forys *et al*. (1996) confirmed that this species still occurs at extremely low densities (mean = 2.29/ha during 24 trapping periods) and is extremely vulnerable to destruction of its habitat. Trapping and monitoring of this species was conducted in 1997 by the FWS and GFC with assistance from the Americorps program.

Literature Cited

Barbour, D.B., and S.R. Humphrey. 1982. Status of the silver rice rat *(Oryzomys argentatus*). Florida Scientist 45:112-116.

Birkenholz, D.E. 1963. Movement and displacement in the rice rat. Quarterly Journal Florida Academy of Sciences 26:269-274.

Churcher, P.B., and J.H. Lawton. 1989. Beware of well-fed felines. Natural History 7:40-46.

Dunson, W.D. and J.D. Lazell, Jr. 1982. Urinary concentrating capacity of *Rattus rattus* and other mammals from the Lower Florida Keys. Comparative Biochemistry and Physiology. 71(A):17-21.

Eberhard, T. 1954. Food habits of Pennsylvania house cats. Journal of Wildlife Management 18:284-286.

Edmonds, K.E. and M.H. Stetson. 1993. The rice rat *Oryzomys palustris* in a Delaware salt marsh: annual reproductive cycle. Canadian Journal of Zoology 71(7):1457-1460.

Forys, E.A., P.A. Frank, and R.S. Kautz. 1996. Recovery Actions for the Lower Keys marsh rabbit, silver rice rat, and Stock Island tree snail. Unpublished report to Florida Game and Fresh Water Fish Commission, Tallahassee, Florida, Cooperative Agreement No. 1448-0004-94-9164. Tallahassee, Florida.

Goodyear, N.C. 1984. Final report on the distribution, habitat, and status of the silver rice rat *Oryzomys argentatus*. Unpublished report prepared for the U.S. Fish and Wildlife Service under contract No. 14-16-0604-83-57. Jacksonville, Florida..

Goodyear, N.C. 1987. Distribution and habitat of the silver rice rat, *Oryzomys argentatus*. Journal of Mammalogy 68:692-695.

Goodyear, N.C. 1991. The taxonomic status of the silver rice rat, *Oryzomys argentatus*. Journal of Mammalogy 72:723-730.

Goodyear, N.C. 1992. Spatial overlap and dietary selection of native rice rats and exotic black rats. Journal of Mammalogy 73:186-200.

Goodyear, N.C. and J.D. Lazell, Jr. 1986. Relationships of the silver rice rat *Oryzomys argentatus* (Rodentia:Muridae). Postilla 198:1-7.

Humphrey, S.R. 1992. Lower Keys population of rice rat, *Oryzomys palustris natator* (in part). Pages 300-309 *in* S. R. Humphrey, ed., Rare and endangered biota of Florida, volume I. Mammals, University Press of Florida, Gainesville, Florida.

Humphrey, S.R., R.W. Repenning and H.W. Setzer. 1986. Status survey of five Florida mammals. Technical Report No. 22, Florida State Museum, Gainesville, Florida.

Humphrey, S.R. and H.W. Setzer. 1989. Geographic variation and taxonomic revision of rice rats (*Oryzomys palustris* and *O. argentatus*) of the United States. Journal of Mammalogy 70:557-570.

Killion, M.J., Grant, W.E., and S.B. Vinson. 1990. The influence of red imported fire ants (*Solenopsis invicta*) on small mammal habitat utilization. Pages 43-44 *in* M. E. Mispagel, ed., Proceedings of the 1990 imported fire ant conference, University of Georgia, Athens.

Killion, M. J., and W.E. Grant. 1993. Scale effects in assessing the impact of fire ants on small mammals. The Southwest Naturalist 38:393-396.

Kincaid, W.B. and G. N. Cameron. 1982. Dietary variation in three sympatric rodents on the Texas coastal prairie. Journal of Mammalogy 63(4):668-672.

Kinsella, J.M. 1974. Seasonal incidence of *Porocephalus crotali* (Pentastomida) in rice rats, *Oryzomys palustris*, from a Florida salt marsh. Journal of Medical Entomology 11(1):116.

Layne, J.N. 1967. Incidence of *Porocephalus crotali* (Pentastomida) in Florida mammals. Bulletin of Wildlife Disease Association 3:105-109.

MacArthur, R.H. and E.O. Wilson. 1963. An equilibrium theory of insular zoogeography. Evolution 17: 373:387.

MacArthur. R.H. and E.O. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, New Jersey.

Mitchell, N.C. 1996. Silver rice rat status. Draft final report to Florida Game and Fresh Water Fish Commission.

Negus, N.C., E. Gould, R.K. Chipman. 1961. Ecology of the rice rat, *Oryzomys palustris* (Harlan) on Breton Island, Gulf of Mexico, with a critique of social stress theory. Tulane Studies in Zoology 8:93-123.

Smith, A.T. and J.M. Vrieze. 1979. Population structure of Everglades rodents: response to a patchy environment. Journal of Mammalogy 60:778-794.

Spitzer, N.C., 1983. Aspects of the biology of the silver rice rat *Oryzomys argentatus*. M.S. Thesis, University of Rhode Island.

Spitzer, A.T. and J.D. Lazell, Jr. 1978. A new rice rat (genus *Oryzomys*) from Florida's Lower Keys. Journal of Mammalogy 59:787-792.

U.S. Fish and Wildlife Service [FWS]. 1991. Final Rule on the determination of endangered status for the Lower Keys population of the rice rat (silver rice rat). Federal Register 56(88):19809-19814.

U.S. Fish and Wildlife Service [FWS]. 1993. Final Rule on the designation of critical habitat for the silver rice rat. Federal Register 58(167):46030-46034.

Vessey, S.H., D.B. Meikle and S.R. Spaulding. 1976. Biological survey of Raccoon Key Florida: a preliminary report to the Charles River Breeding Labs, Wilmington, Massachusetts.

Wolfe, J.L. 1982. *Oryzomys palustris*. Mammalian Species 176:1-5.

Wolfe, J.L. 1985. Population ecology of the rice rat (*Oryzomys palustris*) in a coastal marsh. Journal of Zoology, London (A) 205:235-244.

Wolfe, J.L. 1986. Survey for silver rice rats (*Oryzomys argentatus*) on Raccoon Key, Monroe County, Florida, 12-15 December 1986. Unpublished report to Charles River Laboratory, Summerland Key.

Wolfe, J.L. 1987. A survey for the silver rice rat on U.S. Naval property in the Lower Florida Keys. Final Report to Naval Facilities Engineering Division, Southern Division, Naval Air Station; Boca Chica, Florida.

Recovery for the Rice Rat

Oryzomys palustris natator

Recovery Objective: RECLASSIFY to threatened.

Recovery Criteria

The silver rice rat has a narrow geographic range, small local population, low reproductive rate, and large home range, causing it to be more susceptible to extinction. Information from recent surveys indicates that the silver rice rat is rare and may be threatened with extirpation due to the loss, fragmentation, and degradation of its habitat and anthropogenic factors. Consequently, the objective is to reclassify the silver rice rat from *endangered* to *threatened* by protecting, managing, and restoring its habitat in the Lower Keys; increasing the size of its population; and establishing populations on the periphery of its range. This objective will be achieved when further loss, fragmentation, or degradation of suitable, occupied habitat in the Lower Keys has been prevented; when native and non-native nuisance species have been reduced by 80 percent; when all suitable, occupied habitat on priority acquisition lists for the Lower Keys is protected either through land acquisition or cooperative agreements; when the mangrove and saltmarsh habitat which forms the habitat for the silver rice rat are managed, restored, or rehabilitated on protected lands; when stable populations of the silver rice rat are distributed throughout its historic range; and when three additional, stable populations have been established along the periphery of the historic range of the silver rice rat. These populations will be considered demographically stable when they exhibit a stable age structure and have a rate of increase (*r*) equal to or greater than 0.0 as a 3-year running average for 6 years.

Species-level Recovery Actions

S1. Determine the distribution and status of the silver rice rat. Silver rice rat populations occur at extremely low densities on 12 islands in the Lower Keys, but additional surveys are still needed. Survey the current distribution of the silver rice rat and areas not previously recorded.

S1.1. Conduct presence/absence surveys to determine the status of rice rats and refine definition of range. Conduct presence/absence surveys on (a) the Big Pine Complex (including Big Pine, Little Pine, Annette, Porpoise, Water, Johnson, Horseshoe, and Howe Keys); (b) Saddlebunch Complex (Saddlebunch, Sugarloaf, Cudjoe, Big Torch, Howe); (c) Knockemdown complex; (d) Boca Chica and Big Coppit; and (e) Sawyer Key, Bud Key, and other backcountry islands.

S1.2. Survey for the presence/absence of black rats simultaneously with rice rat trapping. Interspecific competition between silver rice rats and black rats is evident (Goodyear 1992). Determine the number of black rats encountered during the rice rat surveys.

S1.3. **Maintain and improve the GIS database for silver rice rats.** Compile and maintain silver rice rat distribution information through the FWS and GFC Geographic Information System (GIS) databases.

S2. **Protect and enhance existing populations.**

S2.1. **Assign a biologist responsibility for implementing recovery actions for the threatened or endangered species of the Lower Keys.** Recovery actions for the silver rice rat will benefit the other threatened or endangered species in the Lower Florida Keys, including the Key deer, Lower Keys rabbit, Key tree-cactus and Stock Island tree snail. The number of actions that will be necessary to recover threatened or endangered species in the Lower Florida Keys will require the attention of a biologist or similarly-trained professional who is dedicated to specifically addressing the recovery needs of these species.

S2.2. **Conduct silver rice rat reintroductions from natural wild populations.**

S2.2.1. **Develop a standard protocol for conducting, monitoring, and evaluating all reintroduction, translocation, and supplementation efforts of silver rice rats using the IUCN/SSC Guidelines for Reintroductions.** Ensure release sites are free of threats, especially cats and feral hogs, prior to any release of rice rats.

S2.2.2. **Reintroduce silver rice rats on islands on the periphery of the silver rice rat's range.** Suitable habitat exists on the periphery of its range, but silver rice rats have not be found there recently.

S2.2.3. **Reintroduce silver rice rats on Little Pine Key or other remote backcountry islands.** There are 16.6 ha of suitable habitat available on Little Pine Key, which is within the FWS NWR boundaries. Reintroduce rice rats to this area and other suitable habitat.

S2.2.4. **Conduct reinforcement/supplementation of silver rice rats.** Translocate silver rice rats to existing populations on Sugarloaf and Big Pine Key in protected areas.

S2.3. **Utilize Federal regulatory mechanisms for protection.** Conduct section 7 consultations on Federal activities. Federal agencies whose actions may affect the rice rat include, COE, FEMA, Federal Housing Administration, and the Rural Electrification Administration. Determine jeopardy thresholds for the rice rat. Estimate and evaluate the type of Federal activities over the next 20 years that are likely to cause jeopardy and determine threshold levels for the total population. Coordinate with law enforcement to prevent take under section 9. Identify what activities could result in take of silver rice rats, such as habitat loss, cat predation, and vehicular traffic.

S2.4. **Provide information about silver rice rats to Federal, State, county, and city agencies. Distribute information regarding the presence of silver rice rats, their protection under the ESA, and ways to minimize impacts.** Non-federal agencies that may influence the silver rice rat include DEP, DCA, GFC, Department of Agriculture and Consumer Services, Monroe County Mosquito Control, Florida Keys Aqueduct Authority, and Monroe County Government.

S2.5. **Minimize and eliminate disturbance or mortality to the silver rice rat.** Silver rice rats are preyed upon by cats, black rats, raccoons, and fire ants. Predation by these species is increased near areas of urbanization. Eliminate or reduce mortality from these sources.

S2.5.1. Minimize cat predation on silver rice rats. Cats are known predators of silver rice rats. Establish a program to license domestic cats, implement leash laws, eliminate cat-feeding stations, implement spay and neuter programs, increase awareness through educational material, test diseases, and remove nuisance free-roaming cats.

S2.5.2. Minimize competition and predation by black rats. Black rats may be able to outcompete silver rice rats for food and habitat resources and prey on young rice rats. Eliminate black rat food shelters and sources. Enforce proper disposal of refuse around residences and in silver rice rat habitat.

S2.5.3. Minimize raccoon impacts on silver rice rats. Raccoon populations are unnaturally high in some areas of the Lower Keys. Raccoons are capable of killing both adult and juvenile rats. Eliminate supplemental food sources, feeding by humans, outdoor cat-feeding stations, and open dumpsters to reduce raccoon populations.

S2.5.4. Eliminate fire ant colonies near rice rat habitat. Fire ant colonies have been found in silver rice rat habitat. Fire ants can prey on young rats. Eliminate fire ant colonies in silver rice rat habitat.

S2.5.5. Control blatant killing and prevent poisoning. Rice rats may be intentionally killed by humans in an effort to get rid of black rats. Develop a program to educate homeowners to prevent blatant killing. Pesticides used to control black rats also pose a threat to the silver rice rat. Develop methods to reduce poisoning of silver rice rats from black rat poisoning.

S2.6. Investigate captive propagation options. Although captive propagation is not necessary for the silver rice rat at this time, guidelines and protocol should be established to guide captive propagation efforts, if deemed necessary. Any captive propagation efforts should be conducted in the Lower Keys in as similar to natural conditions as possible, continued only when necessary, and all propagation efforts should be strictly monitored. DOI guidelines should be followed.

S3. Conduct research on the life history and population ecology of the silver rice rat. Some baseline information on the life history of rice rats has been gathered (*e.g.,* Spitzer 1983, Goodyear 1992, Forys *et al*. 1996, Mitchell 1996). In order to develop reclassification criteria for the silver rice rat, additional information is still needed. Research should focus on gaining information that will assist in the recovery of the silver rice rat, specifically information lending to reclassification criteria.

S3.1. Determine if the total population size is large enough to prevent functional extinction and genetic extinction. Populations of silver rice rats are at much lower densities than the mainland rice rat populations. Estimated population sizes for silver rice rats from nine islands range from 0 to 16 individuals present, with an average of approximately five per island (Mitchell 1996). Determine the persistence of this species and the effective population size necessary to prevent inbreeding depression.

S3.2. Examine the effects of resource limitation on the persistence of the silver rice rat. The rarity of the silver rice rat appears to be attributed to resource limitation. A low proportion of juveniles in the population may be a result of limited food and freshwater resources. Investigate whether the persistence of the silver rice rat is being affected by limitations of resources (*e.g.,* food, water, shelter).

S3.3. **Examine factors that affect the abundance and distribution of the silver rice rat.** Investigate the relationships of silver rice rats to black rats, raccoons, fire ants, cats, or other animals that are nuisance competitors or predators and determine their effect on the silver rice rats' persistence.

S3.4. **Determine the number of subpopulations necessary to maintain a stable or increasing population.** The silver rice rat is known to occur on 12 islands. Populations have decreased at four of five saline wetland sites originally surveyed in the 1980s. Increases in habitat fragmentation will decrease the rats' ability to recolonize these areas.

S3.4.1. **Identify subpopulations vulnerable to extinction.** In 1984, Johnston Key had 0.83 individuals per ha and by 1996 the population declined to zero. Identify additional subpopulations vulnerable to habitat fragmentation, lost corridors, and reduced dispersal, and focus recovery actions on these sites.

S3.4.2. **Determine the necessary number of subpopulations and level of exchange that will enable the silver rice rat to persist for 100 years.**

S3.5. **Determine a stable age structure, sex ratio, and group size for the silver rice rat.** Investigate these parameters to determine what constitutes a stable population structure. Silver rice rats have a lower proportion of juveniles than mainland rice rat species, which may be affecting successful recruitment. The sex ratio is male biased, which may suggest female silver rice rats are more susceptible to predation or competition. Rice rats occur at very low densities, thus causing them to be more vulnerable to extinction.

S3.6. **Conduct a silver rice rat reintroduction and evaluate its effectiveness in increasing the rats' persistence.** Conduct a reintroduction and collect information on why this species exists in low numbers in some areas and is non-existent in other areas of suitable habitat. Determine factors for a stable population structure (*e.g.*, sex ratio, age structure, group size). Investigate these parameters to determine what constitutes a stable population structure.

S4. **Monitor the status of the silver rice rat.** Due to the rarity and secretive habits of the silver rice rat, population declines could go unnoticed unless a continuous monitoring program is established and implemented (Forys *et al*. 1996).

S4.1. **Develop methods to monitor demographic parameters.** Monitor sex ratios, age class structure, survivorship, home range size, age of dispersal, and dispersal distance of the silver rice rat.

S4.2. **Conduct long-term monitoring of the silver rice rat.** Monitor presence/absence and degree of abundance every year until the rat is recovered.

S5. **Increase public awareness and stewardship.** Develop educational materials and host public workshops to increase awareness about silver rice rats and instill a sense of stewardship for the protection of this endangered species.

S5.1 **Prepare educational material for the general public.** Distribute materials at visitor information centers and local chambers of commerce.

S5.2. **Develop and implement a cat, black rat, and raccoon control program.** Conduct workshops to educate residents about the necessity of controlling cat and raccoon predation on silver rice rats as well as minimizing the effects of black rats and fire ants.

S6. **Establish reclassification criteria.** Develop measurable reclassification criteria based on factors that result in a stable or increasing population, including total population size, number of subpopulations, sex ratio, age structure, habitat condition and availability, and level of threats. Evaluate and monitor the silver rice rat's status in relation to reclassification criteria.

Habitat-level Recovery Actions

H1. **Prevent degradation of existing habitat.** The main threat to the silver rice rat is degradation and loss of habitat due to urbanization. At least 2,643 hectares of suitable rat habitat are in private ownership and have the potential to be destroyed by construction activities.

H1.1. **Determine the status of rice rat habitat, including critical habitat**. Determine the condition of both occupied and unoccupied habitat of the silver rice rat. Characterize occupied habitat and determine why rats are present and characterize unoccupied habitat to determine why they are absent. Determine presence/absence of silver rice rats in freshwater marshes.

H1.2. **Acquire silver rice rat habitat.** Acquire habitat essential to the silver rice rat's survival. Develop a range-wide plan outlining priority acquisition areas for the silver rice rat that uses a reserve design approach to take such factors as connectivity, corridors, and fragmentation into consideration. Identify acquisition areas for occupied habitat (Priority 1) and unoccupied, suitable habitat (Priority 2).

H1.2.1. **Continue Federal acquisition efforts**. Continue acquisition efforts within the National Key Deer Refuge and Great White Heron NWR.

H1.2.2. **Support State, local, and non-government organizations' acquisition efforts.** Support efforts to acquire silver rice rat habitat by entities such as CARL, Monroe County Land Authority, Florida Community Trust, Florida Keys Land Trust, and The Nature Conservancy. Also support state conservation easements.

H1.3. **Protect and manage silver rice rat habitat.**

H1.3.1. **Protect rice rats on public lands.** Develop a habitat management plan that outlines priority habitat for acquisition and methods to protect, restore, and minimize impacts on rice rats and their habitat. Manage habitat for exotics, off-road vehicles, dumping, feral cats and other predators, and vehicular traffic.

H1.3.2. **Protect rice rats on private lands.** Protect rice rat populations on private land through acquisition, conservation easements or agreements, and education of land owners. Develop agreements (*e.g.*, Memorandum of Agreement) between the FWS and private land owners to minimize impacts such as feral cats and exotics.

H1.3.3. **Coordinate with Federal, State and Monroe County agencies and private entities to develop management actions to protect silver rice rat habitat.** Coordinate with these entities to ensure proposed construction activities that result in land clearing or alteration do not impact the silver rice rat and its habitat. Habitat loss through construction activities, resource limitation, and domestic and non-native predators and competitors are all factors contributing to the low numbers of the silver rice rat in the Lower Keys.

H1.3.4. **Establish and protect 500 m buffers around Priority 1 habitat.** The necessity for a 500 m protection buffer is based on the likelihood that human influences (*e.g.,* increased habitat fragmentation, cat predation) encroach upon and impact the silver rice rat.

H1.3.5. **Control free roaming horses on Cudjoe Key.** Control roaming horses on Cudjoe Key to minimize destruction of silver rice rat habitat.

H1.3.6. **Restrict access to silver rice rat habitat.** Restrict access to remote habitat areas to prevent damage caused by camping, homesteading, trash dumping, and vehicular traffic.

H1.3.7. **Eliminate exotic vegetation.** Remove exotic vegetation in silver rice rat habitat and in adjacent upland buffers.

H2. **Restore suitable silver rice rat habitat.** Habitat degradation from road construction, mosquito ditching, fill excavation, illegal solid waste disposal, and invasive exotic vegetation have altered natural hydrology patterns and facilitated the ability of exotic plants and animals to invade silver rice rat habitat. As a result, habitat quality and availability has been reduced or eliminated. Identify areas in greatest need of restoration and initiate restoration efforts.

H2.1. **Re-establish natural hydrology and water circulation in silver rice rat habitat.** Maintain and manage mosquito ditches so they do not impact rice rat habitat. The alteration of the natural hydrologic regime by dredge and fill activity alters nesting behaviors by causing rice rats to nest in nearby spoil areas. Water level variations influence where rice rats can forage. Implement hydrological restoration efforts in other areas of need.

H2.2. **Restore both occupied and unoccupied silver rice rat habitat.** Restore habitat that has been degraded by road construction, mosquito ditching, fill excavation, illegal solid waste disposal, and exotic vegetation to historic, natural conditions.

H2.3. **Improve water quality in freshwater sources and create freshwater sources.** The availability of fresh water is important to the survival of silver rice rats since they cannot effectively concentrate urine to meet their metabolic needs (Dunson and Lazell 1982, Goodyear 1987). Improve water quality in other freshwater areas or create additional sources.

H2.4. **Improve habitat by planting or encouraging native plant species.** Plant native vegetation in areas that have been scarified or degraded.

H2.5. **Create habitat by refilling and creating suitable habitat areas.** Restore or create habitat in areas that have been dredged or altered. Mulch areas or regrade roads to create habitat.

H3. **Conduct research on rice rat habitat and how it affects the rat's distribution and abundance.** Silver rice rats depend on both freshwater wetlands and saline wetland habitat, especially large areas of adjacent or contiguous habitat.

H3.1. **Investigate how rats use different habitat components for survival.** In general, mangrove habitats are used primarily for foraging, while higher-elevation salt marshes are used for nesting and foraging (Forys et al. 1996). Investigate other patterns of habitat use (*e.g.,* food, shelter, nesting, traveling).

H3.1.1. Investigate stable home range and minimum area requirements. Silver rice rat home ranges and average dispersal distances are much larger than rice rats in the Everglades. Conduct radio telemetry and other surveys on silver rice rats to determine the minimum habitat area requirements. Compare size of home range in freshwater habitat versus saltmarsh habitat.

H3.1.2. Investigate the effect of habitat change. Determine how the silver rice rat's distribution and abundance is affected by increased road mortality, habitat degradation, and hydrology changes.

H3.2. Determine an index of habitat fragmentation. The rice rat requires large, contiguous areas of mangrove and saltmarsh habitats to sustain viable populations. In general, islands located on the periphery of the silver rice rat's range do not support populations although suitable habitat is present. Fragmentation of habitat interferes with dispersal, foraging, and nesting. Areas of concern from urbanization include all mangrove habitat within 1 km of known silver rice rat habitat.

H3.2.1. Investigate movement patterns and the spatial use of habitat to identify important core areas and corridors.

H3.2.2. Determine if the amount and configuration of habitat is sufficient to support a stable or increasing population of silver rice rats.

H4. Monitor the status of silver rice rat habitat, particularly critical habitat, and examine ecological processes. Conduct yearly monitoring evaluations of the status of the rice rat's habitat. Overlay habitat quality with GIS mapping of habitat locations, including what patches are being altered or lost each year. Monitor the availability of rice rat habitat by updating the loss or change of habitat due to residential or commercial construction through GIS.

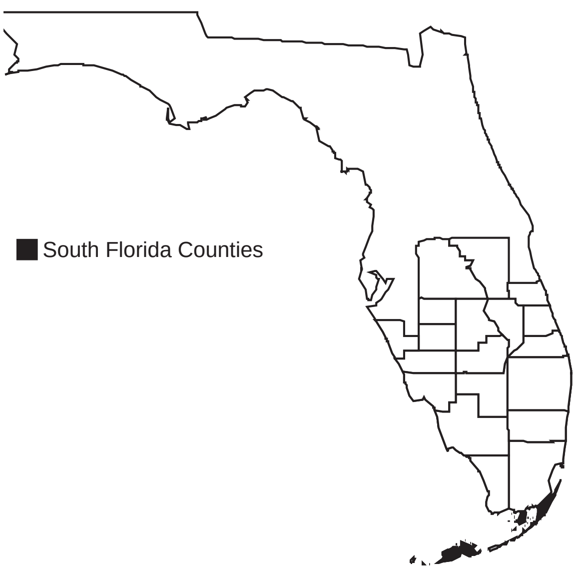
H5. Increase public awareness of silver rice rat habitat, especially critical habitat, and instill stewardship. Conduct workshops with the public to inform private land owners of appropriate management practices to preserve rice rat habitat. Encourage private land owners to remove exotics, maintain natural hydrology, refrain from destroying rice rat habitat, and restore disturbed areas. Prepare literature to provide information regarding the rice rat's habitat and its preservation and conservation.

Key Largo Woodrat

Neotoma floridana smalli

Federal Status:	**Endangered (August 31, 1984)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Original (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. Distribution of the Key Largo woodrat; this species is endemic only to Key Largo in the Florida Keys.



The Key Largo woodrat resides in tropical hardwood hammocks on Key Largo. This small endemic rodent once ranged throughout all of Key Largo, but today is limited to the northernmost portions. Known for its habit of building large stick houses, Key Largo woodrats depend heavily on the natural vegetation of the tropical hardwood hammocks to obtain material for constructing these houses. Although large portions of the remaining habitat are now in protection, there has been such a reduction in its total range and habitat that the future of this species remains in an endangered condition.

This account represents the range-wide recovery plan for the Key Largo woodrat.

Description

The color of the Key Largo woodrat is described as sepia or grey-brown above shading into cinnamon on the sides, with cream or white ventral coloration. The forefeet are white to the wrist and the hindfeet are primarily white to the ankles. The Key Largo woodrat has large ears, protuberant eyes, and a hairy tail. The head-and-body-length of the Key Largo woodrat ranges from 120 to 230 mm, their tail length ranges from 130 to 190 mm, and their hindfoot length ranges from 32 to 39 mm. Males, on average, weigh 258 g, while the females tend to be much smaller, weighing only 210 g (Hersh 1981).

Taxonomy

Key Largo woodrats are endemic to Key Largo, Monroe County, Florida and represent the southernmost subspecies of the eastern woodrat *(Neotoma floridana)*, which occurs widely in the eastern United States. Woodrat houses from Key Largo were first reported by Small (1932), after whom the subspecies is named, and later described in more detail by Schwartz (1952a). The Key Largo woodrat was distinguished as a separate subspecies by Sherman (1955) and later confirmed by Schwartz and Odum (1957).

Distribution

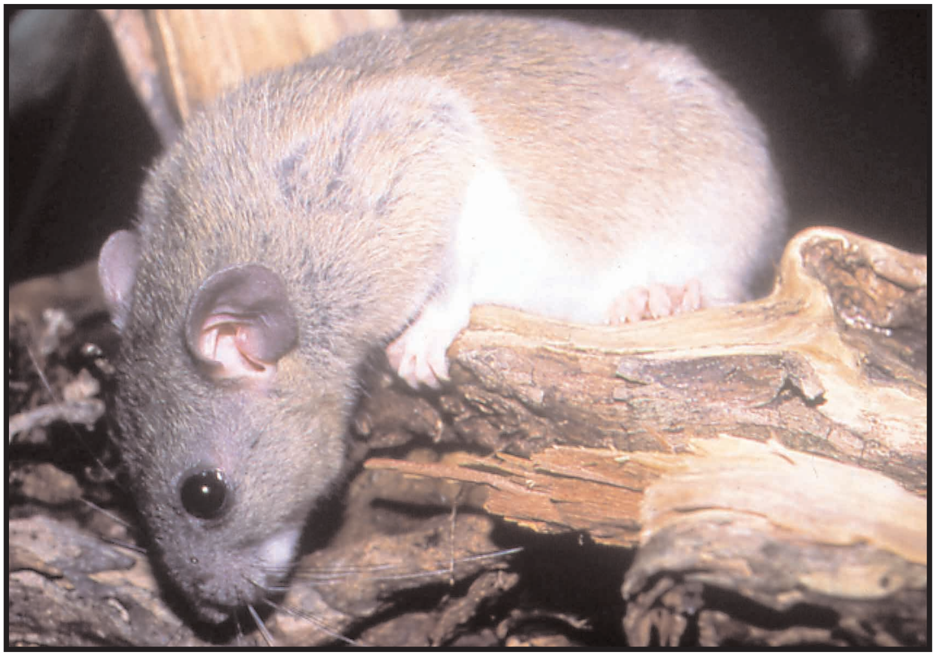
The Key Largo woodrat is restricted to the northern one-third of Key Largo and is separated from other United States woodrat populations by the southern third of the Florida peninsula (Hersh 1981) (Figure 1). Key Largo is the first and largest of the chain of keys or islands of the Florida Keys. Woodrats formerly occurred throughout uplands on all of Key Largo, but are now restricted to tropical hardwood hammocks on north Key Largo, representing about one-half of their original distribution (Brown 1978a, 1978b; Barbour and Humphrey 1982). Key Largo woodrats were once believed to be restricted to mature hammocks, but are now known to use a variety of microhabitats within tropical hardwood hammocks. Schwartz (1952b) captured woodrats near Rock Harbor in the south portion of Key Largo; however, attempts to collect it there in recent years have been unsuccessful (Barbour and Humphrey 1982). Goodyear (1985) also trapped woodrats slightly outside the range delineated by Barbour and Humphrey, documenting the species' presence in the Garden Cove area northeast of the U.S. Highway 1-C.R. 905 intersection. A population of Key Largo woodrats was introduced and established in 1970 on Lignumvitae Key (Brown and Williams 1971, Barbour and Humphrey 1982), but that population has since been extirpated.

Habitat

The Key Largo woodrat is a resident of tropical hardwood hammocks, the climax vegetation of upland areas in the Keys. Hammocks provide a shady, humid microclimate with less wind and temperature variation than more exposed habitats. The soils are poorly developed, typically consisting of shallow humus and litter overlying the limestone substrate, but may become deep in some forested areas.

Tropical hardwood hammocks on Key Largo include a greater number of tropical plants than hammocks on the mainland. Most of these tropical species are West Indian shrubs and trees with a variety of vine species from temperate North America and the West Indies. Tropical hardwood hammock canopy ranges from 9 to 12 m in height. Canopy trees include black ironwood (*Krugiodendron ferreum*), gumbo limbo (*Bursera simaruba*), Jamaican dogwood (*Piscidia piscipula*), mahogany (*Swietenia mahagani*), pigeon plum (*Cocoloba diversifolia*), poisonwood (*Metopium toxiferum*), strangler fig (*Ficus aurea*), and wild tamarind (*Lysoloma latisiliquum*). Tropical hardwood hammock understory contains torchwood (*Amyris elemifera*), milkbark (*Drypetes diversifolia*), wild coffee (*Psychotria undata*), marlberry (*Arisia escallonioides*), stoppers (*Eugenia* spp.), soldierwood (*Colubrina elliptica*), crabwood (*Gymnanthes lucida*), and velvetseed (*Guettarda scabra*). Ground cover contains yellowroot (*Morinda royoc*) and snowberry (*Chicocca parviflora*).

Key Largo woodrat.
Original photograph by Phil Frank.



Vegetative composition and structure influence density and distribution of woodrats by affecting their ability to find food resources, nest materials, and secure cover. The two most important aspects of woodrat habitat are materials for building stick nests and ample cover (Rainey 1956). Stick nests are used for resting, feeding, and breeding, and ground cover provides travel and escape routes.

Behavior

The Key Largo woodrat, like other members of the genus *Neotoma*, is known for its habit of building large stick nests (Brown 1978b). Woodrats typically excavate humus at the base of a tree to build their large stick nests, which can be 1.2 m in height and 2 to 2.5 m in diameter. The woodrat constructs its nest out of sticks, twigs, and various other objects 2.5 to 7.6 cm in diameter that are piled into mounds in an irregular fashion. They frequently build their nests against a stump, fallen tree, or boulder and may also use old sheds, abandoned cars, rock piles, and machinery as nest sites. Their nests have several entrances and a single, central nest chamber. Normally, only one adult Key Largo woodrat inhabits a nest and one animal may use several nests. Eastern woodrats continually maintain and repair their stick houses, which may be used by several generations and can be enlarged over time with increased use (Rainey 1956). Goodyear (1985) found that Key Largo woodrats occupied some areas on north Key Largo without obvious stick nests, although she noted that the animals had at least a few sticks placed at the entrance to rock crevices they used for their nests. During a 1995 joint GFC and FWS survey, stick nests were absent from North Key Largo but woodrats were present. It appears they are nesting below ground in solution holes and in the root systems of large trees (Frank *et al.* 1997).

Key Largo woodrats are probably similar to eastern woodrats that interact socially with some form of social hierarchy, and they may exhibit territorial defense behaviors at individual nest sites (Kinsey 1977). Defensive behaviors are usually dependent on age, sex, season of the year, and the availability of nest sites (Kinsey 1977). During breeding periods, females actively search for nest sites and defend their nests, while the males tend to be less aggressive. Males and young woodrats are more submissive and avoid encounters with territorial woodrats. During cooler periods, males may become more aggressive and competitive in their search for nest sites.

Similar to other woodrats, Key Largo woodrats have overlapping home ranges. Hersh (1978) reported that the mean home ranges of six male and four female Key Largo woodrats were about 2,370 m^2, which is comparable to the home range of other *Neotoma floridana* populations. Following dispersal, Key Largo woodrats are believed to remain within their new home range as is the case with eastern woodrats.

Key Largo woodrats appear to reach their highest densities in mature hardwood hammocks (FWS 1973, Brown 1978b, Barbour and Humphrey 1982, Hersh 1981). The woodrats will use younger hardwood hammocks and disturbed areas adjacent to mature hammocks, but occur at lower densities (Goodyear 1985, Humphrey 1988). Younger stands of hardwood hammock have significant evidence of woodrat nesting activity. Key Largo woodrats are active climbers, spending considerable amounts of time in trees (Goodyear 1985). Key Largo woodrats also seem to have definite trails and often use fallen trees to move over the forest floor (Goodyear 1985, Hersh 1978).

Reproduction

The Key Largo woodrat is capable of reproducing all year, although seasonal peaks in winter are evident (Hersh 1981). Key Largo woodrat litter sizes range from one to four young, with two most common. Female woodrats can produce two litters a year (Brown 1978b). Sex ratio favors 1.2 : 1 male to female (Hersh 1981). Both sexes require about 5 months to reach sexual maturity (Hersh 1981). The life expectancy of the Key Largo woodrat is unknown, but is probably similar to other subspecies of *Neotoma floridana,* which may live for 3 years but probably average less than 1 year (Fitch and Rainey 1956, Goertz 1970).

An alteration in food availability can result in a higher mortality and reduced growth rate of nestlings and may produce a sexual bias in growth and mortality that favors female nestlings. McClure (1981) found this brood reduction strategy for eastern woodrats was an adaptative response to limited food resources, where Sikes (1995) did not find any sex bias behaviors, but instead found a reduction in fitness of large litters whose mothers experience limited food availability. It is likely that eastern woodrat mothers have the ability to assess resource conditions and respond in a way that maximizes their own fitness. Key Largo woodrats may be capable of responding to resource changes in a similar way.

Key Largo woodrat densities on north Key Largo have been variously estimated at 1.2 animals/ha (Brown 1978b), 2.2/ha (Barbour and Humphrey

1982), 2.5/ha (Hersh 1981), and 7.6/ha (Humphrey 1988). The large differences in the density estimates of Barbour and Humphrey (1982) and Humphrey (1988) apparently result from differences in sampling techniques. The methods used by Humphrey (1988) are statistically based and may provide the most reliable estimate of population densities. Overall, Key Largo woodrat populations occur in low densities but are highest in mature forest (Barbour and Humphrey 1982). Both male and female densities follow a similar pattern of gradual increase in late summer to early fall (Hersh 1981). Populations adjacent to housing complexes usually have much lower densities (3.1/ha), than areas removed from development (12.2/ha).

Foraging

Key Largo woodrats are nocturnal omnivores, but feed primarily on a variety of leaves, buds, seeds, and fruits (Brown 1978b). They are dependent upon the diversity of tropical hardwood fruits. Other woodrat species cache foods such as seeds and acorns for long periods of time (Post and Reichman 1991), but it is not known if Key Largo woodrats cache food items. Eastern woodrats primarily exhibit opportunistic feeding behaviors, eating any suitable food items available, although some selective foraging preferences seen may be due to palatability, nutritional quality, or perishability of food items (Post and Reichman 1991, McMurray *et al.* 1993). Eastern woodrats are able to discriminate between food items based on their perishability and decide what food items should be ingested immediately or stored for later consumption (Reichman 1988).

Relationship to Other Species

Hardwood hammocks and adjacent habitats on Key Largo support four other federally listed animals: American crocodile (*Crocodylus acutus*), eastern indigo snake (*Drymarchon corais couperi*), Key Largo cotton mouse (*Peromyscus gossypinus allapaticola*), and Schaus swallowtail butterfly (*Heraclides aristodemus ponceanus*). Similarly to the Key Largo woodrat, indigo snakes, cotton mice, and Schaus butterflies also rely on the unique habitat components of the tropical hardwood forests on Key Largo. In addition, there are at least seven state-protected animals, and 20 state-listed plants, such as the threatened white-crowned pigeon (*Columba leucocephala*) and Miami black-headed snake (*Tantilla oolitica*) and the endangered lignumvitae tree (*Guaiacum sanctum*), prickly apple (*Cereus gracilis*), tamarindillo (*Acacia choriophylla*), powdery catopsis (*Catopsis berteroniana*) and long strap fern (*Campyloneurum phyllitidus*). The Key Largo woodrat uses many of these plants for building stick nests, shelter, or foraging.

Status and Trends

The Key Largo woodrat was first listed as a threatened species under the Endangered Species Conservation Act of 1969, affording the woodrat protection on Federal lands. The Key Largo woodrat was recognized as a candidate for listing in a notice of review on July 28, 1980 (45 FR 49961). The woodrat was listed as endangered for 240 days on September 21, 1983, through an emergency listing action (48 FR 43040). The emergency listing was necessary to provide full consideration of the welfare of this species during a FWS consultation with the Rural Electrification Administration. The proposed action was construction of a residential housing project that would result in accelerated habitat loss.

The Key Largo woodrat was proposed for listing as an endangered species with critical habitat on February 9, 1984 (49 FR 4951) and was finally listed as endangered on August 31, 1984 (49 FR 34504). The proposal to designate critical habitat was withdrawn on February 18, 1986 (51 FR 5746). Effects of residential housing and commercial construction activity in tropical hardwood hammocks have been more extreme in the Upper Keys than in the Lower Keys. By 1991, 41.2 percent of the deciduous seasonal forests (1,985 ha) had been either cleared or filled to meet human needs (Strong and Bancroft 1994). Today, Key Largo has the highest concentration of platted lots (4,178), comprising 72 percent of all lots in the Upper Keys. Although much of northern Key Largo is protected, there are still areas where development could occur. An analysis of this area showed that 775 ha of vacant, dry, privately held lands with development potential remains (Monroe County 1989). South Key Largo has experienced extensive habitat destruction and fragmentation.

The Key Largo woodrat historically occurred throughout the forested uplands of Key Largo, but is currently restricted to approximately half of its historic range, now occurring only north of the U.S. Highway 1-C.R. 905 intersection. The decline in the woodrat's range and apparent extirpation of this species from Key Largo south of the U.S. 1-C.R. 905 intersection has been generally attributed to land clearing followed by residential and commercial development (Brown 1978a, b; Hersh 1981).

The primary threat to the Key Largo woodrat is habitat loss and fragmentation caused by increasing urbanization. Hammock vegetation on Key Largo has been removed or thinned by construction practices that remove all vegetation, then grade and fill the limestone substrate. In addition to land clearing practices, there are other threats to the hardwood hammock habitat resulting from human encroachment that also indirectly affect the woodrat. Increasing habitat fragmentation, combined with a decreased range, makes the Key Largo woodrat more vulnerable to genetic isolation, and to natural catastrophes such as hurricanes or fire (FWS 1993). Other threats associated with human encroachment, include predation by feral cats, dumping of trash, and competition with black rats.

Remaining hardwood hammock habitats are critical for the survival of the Key Largo woodrat. Brown (1978b) estimated that only about 120 to 160 ha of hammock suitable for woodrats remained on north Key Largo. Barbour and Humphrey (1982) estimated that 475 ha remained there, supporting an estimated 654 woodrats. Humphrey (1988) estimated that 851 ha of remaining forest supported average densities of 3.1 woodrats per ha. The numbers appear to have decreased since then, and the population may have been at high point in 1984. The Key Largo woodrat was considered to be extirpated from Lignumvitae Key by 1997 (Frank *et al.* 1997). A 1995 GFC survey shows a decline of the rat toward the southern end of its range.

Eastern woodrats appear to be more limited by availability of shelter than by food, which may also be true for Key Largo woodrats. The destruction of hammock trees can directly affect the woodrat's ability to build its large stick nests which provide a place for shelter, nesting, feeding, and breeding. The availability of stick nest material and ground cover may be essential for the woodrat's survival. Loss of hammock trees also results in the loss of arboreal habitat used by this species. Sufficient available habitat is also necessary for the development of social interactions and systems of organization (Kinsey 1977). Where shelter is sparse and stick nests are limited, territorial and competitive behaviors are exhibited more frequently. These behaviors result in a breakdown of social organization and aggressive behaviors that may result in death or casting out of subordinate animals (Kinsey 1977, McClure 1981).

Although woodrats are omnivorous, habitat destruction or degradation directly affects food resources and the ability of woodrats to forage. Without adequate nutrition, reproductive behaviors may be impaired. Under normal conditions, some small mammal mothers expend lactation energy equally between male and female offspring, but when food resources are limited, the mothers tend to a greater bias for nursing female young over males (McClure 1981). If Key Largo woodrat mothers are faced with limited food resources, then they may respond similarly by either favoring female offspring, or reducing the fitness of large litters. Either way, a reduction in fitness in the young may be a maternal response to adverse environmental conditions (Sikes 1995).

Physical separation caused by habitat loss and fragmentation makes it increasingly difficult to locate a mate and can isolate populations. Any lack of recruitment of juveniles into the population will result in a decline of the population. Small, isolated populations are subject to inbreeding depression, which can cause populations to decline over time. An increase in urbanization also results in an increase in the need for roads that separate and fragment habitats. The woodrat requires a minimum habitat size for daily activities; habitat destruction can directly reduce home range size and disrupt movement and dispersal patterns. The hammocks on north Key Largo are already bisected by a high-speed road (C.R. 905), which disrupts the integrity of the hammocks and causes road mortality of dispersing woodrats.

Trash dumping occurs throughout the woodrat's range. Actual debris may not greatly affect Key Largo woodrats; however, dumping may encourage invasion by black rats (*Rattus rattus*). Rodent control agents used for black rats or Norway rats also pose a threat to the woodrat (FWS 1993). Hersh (1981) suggested that the introduced black rat might be a serious competitor for the Key Largo woodrat because black rats equaled or exceeded Key Largo woodrat numbers at her study site. Barbour and Humphrey (1982), however, collected only one black rat in 1,696 trap nights, while Goodyear (1985) collected only two black rats at 45 trap sites. Competition between the two species is possible, but the extent of these effects is not known.

Eastern woodrats are believed to be highly susceptible to predation because of their moderate size and terrestrial mode of life (Rainey 1956). Key Largo woodrats are vulnerable to predation for the same reasons from such potential predators as red-shouldered hawks (*Buteo lineatus*), bobcats (*Lynx rufus*), corn snakes (*Elaphe guttata*), diamondback rattlesnakes (*Crotalus adamanteus*), eastern indigo snakes (*Drymarchon corais couperi*), Florida black racers (*Coluber constrictor priapus)*, Keys rat snakes (*Elaphe obsoleta deckerti*), barn owls (*Tyto alba)*, raccoons (*Procyon lotor*) and feral and domestic cats. Natural and increased levels of predation pose a major threat to the survival of these rodents. The drastic decline of Allegheny woodrats in Pennsylvania was attributed primarily to predation by great horned owls and exposure to raccoon roundworms (Balcom and Yahner 1996). Key Largo woodrats may also be susceptible to raccoon roundworms.

Hurricanes influence vegetational succession in the Florida Keys. Undisturbed hammocks are presumably more resistant to storms than hammocks that have been fragmented or have had surrounding mangrove and transitional vegetation removed. On August 1992, Hurricane Andrew hit Elliott Key, a few miles north of north Key Largo. The northern one-third of Key Largo suffered the most extensive damage, with about 240 to 280 ha affected. The area of greatest impact, comprising about 80 ha, suffered 70 percent canopy loss. Damage included windshear, uprooting of large trees, understory damage, and significant soil disturbance.

Recent surveys of woodrats on Northern Key Largo have been discouraging. In 1997 and 1998, only 6 and 7 animals were trapped, respectively, after 1500 trap nights of effort (S. Klett, FWS, personal communication 1998). It is expected that the results of habitat fragmentation, combined with other threats, and the effects of Hurricane Andrew and Hurricane Georges may have reduced the population below a minimum threshold needed to rebound.

Management

In an attempt to curtail the decline of the Key Largo woodrat population, 19 Key Largo woodrats were introduced to Lignumvitae Key in 1970 (Brown and Williams 1971). Although woodrats are not native to Lignumvitae Key, the hammock habitats of this key are similar to those of Key Largo. The woodrat population on Lignumvitae Key apparently remained at low levels at least until 1977, when Hersh (1978) found only six stick nests. Barbour and Humphrey (1982), however, estimated that 476 stick nests and 85 woodrats were present on Lignumvitae Key in 1979. In the late 1980s, woodrats appeared to decline, and by the spring and early summer of 1990, no woodrats were taken in approximately 400 trap-nights. Little or no sign of woodrats could be found, and it appeared that the woodrat population must be at a very low level or even extirpated.

The FWS issued two Biological Opinions, pursuant to section 7 of the ESA, with regard to Federal activities on north Key Largo that had a considerable impact on the future of development. The first opinion addressed Farmers Home Administration's financing of the Florida Keys Aqueduct Authority pipeline improvements in the Keys. The species of concern on north Key Largo were the American crocodile (C*rocodylus acutus*) and the Schaus swallowtail butterfly (*Heraclides aristodemus ponceanus*); the Key Largo woodrat and cotton mouse were not federally listed at that time (May 1980). The Biological Opinion concluded that the crocodile and Schaus swallowtail would be jeopardized by development made possible by the greatly increased water supply to north Key Largo. As an alternative, the Farmers Home Administration chose to exclude certain areas from water delivery. These loan conditions were subsequently accepted by the Florida Keys Aqueduct Authority.

The second Biological Opinion was issued by the FWS in October, 1983. This opinion addressed the crocodile, Schaus swallowtail, and the Key Largo woodrat and cotton mouse, and found that these species would be jeopardized by the Rural Electrification Administration funding for increased electrical capacity by the Florida Keys Electric Cooperative. The FWS's concern was that increased electrical delivery capacity would facilitate development in the hammocks of north Key Largo. No new electrical hookups have subsequently been made to any of the exclusionary areas described in the Biological Opinion.

In 1984, several landowners became interested in developing a Habitat Conservation Plan for the Key Largo woodrat, pursuant to section 10(a)(B)(1) of the ESA, to allow for residential and commercial development on north Key Largo, while conserving federally listed species in the area. The planning process was initiated, involving representatives of landowners, conservation groups, and State agencies. Density and distribution studies of the Key Largo woodrat were conducted (Humphrey 1988). Subsequent public land acquisition largely precluded the need for an overall habitat conservation plan. At least two incidental take permits have been issued to subdivisions for the authorized take of Key Largo woodrats.

The most important effort to conserve the Key Largo woodrat has been public land acquisition on north Key Largo. Most undeveloped land west of C.R. 905 has been acquired by the FWS as part of the Crocodile Lake NWR, while the undeveloped land on the east side of the road has been acquired by Florida DEP's Key Largo Hammocks State Botanical Preserve. Generally, these areas have limited public access and are managed for trash removal and exotic vegetation control.

In April 1996, the FWS Multi-Species Recovery Team met to discuss the listed species in the Keys and ways to improve their status. The team determined several priority actions necessary to protect and conserve the Key Largo woodrat, including the stabilization of existing woodrat populations, protection and restoration of habitat, monitoring of existing populations and re-evaluation of its status in 5 years, secondary evaluation and minimization of impacts (cats, black rats, fire ants), and development reclassification and delisting criteria (FWS 1996).

Recently, the FWS consulted on how the administration of the National Flood Insurance Program (NFIP) by the Federal Emergency Management Agency (FEMA) affects threatened and endangered species in Monroe County. The Key Largo woodrat was one of 10 species that was determined to be affected by FEMA's actions. Prior to this consultation, FEMA did not address listed species issues as required by section 7 of the ESA. FEMA's responsibilities to consult arise from a sequence of events that begins before a structure is designed and ends with habitat destruction or modification for the construction of residential or commercial structures. Although FEMA is not the only entity involved in this sequence of events, it still has the obligation, as a Federal agency, to ensure its actions do not jeopardize the continued existence of a listed species, like the woodrat. The FWS concluded that the continued administration of the National Flood Insurance Program by FEMA in the Keys, with its attendant effects on land-use planning and zoning and incentives for landowners, is likely to jeopardize the continued existence of the Key Largo woodrat. As a reasonable and prudent alternative to alleviate jeopardy, FEMA committed to implement procedures to ensure their actions do not jeopardize the woodrat.

In conjunction with the GFC, the FWS recently produced Geographic Information System (GIS) maps of suitable Key Largo woodrat habitat to assist in making better management decisions. Areas in private ownership that are either occupied or unoccupied by woodrats are the most vulnerable to loss. Based on our GIS analyses, only 4,877 ha of habitat remain for the Key Largo woodrat. Of this total, 4,445 ha (91 percent) are protected and 432 ha are vulnerable to urbanization. Most of this unprotected acreage occurs in the golf course of the Harbor Course residential area on north Key Largo, with a small fragment south of the marina on the western edge of the residential area (west of Gateway Road). The FWS believes all remaining occupied and unoccupied suitable habitat should be protected in order to ensure the continued existence of the Key Largo woodrat. In addition, the FWS also recommends that a 500-m buffer zone around these areas be put in place since adjacent areas are vulnerable to urbanization as well. The necessity for a protected buffer is based on the likelihood that human influences encroach upon and impact the woodrat. The distance of 500 m is based on the use of upland areas by this species and the estimated range of domestic cats. Upland and wetland buffers are important habitat because they provide connectivity between subpopulations and minimize secondary impacts such as road and cat mortality. Protection of the remaining tropical hardwood hammock areas on north Key Largo from further development is critical to the survival and recovery of the Key Largo woodrat. The National Audubon Society *et al.* (1990) identified areas of tropical hardwood hammocks throughout Key Largo for proposed acquisition by the State that would preserve the biological diversity of the hammock ecosystem. The FWS believes that protection, conservation, and management of these additional areas is critical to future actions, such as reintroduction, to recover the Key Largo woodrat.

The FWS, GFC, and the University of Miami are currently conducting a status survey of the woodrat that will provide information on the population density, population fluctuations, survival, reproduction, and movements of this species on north Key Largo (Quarterly Progress Report, FWS Research Work

Order No. 123). Other current research for the woodrat includes studies on territoriality (University of Florida) and analysis of genetic variations (University of Miami).

The FWS has placed a refuge manager at the Crocodile Lake NWR to increase the level of law enforcement, restore habitat, and protect and monitor woodrats and other species. In addition, a Student Conservation Association intern volunteer has been assisting with these duties and removing exotic

Literature Cited

vegetation at the refuge.

Balcom, B.J. and R.H. Yahner. 1996. Microhabitat and landscape characteristics associated with the threatened Allegheny woodrat. Conservation Biology 10(2): 515-525.

Barbour, D.B. and S.R. Humphrey. 1982. Status and habitat of the Key Largo woodrat and cotton mouse (*Neotoma floridana smalli* and *Peromyscus gossypinus allapaticola*). Journal of Mammalogy 63(1): 144-148.

Brown, L.N. 1978a. Key Largo cotton mouse. Pages 10-11 *in* J.N. Layne, ed. Mammals. University Press of Florida; Gainesville, Florida.

Brown, L.N. 1978b. Key Largo woodrat. Pages 11-12 *in* J.N. Layne, ed. Rare and endangered biota of Florida. Mammals. University Press of Florida; Gainesville, Florida.

Brown, L.N. and R.L. Williams. 1971. The Key Largo woodrat (*Neotoma floridana smalli*) and cotton mouse (*Peromyscus gossypinus allapaticola*) on Lignum Vitae Key, Florida. Florida Naturalist 44: 95-96.

Fitch, H.S. and D.G. Rainey. 1956. Ecological observations on the woodrat, *Neotoma floridana*. University of Kansas publications, Museum of Natural History 8: 499-533.

Frank P., F. Percival, and K. Britt. 1997. A status survey for the Key Largo woodrat (*Neotoma floridana smallii*) and Key Largo cotton mouse (*Peromyscus gossypinus allapaticola*) on north Key Largo, Monroe County, Florida. Florida Game and Fresh Water Fish Commission Final Report to the FWS, Jacksonville, Florida.

Goertz, J.W. 1970. An ecological study of *Neotoma floridana* in Oklahoma. Journal of Mammalogy 51: 94-104.

Goodyear, N.C. 1985. Results of a study of Key Largo woodrats and cotton mice: Phase I, spring and summer 1985. Unpublished report to North Key Largo Study Committee.

Hersh, S.L. 1978. Ecology of the Key Largo woodrat. M.S. thesis, University of Miami; Coral Gables, Florida.

Hersh, S.L. 1981. Ecology of the Key Largo woodrat (*Neotoma floridana smalli*). Journal of Mammalogy 62(1): 201-206.

Humphrey, S.R. 1988. Density estimates of the endangered Key Largo woodrat and cotton mouse (*Neotoma floridana smalli* and *Peromyscus gossypinus allapaticola*), using the nested-grid approach. Journal of Mammalogy 69(3): 524-531.

Kinsey, K.P. Agonistic behavior and social organization in a reproductive population of Allegheny woodrats, *Neotoma floridana magister.* Journal of Mammalogy 58(3): 417-419.

Klett, S. 1998. Telephone conversation. October 1998.

McClure, P.A. 1981. Sex-biased litter reduction in food-restricted woodrats (*Neotoma floridana*). Science 211(4486): 1058-1060.

McMurray, S.T., R.L. Lochmiller, J.F. Boggs, D.M. Leslie, Jr., and D.M. Engle. 1993. Opportunistic foraging of eastern woodrats (*Neotoma floridana*) in manipulated habitats. American Midland Naturalist 130(2): 325-337.

Monroe County. 1989. North Key Largo Habitat Conservation Plan. Growth

Management Division; Monroe County, Florida.

National Audubon Society, Florida Natural Areas Inventory, and The Nature Conservancy. 1990. Tropical Flyways, A Proposal to: Conservation and Recreational Lands (CARL), State of Florida Department of Natural Resources.

Post, D.S. and O.J. Reichman. 1991. Effects of food perishability, distance, and competitors on caching behavior by eastern woodrats. Journal of Mammalogy 72(3): 513-517.

Rainey, D.G. 1956. Eastern woodrat, *Neotoma floridana*: life history and ecology. University of Kansas Publications, Natural Museum of History 8: 535-646.

Reichman, O.J. 1988. Caching behavior by eastern woodrats, *Neotoma floridana*, in relation to food perishability. Animal Behavior 36(5): 1525-1532.

Schwartz, A. 1952a. Three new mammals from southern Florida. Journal of Mammalogy 33(3): 381-385.

Schwartz, A. 1952b. The land mammals of southern Florida and the upper Florida Keys. Ph.D. dissertation, University of Michigan; Ann Arbor, Michigan.

Schwartz, A. and E.P. Odum. 1957. The woodrats of the eastern United States. Journal of Mammalogy 38: 197-206.

Sherman, H.B. 1955. Description of a new race of woodrat from Key Largo, Florida. Journal of Mammalogy 36(1): 113-120.

Sikes, R.S. 1995. Maternal response to resource limitations in eastern woodrats. Animal Behavior 49(6): 1551-1558.

Strong, A.M. and G.T. Bancroft. 1994. Patterns of deforestation and fragmentation of mangrove and deciduous seasonal forests in the Upper Florida Keys. Bulletin of Marine Science 54(3): 795-804.

U.S. Fish and Wildlife Service [FWS]. 1996. Multi-species Recovery Team/Keys Group meeting, April 1996.

U.S. Fish and Wildlife Service. 1973. Threatened wildlife of the United States. Resource Publications, Washington, D.C.

U.S. Fish and Wildlife Service. 1984. Endangered and threatened wildlife and plants; determination of endangered status for the Key Largo woodrat and Key Largo cotton mouse. Federal Register 49(171): 34504-34510.

U.S. Fish and Wildlife Service. 1993. Technical/agency draft recovery plan for the Key Largo woodrat and the Key Largo cotton mouse. Atlanta, Georgia.

Recovery for the Key Largo Woodrat

Neotoma floridana smalli

Recovery Objective: RECLASSIFY to threatened.

Recovery Criteria

A recent GIS analysis of tropical hardwood hammock habitat on Key Largo suggests that the Key Largo woodrat has lost more than 50 percent of its habitat to urbanization; much of the remaining habitat has been fragmented or degraded, and the nature of the habitat loss provides extremely limited potential for habitat restoration or rehabilitation. Consequently, the objective is to reclassify the Key Largo woodrat from endangered to threatened by protecting and managing its habitat on Key Largo, restoring potential habitat, and increasing the size of its population. This objective will be achieved when: further loss, fragmentation, or degradation of suitable, occupied habitat on Key Largo has been prevented; when native and non-native nuisance species have been reduced by 80 percent; when all suitable, occupied habitat on priority acquisition lists on Key Largo is protected either through land acquisition or cooperative agreements; when the tropical hardwood hammocks that form the habitat for the Key Largo woodrat are managed on protected lands to eliminate trash and control exotics; when potential habitat on these protected lands is restored or rehabilitated for the Key Largo woodrat; when stable populations of the Key Largo woodrat are distributed throughout north Key Largo and three, additional, stable populations have been established elsewhere within the historic range. These populations will be considered demographically stable when they exhibit a stable age structure and have a rate of increase (r) equal to or greater than 0.0 as a 3-year running average for 6 years.

Species-level Recovery Actions

S1. Determine the distribution and status of the Key Largo woodrat. Key Largo woodrats formerly occurred throughout uplands of Key Largo but are now restricted to hammocks on the northern one-third of Key Largo.

S1.1. Conduct presence/absence surveys on north Key Largo to determine the status of woodrats. Survey the southern part of north Key Largo along the ecotone of human habitation and hardwood hammock. Evaluate the status of woodrats here as compared to more contiguous, remote areas.

S1.2. Survey suitable areas in other parts of Key Largo. Woodrats were historically found in southern Key Largo (Schwartz 1952b), but recent surveys have been un-successful (Barbour and Humphrey 1982.) Survey suitable habitat in other areas.

S1.3. Determine the status of woodrats north of Key Largo. Survey habitat on Palo Alto, Pumpkin, Swan, Little Totten, and Old Rhodes keys. These areas contain suitable habitat, but have not been surveyed in detail.

S1.4. Survey woodrat habitat. Determine habitat characterization and use by woodrats. Determine why woodrats are absent in areas with suitable habitat. Assess the condition of occupied habitat and potential habitat. Compare presence of woodrats in areas of contiguous versus fragmented habitat.

S1.5. Survey for the presence/absence of black rats simultaneously with woodrat surveys. Black rats may compete against woodrats, with black rats having larger populations than woodrats in some areas (Hersh 1981). Determine the prevalence of habitat use and overlap between woodrats and black rats.

S1.6. Maintain and improve the GIS database for woodrats information. Compile additional survey information into the FWS' existing GIS database.

S2. Protect and enhance existing populations.

S2.1. Utilize Federal regulatory mechanisms for protection. Conduct section 7 consultations on Federal activities that may affect the woodrat and determine a jeopardy threshold. Coordinate with law enforcement to improve and increase enforcement of section 9 of the ESA, which prohibits the taking of any listed species like the woodrat. Obtain evidence that shows habitat modification or degradation and secondary impacts (*e.g.*, black rats) have an adverse impact on the woodrat's ability to survive or recover and thus constitute take.

S2.2. Provide woodrat information to Federal, State, county, and city agencies, including GIS information regarding the presence of woodrats, their protection under the ESA, and ways to minimize impacts. Non-Federal agencies that may influence the woodrat include DEP, DCA, GFC, DACS and Monroe County Mosquito Control, Florida Keys Aqueduct Authority, and Monroe County Government.

S2.3. Minimize and eliminate disturbance or mortality to the woodrat. The level of woodrat mortality has not been characterized, although sources of mortality are documented. Implement management actions that reduce mortality.

S2.3.1. Remove nuisance predators. Feral dogs and cats, black rats, raccoons, and fire ants can increase woodrats' mortality. Eliminate food sources and home sites for raccoons and black rats, control free-roaming feral cats and dogs, and destroy fire ant colonies near and in woodrat habitat. Enforce deed restrictions of cat control in Ocean Reef Club and other areas.

S2.3.2. Minimize the effects of pesticides and other biocides. Mosquito spraying may impact the availability of food species. Rodent control agents used for black rats pose a threat to the woodrat (FWS 1993). Investigate the effects of these biocides and eliminate any adverse effects on the woodrat.

S2.3.3. Control blatant killing and poisoning. Woodrats may be killed by humans in an effort to get rid of nuisance black rats. Educate homeowners on the protection of woodrats and ways to minimize impacts. Develop methods to prevent woodrat poisoning.

S2.3.4. Reduce the effects of road mortality. Investigate the effects of road mortality on the woodrat. Implement appropriate management actions to reduce impacts of road mortality.

S2.3.5. **Minimize the effects of contaminants.** Investigate the effects of contaminants around the old missile site on the refuge, the firing range at Harbor Course, and illegal dumpsites. Remove contaminants that pose an adverse threat to the woodrat.

S2.4. **Conduct woodrat reintroductions if the population reaches numbers conducive to reintroduction and translocation.**

S2.4.1. **Develop a standard protocol for conducting, monitoring, and evaluating all reintroduction, translocation, and supplementation efforts of woodrats using the IUCN/SSC Guidelines for Reintroductions.** Develop criteria that determine the type of release to be conducted, evaluation and selection of release site, source and health of release stock, development and monitoring of short and long-term success indicators, and policy on intervention. Ensure release sites are free of threats prior to any release of woodrats.

S2.4.2. **Identify potential release sites.** Prioritize relocation sites based on population needs and habitat suitability. Ensure habitat is of sufficient size, is within historic range, contains suitable vegetation, and has long-term protection. Ensure site has sufficient carrying capacity to sustain growth of the reintroduced population for a minimum of 25 years.

S2.4.3. **Restore or improve habitat where possible to ensure sites are suitable for augmentation/reintroductions.**

S2.4.4. **Identify suitable release stock.** Identify donor populations and determine size and health of these populations. Determine the effects of translocation on the donor population.

S2.4.5. **Obtain stock for translocation.** Select the number, ages, and sex ratios of woodrats to be translocated, and the timing of the translocation. Select animals from existing stable populations in a way that does not negatively impact the donor population.

S2.4.6. **Release woodrats into new sites.** First, augment populations in habitat on north Key Largo that has been restored. Second, reintroduce woodrats in habitat on the periphery of the range. Third, establish new populations in other suitable areas within the historic range.

S2.4.7. **Monitor introduced populations to determine survival, growth, and reproductive success.**

S2.5. **Investigate captive propagation options.** Captive propagation may be necessary in the near future if results of population studies do not begin to show signs of a rebound. Captive propagation guidelines will need to be developed that follow DOI guidelines.

S3. **Conduct research on the biology and life history of the woodrat.** Conduct studies on the basic biology of the woodrat. Investigate reproductive success, productivity, longevity, population size, movements, and dispersal.

S3.1. **Determine if the total population size is large enough to prevent functional extinction and genetic extinction.** Determine the effective population size necessary for survival and recovery. Conduct population modeling *(e.g.*, PVA, risk assessment) to predict the persistence of this species.

S3.2. Determine the number of sub-populations necessary to constitute a stable or increasing population.

S3.2.1. Identify subpopulations vulnerable to extinction. Identify subpopulations vulnerable to fragmentation, lost corridors, and reduced dispersal. Populations adjacent to housing complexes tend to have lower densities than those in more remote areas (Hersh 1981). Investigate whether populations on the periphery or near human habitation are more vulnerable to extinction.

S3.2.2. Determine the necessary number of subpopulations and level of exchange that will enable the woodrat to persist for 100 years.

S3.3. Determine a stable age structure, sex ratio, and group size for the woodrat.

S3.4. Examine factors that affect the abundance and distribution of the woodrat. Determine what aspects of this species' ecology make it most vulnerable to extinction (*e.g.,* predation, lack of food, lack of nesting materials, inability to find a mate).

S3.5. Conduct an experimental woodrat augmentation/reintroduction and evaluate its effectiveness in increasing the woodrat's persistence. Determine if augmentation is effective in establishing stable populations throughout the woodrat's range. Investigate the exchange rate to be used between donor and re-established populations to retain genetic integrity and similarity of both.

S4. Monitor the status of the woodrat (and its habitat). Due to the short life span and normal population fluctuation, population declines could go unnoticed unless a continuous monitoring program is established and implemented.

S4.1. Develop methods to monitor demographic parameters. Develop methods to monitor sex ratios, age class structure, survivorship, home range size, age of dispersal, and dispersal distance of the woodrat.

S4.2. Conduct long-term monitoring of the woodrat. Monitor presence/absence and degree of abundance semi-annually until the woodrat is recovered.

S5. Increase public awareness and stewardship. Develop educational materials and host public workshops to increase awareness about woodrats and instill a sense of stewardship for the protection of this endangered species.

S5.1. Prepare informational material for the general public. Distribute materials at visitor information centers and local chambers of commerce.

S5.2. Develop and implement a cat, black rat, fire ant, and raccoon control program. Conduct workshops to educate residents about the necessity to control cat and raccoon predation on woodrats and to reduce the effects of black rats and fire ants.

S6. Establish reclassification criteria. Develop measurable reclassification criteria based on what factors constitute a stable population, including total population size, number of subpopulations, sex ratio, age structure, habitat condition and availability, and level of threats. Evaluate and monitor the woodrat's status in relation to reclassification criteria.

Habitat-related Recovery Actions

H1. Prevent degradation of existing habitat. The primary threat to the Key Largo woodrat is habitat loss and fragmentation caused by increasing urbanization. The range of the Key Largo woodrat has declined by more than 50 percent and remaining habitat is restricted to the northern portion of this Key.

H1.1. Acquire all occupied habitat first, then unoccupied. Identify priority areas for acquisition. Acquire all occupied suitable habitat first (Priority 1), then unoccupied (Priority 2). Unoccupied, but suitable habitat is important for future reintroduction activity. Inholding areas are also high priority.

H1.1.1. Continue Federal acquisition efforts. Continue acquisition efforts within the Crocodile Lake NWR. The Crocodile Lake NWR is developing a priority acquisition and restoration list.

H1.1.2. Support State, local, and non-governmental organizations including acquisition efforts. Support efforts of entities to acquire woodrat habitat including state conservation easements, CARL, Monroe County Land Authority, Florida Community Trust, Florida Keys Land Trust, and The Nature Conservancy. Support the acquisition of lands to be incorporated into the Key Largo State Botanical Site.

H1.2. Protect and manage woodrat habitat.

H1.2.1. Protect woodrats on public lands. Develop a habitat management plan that outlines priority habitat for acquisition and methods to protect, restore, and minimize impacts on woodrats and their habitat.

H1.2.2. Protect woodrats on private lands. Protect woodrat populations on private land through acquisition, conservation easements or agreements, and education of landowners. Develop agreements (*e.g.,* Memorandum of Agreement) between the FWS and private landowners to minimize impacts such as feral cats and exotics.

H1.2.3. Coordinate with Federal, State and Monroe County agencies and private entities to develop management actions to protect woodrat habitat. Coordinate with all Federal agencies to ensure Federal actions do not impact woodrat habitat. Coordinate with these entities to ensure proposed construction activities that result in land clearing or alteration do not impact the woodrat and its habitat. Coordinate with the Audubon Society to develop a management plan for Parcel 22. Coordinate with the landowner to protect and manage habitat and minimize impacts to the woodrat (*e.g.*, trash, feral cats, *etc.*).

H1.2.4. Avoid clearing or disturbing hammocks. Prevent direct clearing of hardwood hammocks. Direct construction activities toward already cleared areas.

H1.2.5. Restrict access to woodrat habitat. Restrict access to remote habitat areas to prevent damage caused by campers, homesteaders, trash dumpers, and vehicular traffic.

H1.2.6. **Establish and protect 500-m buffers around Priority 1 habitat.** The necessity for 500-m protection buffer zones is based on the likelihood that human influences encroach and impact the woodrat.

H1.2.7. **Prevent fires in woodrat habitat.** Uncontrolled wildfires can quickly destroy large areas of hardwood hammocks. Develop effective fire control plans. Prohibit fires and smoking in or near hardwood hammocks.

H1.2.8. **Eliminate exotic vegetation.** Remove exotic vegetation in woodrat habitat and in adjacent upland buffers. Use deed restrictions, covenants, or other means to minimize the likelihood that exotic plants will invade hardwood hammocks. Remove exotic vegetation in refuge boundaries. Support the removal of exotics in other woodrat habitat, including Port Bougainvillaea and Ocean Forest Tract (ocean side of Harrison Tract).

H2. Restore both suitable occupied and unoccupied woodrat habitat or create habitat. Several areas are suitable for restoration. Restoration efforts will benefit the hammock habitat, existing woodrat populations, and future-released populations. Conduct and support restoration activities in woodrat habitat.

H2.1. **Prepare a hardwood hammock restoration plan for north Key Largo.** Several large-scale restoration efforts are underway in South Florida, and it will be advantageous to have a plan to link into funding and implementation opportunities.

H2.2. **Restore woodrat habitat on refuge property.** Restore habitat near the missile site, borrow pit, gun range, the cockfighting ring, and radio tower.

H2.3. **Restore old 905 Road to promote woodrat habitat.**

H2.4. **Remove trash and debris.** Several old roads in the Crocodile Lake NWR are littered with trash and debris. Remove trash and debris from these and other areas in woodrat habitat.

H2.5. **Improve hydrology and water quality in woodrat habitat.** Restore hydrology of Dispatch Slough and other areas in need.

H2.6. **Improve habitat by planting or encouraging native plant species.** Plant native vegetation in areas that have been scarified or degraded.

H2.7. **Create habitat by refilling and recreating areas that have been dredged or altered.**

H3. Conduct research to determine habitat needs for the woodrat.

H3.1. **Investigate how woodrats utilize different habitat components for survival (*e.g.,* for food, shelter, nesting, traveling).** Woodrats rely heavily on the availability of materials to construct their stick nests. Eastern woodrats may be more limited by availability of shelter than by food, which may also be true for Key Largo woodrats.

H3.1.1. **Investigate stable home range and minimum area requirements.** Key Largo woodrats have overlapping home ranges (about 2,370 m^2).

H3.1.2. **Investigate the effect of habitat change.** Determine how the woodrat's distribution and abundance is affected by habitat degradation and other human factors.

H3.2. Determine an index of habitat fragmentation.

H3.2.1. Investigate movement patterns and the spatial use of habitat to identify important core areas and corridors.

H3.2.2. Determine if the amount and configuration of habitat is sufficient to support a stable or increasing population of woodrats.

H4. Monitor the status of woodrat habitat and examine ecological processes. Conduct yearly monitoring evaluations of the status of the woodrat's habitat. including what patches are being altered or lost each year. Use GIS to map locations and quality of habitat. Monitor the availability of woodrat habitat by updating the loss or change of habitat due to residential or commercial construction.

H5. Increase public awareness of woodrat habitat and instill stewardship. Conduct workshops with the public to educate private landowners on appropriate management practices to preserve woodrat habitat. Encourage private landowners to remove exotics, maintain natural waterflow, refrain from destroying woodrat habitat, and restore disturbed areas. Prepare literature to provide information regarding the woodrat's habitat and ways to protect and conserve it.

The Birds

Thirteen federally threatened or endangered bird species have been recorded from South Florida. Some of these species, like the Cape Sable seaside sparrow, only occur in South Florida. Other species, like the bald eagle and the red-cockaded woodpecker, occur in South Florida but are also more widely distributed throughout the United States. A third category consists of species like the Kirtland's warbler and piping plover, which are winter residents or migrants. The final category consists of species like the ivory-billed woodpecker, which once occurred in South Florida, but have not been seen for many years and may no longer exist in South Florida.

This section of the Multi-Species Recovery Plan contains accounts of the threatened and endangered bird species of South Florida. These accounts detail the biology, ecology, status and trends, and management for each of these bird species. Each account is followed by a summary of the recovery needs of the species which consists of the recovery objective, criteria that will be used to determine when the objective has been achieved (called recovery criteria), and the tasks that will be necessary to achieve the objective (called recovery actions). The recovery tasks are divided into species-level recovery actions that address species-specific conservation and biology, and habitat-level recovery actions that address habitat management, conservation, and restoration needs for the species. The habitat-level recovery actions form the basis for the multi-species/community-level restoration actions that are provided in the community accounts. For species that have distributions outside of South Florida, there are two sections to the recovery objective: the first is the recovery objective for the species throughout its range; the second section identifies how South Florida will contribute to the species' recovery throughout its range.

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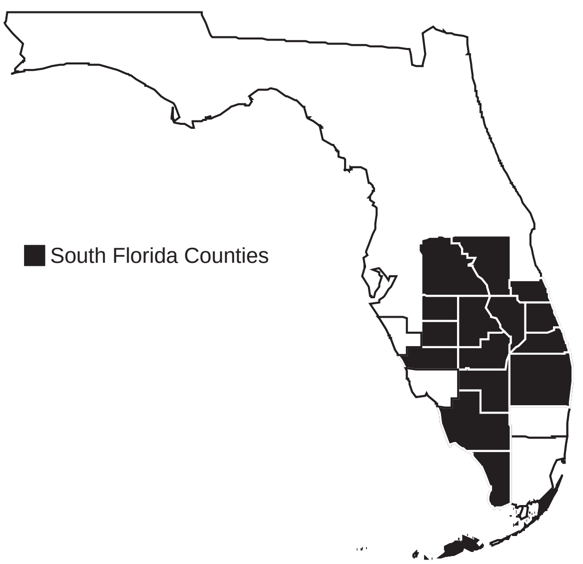
Audubon's Crested Caracara

Polyborus plancus audubonii

Federal Status:	**Threatened (July 6, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of Audubon's crested caracara.



Audubon's crested caracara is a large, boldly patterned raptor, with a crest and unusually long legs. It is a resident, diurnal, and non-migratory species that occurs in Florida as well as the southwestern U.S. and Central America. In Florida, this species is found in the prairie area of the south-central region of the state. The subspecies is no longer present at its type locality, which is near St. Augustine, St. Johns County, Florida.

Only the Florida population, which is isolated from the remainder of the subspecies in the southwestern U.S. and Central America, is listed under the Endangered Species Act. Although no management activities have been undertaken for the U.S. population of this species, draft habitat management guidelines are being developed that should aid in the caracara's recovery.

This account represents a revision of the existing recovery plan for the Audubon's crested caracara (FWS 1989).

Description

Audubon's crested caracara is a large raptor with a crest, naked face, heavy bill, elongate neck, and unusually long legs. It is about 50 to 64 cm long and has a wingspan of 120 cm. The adult is dark brownish black on the crown, wings, back, and lower abdomen. The lower part of the head, throat, upper abdomen, and under tail coverts are white, sometimes tinged with yellow; the breast and upper back are whitish, heavily barred with black. The tail is white with narrow, dark crossbars and a broad, dark terminal band. Prominent white patches are visible near the tips of the wings in flight. The large, white patches in the primaries and the white tail, broadly tipped with black, are both very conspicuous in flight and can be recognized at a long distance (Bent 1961). Juveniles have a similar color pattern but are brownish and buffy with the breast and upper back streaked instead of barred. Subadults resemble adults but are more brownish in color. Adults have yellow-orange facial skin and yellow legs. Facial skin of juveniles is pinkish in color, and the legs are gray (Layne 1978). Full adult plumage is obtained sometime after 2 years of age (J. Morrison, University of Florida, personal communication 1997).

There is no evidence of sexual dimorphism, the sexes being similar in color and size (J. Morrison, University of Florida, personal communication 1996a); however, gender can be determined surgically or through blood analysis (Humphrey and Morrison 1996).

The bare skin on the face of this bird is an interesting and distinctive feature. When the bird is at rest, preening or being preened, or engaged in other non-aggressive behaviors, the facial skin is bright orange-red. When threatened, the color of the facial skin changes to a pumpkin color and finally to pale yellow (Lyons 1984). Apparently, threat or fear causes blood to bypass the subepidermal blood vessels, resulting in a change in facial skin color. The caracara's crest provides another method for communication. When a caracara is comfortable and not threatened, the crest lies flat. The crest is raised when they feel threatened, frightened, or are on alert (Lyons 1984).

A caracara's feet and flight behavior are also notable. Their feet are clearly those of a raptor; however, their talons are flatter, enabling caracaras to run and walk more easily than other raptors. Bent (1938) and Layne (1985) noted that the caracara's flight pattern resembles that of a northern harrier (*Circus cyaneus*), but caracaras fly faster and more gracefully. Caracaras are strong fliers and may reach speeds of 40 mph. They have also been observed soaring in large circles at great heights (Howell 1932).

Little information is available on vocalizations of this species; however, in the morning or evening, the caracara may throw its head back until it almost touches its shoulders and emit a high, cackling cry that resembles its Brazilian name (Bent 1961). Observations of caracaras in Costa Rica and Mexico indicate that this call may be a part of pair formation or courtship. The only other vocalizations heard in Costa Rica were a one-syllable greeting and an alarm call (Palmer 1988).

Taxonomy

Audubon's crested caracara is a member of the Class Aves, Order Falconiformes, Family Falconidae. It was originally described by John James Audubon (1834), who discovered the caracara on November 21, 1831, and published an account under the name *Polyborus vulgaris*. It was renamed in 1865 by John Cassin to *Polyborus audubonii* and has had several other scientific names since that time. Most recently it was renamed *Caracara plancus* (Banks and Dove 1992). Banks (1985) provided a historical review of the taxonomy of the caracara prior to its listing.

The only other species of *Polyborus* known from recent times is the Guadalupe caracara (*Polyborus lutosus*). This species was extirpated from Guadalupe Island, Mexico in the early part of the 20th century (Abbott 1933).

Audubon's crested caracara. *Original photograph by Joan Morrison.*

Distribution

The overall range of the crested caracara is from Florida, southern Texas, southwestern Arizona, and northern Baja California, through Mexico and Central America to Panama, including Cuba and the Isle of Pines. It is accidental in Jamaica. Other subspecies range into South America as far as Tierra del Fuego and the Falkland Islands (Stevenson 1976, Layne 1978).

Historically, this subspecies was a common resident in Florida from northern Brevard County, south to Fort Pierce, Lake Okeechobee, and Hendry County. It has been reported as far north as Nassau County, and as far south as Collier County and the lower Florida Keys in Monroe County. Some of the birds sighted in the Florida Keys most likely escaped or were released from captivity. Available evidence indicates that the range of this subspecies in Florida has experienced a long-term continuing contraction, with birds now rarely found as far north as Orlando in Orange County or on the east side of the St. Johns River. Presently, Audubon's crested caracara may be found in Charlotte, Collier, DeSoto, Glades, Hardee, Hendry, Highlands, Martin, Monroe, Okeechobee, Osceola, Palm Beach, Polk, and St. Lucie counties (Figure 1). However, there is little evidence of breeding in Palm Beach, Indian River, Martin and Monroe counties (Layne 1978, Stevenson 1976, Sprunt 1954, FWS 1989, J. Morrison, University of Florida, personal communication 1996a). The region of greatest abundance for this subspecies is a five-county area north and west of Lake Okeechobee, including Glades, Desoto, Highlands, Okeechobee, and Osceola counties.

Habitat

The Florida population commonly occurs in dry or wet prairie areas with scattered cabbage palms (*Sabal palmetto*). It may also be found in lightly wooded areas. Scattered saw palmetto (*Serenoa repens*), scrub oaks (*Quercus geminata*, *Q. minima*, *Q. pumila*), and cypress (*Taxodium* spp.) may also be present. Widespread changes in land use may have forced a change in the type of habitat this subspecies will use. The caracara now uses improved or semi-improved pasture (Layne 1996b, J. Morrison, University of Florida, personal communication 1996a). The presence of seasonal wetlands may be an important factor in the attractiveness of these pastures to caracaras (K. Dryden, GFC, personal communication 1996).

Humphrey and Morrison (1997) characterized habitat features and land use patterns at active caracara nest sites in south-central Florida. They found that caracaras prefer to nest in cabbage palms (*Sabal palmetto*) surrounded by open habitats with low ground cover and low density of tall or shrubby vegetation. The study also indicated that there was a strong association of caracara home ranges with improved pasture. In addition, occupancy rate, breeding rates, and nesting success were consistently higher on private lands during the 3-year study. One of the variables that may contribute to the difference in success is vegetation height. This may be related to lower predation rates in areas with less cover, or it may simply be easier for caracaras to walk around and forage in shorter vegetation. Other factors contributing to nest success may be nest tree height, and distance to major roads or human activity.

Routine observation and radiotelemetry monitoring suggest that there are three congregation areas in south-central Florida which may be important to caracaras during the first year after leaving their natal territory (Humphrey and Morrison 1996). One is along the Kissimmee River, north of State Route 98, one is north of U.S. Highway 27 in Glades County, and one is in the vicinity of Eagle Island Road in northern Okeechobee County. These congregation areas consist of large expanses of improved pasture; however, the particular habitat values of these areas have not yet been evaluated.

Behavior

Reproduction

Caracaras are relatively long-lived. A caracara was kept in captivity for at least 30 years, suggesting that this falconid may have a high reproductive potential (Brown and Amadon 1968). Layne (1996b) describes a 20 year-old female brought into captivity as a nestling as still being in good health. The age at first breeding is unknown (Palmer 1988).

Breeding behavior in Audubon's crested caracara is relatively unknown. Based on the limited amount of information available, courtship behavior may involve the pair perching next to each other, almost touching, uttering the cackling call with their heads thrown back (Batten 1969). Brown and Amadon (1968) stated that males may occasionally fight in the air. Caracaras in Costa Rica have been observed in a ritual involving the rattle call where one of the birds had a lizard that was later broken apart so that both individuals could eat.

It is not known if this is a true courtship ritual or pair bond maintenance (Palmer 1988). The pair bond is relatively strong, lasting until one mate dies (FWS 1989).

Caracaras are one of the first of Florida's raptors to begin nesting. Egg laying has been estimated to begin as early as late September based upon evidence of chicks fledging in December (Humphrey and Morrison 1997). The height of the nesting season is in January and February. Nests with eggs have also been found as late as April (Nicholson 1929). In their study, Humphrey and Morrison (1997) suggest that most reproductive activity occurs during the winter dry season, although nesting attempts may occur throughout the year.

Caracaras construct new nests each nesting season, often in the same tree as the previous year. Nests are well-concealed and most often found in the tops of cabbage palms (J. Morrison, University of Florida, personal communication 1996a) although nests have been found in live oaks (*Q. virginiana*), cypress (first record, 1996), Australian pine (*Casuarina* spp.), saw palmetto, and black gum (*Nyssa sylvatica*). Caracaras usually construct their nests 4 to 18 m above the ground; their nests primarily consist of haphazardly woven vines trampled to form a depression (Bent 1938, Sprunt 1954, Humphrey and Morrison 1996, Layne, Archbold Biological Station, personal communication 1996a). Both adults participate in nest construction. Caracaras do not vigorously defend their nest site although they are aggressive toward other adult caracaras intruding near the nest itself (J. Morrison, University of Florida, personal communication 1996a). Sprunt (1954) wrote, "One female remained on the nest until approached to within four feet, when she flew to a stub about 12 feet away and watched. The male soon joined her and they together uttered rasping, cackling noises with their heads bent back upon their backs." A.C. Bent (1961) wrote, "Almost any small bird would probably drive one away from the vicinity of its nest, or at least attempt to do so."

Clutch size is two or three eggs, but most often two. Incubation lasts for about 28 days and is shared by both sexes. Ordinarily only one brood is raised in a season. If the eggs are taken, a second or even third set may be laid (Bent 1961). The young fledge at about 8 weeks of age (Layne 1978). Double brooding (two clutches successfully reared in one breeding season) has been documented in the Florida population, particularly for pairs that initiate nesting early in December or January (Humphrey and Morrison 1996; J. Morrison, University of Florida, personal communication 1996a).

Foraging

Caracaras are highly opportunistic in their feeding habits, eating carrion and capturing live prey. Their diets include insects and other invertebrates, fish, snakes, turtles, birds, and mammals (Layne 1978). Live prey also include rabbits, skunks, prairie dogs, opossums (*Didelphis marsupialis*), rats (*Rattus* spp.), mice, squirrels, frogs, lizards, young alligators (*Alligator mississippiensis*), crabs, crayfish, fish, young birds, cattle egrets (*Bubulcus ibis*), beetles, grasshoppers, maggots, and worms (Bent 1961, Layne *et al*. 1977). Several authors have noted that caracaras may consume unusual items, including turtle and other eggs (Terres 1980, Grossman and Hamlet 1964) as well as coconut meat (Haverschmidt 1947). This last food item may have been taken while foraging for insects on the coconut.

These raptors hunt on the wing, from perches, and on the ground (FWS 1989). They will also regularly patrol sections of highway in search of carrion (Palmer 1988). They may be seen feeding on road kills with vultures. However, caracaras are dominant over vultures and may occasionally chase the larger raptor from the road kill (Howell 1932).

Caracaras may also attack or harass other avian species in order to steal their food. Bent (1938) observed a caracara attacking a bald eagle (*Haliaeetus leucocephalus*) to steal its food. Caracaras may also attack other caracaras, pelicans (*Pelecanus* spp.), gulls (*Larus* spp.), and other large birds. They jump on the victim's back or strike from above with the talons; the victim usually drops its prey or regurgitates its food. The caracara then dives and snatches the prey before it hits the ground (Lyons 1985).

Localized Movements

Caracaras are resident, diurnal, and nonmigratory. Adult caracaras may be found in their home range year-round. Home ranges may encompass an area of up to 2,389 ha with an average of 1,552 ha. There is no significant difference between male and female home ranges; Humphrey and Morrison (1996) found female home ranges from 3.8 to 24.9 km^2 and male home ranges ranging from 3.9 km^2 to 22.5 km^2.

Occasionally large groups of individuals are encountered (Layne 1978). Oberholser (1974) attributes this to the birds' carrion feeding habit although Morrison (University of Florida, personal communication 1996a) has noted that juvenile caracaras are nomadic. This may account for the number of sightings far outside the core area in Glades, Hendry, Okeechobee, Osceola, and Highlands counties. Occasional sightings have been reported in Polk, Orange, Indian River, St. Lucie, Martin, Palm Beach, Monroe, and Charlotte counties. When subadult birds are associated with one of the aggregation areas, the aggregation areas are comprised of similar habitat to that found in the natal territory.

Relationship to Other Species

There appears to be no migration or genetic exchange between the Florida population and other populations of the subspecies. The only other member of the genus *Polyborus* was the Guadalupe caracara that was extirpated in the early 1900s. Detailed studies on natural predators are lacking; however, fish crows (*Corvus ossifragus*) and raccoons (*Procyon lotor*) have been documented as nest predators (J. Layne, Archbold Biological Station, personal communication 1996a, J. Morrison, University of Florida, personal communication 1996b).

Status and Trends

The caracara has declined throughout its range, from the early 1900s until the 1980s. It was once plentiful in Texas, and was more numerous in Arizona than it is at this time. It was considered uncommon in New Mexico and extremely rare in Oklahoma (Ellis *et al.*1988). It would appear that the distribution of the bird presently is similar to the historic distribution, however, numbers of individuals are lower. The status in most areas where the caracara is found is largely unknown, however, it is thought to be severely declining in Mexico. It is relatively unprotected except in Florida and is actively shot in Argentina (J. Morrison, University of Florida, personal communication 1996b).

The size of the Florida caracara population remains in question. Accurate counts become difficult because of limited access to areas of suitable habitat and because of the bird's behavior and detectability (Humphrey and Morrison 1997). In 1970, Heinzmann published the results of a 4-year survey (1967 - 1970) which indicated that fewer than 100 individual caracaras at 58 localities remained in Florida. Stevenson (1976) concurred with this estimate in 1974. Layne (1995), however monitored caracara distribution and population status in Florida from 1972 to 1991. He estimated that the population was stable with a minimum of about 300 adults in 150 territories. The immature population was estimated to be between 100 and 200 individuals, bringing the total statewide population to between 400 and 500 birds.

The caracara's decline, as described in historic literature, is primarily due to habitat loss (Layne 1985); the documentation of this decline eventually resulted in the caracara's listing as threatened in 1987 (52 FR 25232). In particular, the caracara was listed as threatened because its dry prairie habitat had been destroyed or modified for agriculture and residential development. It was also listed because existing regulatory mechanisms did not adequately prevent the destruction or modification of the caracara's habitat, which is mainly located on private land. (The only federal property that supports caracaras is Avon Park AFR in Polk and Highlands counties. In recent years, nesting on the AFR has been limited to only one nesting pair (J. Morrison, University of Florida, personal communication 1996a).

The presence of disease in caracara remains largely unknown. However, Lyons (1985) reported that some cases of avian pox had been diagnosed in the past.

In addition to population declines related to habitat loss, direct human-caused mortality may also be a factor in the slow recovery of the species. Caracaras may still be killed in the false belief that they prey on newborn calves. In the past, large numbers of caracaras were killed in vulture traps (FWS 1989). Individuals may also be caught in leghold traps used to control mammalian predators (Morrison 1996c). Road mortalities may be a significant cause of caracara decline; Morrison (University of Florida, personal communication 1996a) identifies highway mortalities as a major cause of juvenile mortalities with young birds especially vulnerable within the first 6 months of fledging.

The Florida population of caracaras is isolated and habitat-specific. Therefore, it may be susceptible to environmental catastrophes and potentially reduced reproductive rates because of demographic accidents such as skewed sex ratios or disproportionate age-related mortality. Because of its scavenging habits, the caracara may be susceptible to mass poisonings. Low numbers may also reduce the genetic viability through loss of heterozygosity, thereby increasing vulnerability to environmental stresses. The location of many of the occupied territories on private land, and the inaccessibility of these territories to surveyors, makes it difficult to census the caracara and detect changes in its population size and distribution. This difficulty increases the possibility of not detecting a population decline that could result in extinction.

Large areas of native prairie have been lost in south-central Florida to citrus operations, tree farms, improved pasture, other forms of agriculture, and real estate development (Layne 1978, Layne 1985). The threat of habitat loss persists as these changes in land use continue. Florida's burgeoning population has also increased the number of motor vehicles and the need for roads. The increase in traffic as well as the caracara's predisposition for feeding on road-killed animals has probably increased this type of mortality.

Cattle ranching on large tracts of land seems to be compatible with caracara survival. The number of territories occurring in improved or unimproved pasture is expected to increase as juvenile caracaras establish their territories in similar, adjacent settings (J. Morrison, University of Florida, personal communication 1996a). The conversion of pasture to citrus (Cox *et al*. 1994), sugarcane and residential development is reason for concern. Humphrey and Morrison (1996) found that pasture constitutes the highest percentage of habitat cover type found within the home ranges of breeding caracaras.

Management

To date, no active conservation measures have been undertaken for this species in Florida. Management activities are also lacking throughout its range. Avon Park AFR has conducted caracara surveys in the past. This contract allowed a biologist to perform research activities both on the AFR and in the surrounding region. In recent biological opinions and informal consultations, the FWS has endeavored to better address effects to the caracara through recommendations to: set aside home ranges, allow research and monitoring, perform surveys, avoid work during the nesting season, and formulate a management plan for protection of the resident pair. Proposed development projects evaluated by the FWS for their effect on the caracara have included the conversion of pasture to citrus, a DOT road improvement project, and the construction of a juvenile detention center.

Caracaras appear to benefit from prescribed burning, plowing, and mowing (Morrison 1996c). These activities reduce available cover and may facilitate the observation and capture of prey. In addition, regular mowing, burning, and high-density grazing maintain low vegetative structure, an important habitat characteristic of the caracara's nest stand area (Humphrey and Morrison 1996).

Draft habitat management guidelines similar to those in place for the bald eagle (*Haliaeetus leucocephalus*) are being developed (J. Morrison, University of Florida, personal communication 1996a). The bald eagle guidelines (FWS 1987) have been useful in preserving bald eagle nest sites in areas subject to development pressure.

Literature Cited

Abbott, C.G. 1933. Closing history of the Guadalupe caracara. Condor 35:10-14.

Audubon, J.J. 1834. Ornithological biography. vol. 1. Adam and Charles Black; Edinburgh, Scotland.

Banks, R.C. 1985. Letter to John Paradiso, U.S. Fish and Wildlife Service. Dated October 29, 1985.

Banks, R.C. and C.J. Dove. 1992. The generic name for crested caracaras (Aves: Falconidae). Proceedings of the Biological Society of Washington. 105(3): 420-425.

Batten. L. 1969. Common caracara. Birds of the world 2(2):575-577.

Bent, A.C. 1938. Life histories of North American birds of prey, part 2. U.S. National Museum Bulletin 170. Government Printing Office; Washington, D.C.

Bent, A.C. 1961. Life histories of North American birds of prey, vol. 1. Dover Publishers, Inc.; New York, New York.

Brown, L., and D. Amadon. 1968. Eagles, hawks, and falcons of the world (2 volumes). McGraw-Hill; New York, New York.

Cassin, J. 1865. Notes on some new and little known rapacious birds. Proceedings of the Academy of Natural Sciences of Philadelphia 17:2-3.

Cox. J, R. Kautz, M. MacLaughlin, and T. Gilbert. 1994. Closing the gaps in Florida's wildlife habitat conservation system. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Dryden, K.A. 1996. Letter to the U.S. Fish and Wildlife Service, South Florida Ecosystem Office, dated May 13, 1996.

Ellis, D.H., D.G. Smith, W.H. Whaley, and C.H. Ellis. 1988. Crested caracara. Pages 119-126. *In*: Proceedings of the southwest raptor management symposium and workshop; National Wildlife Federation Scientific and Technical Series No. 11. National Wildlife Federation; Washington, D.C.

Grossman, M.L., and J. Hamlet. 1964. Birds of prey of the world. C.N. Potter, Inc.; New York, New York.

Haverschmidt, F. 1947. The black vulture and the caracara as vegetarians. Condor 49(5):210.

Heinzman, G. 1970. The caracara survey: A four year report. Florida Naturalist 43(4):149.

Howell, A.H. 1932. Florida bird life. Coward-McCann, Inc.; New York, New York.

Humphrey, S.R. and J.L. Morrison. 1996. Audubon's crested caracara ecology. Unpublished annual report to Florida Game and Fresh Water Fish Commission for Project No. NG91-007. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Humphrey, S.R. and J.L. Morrison. 1997. Habitat associations, reproduction and foraging ecology of the Audubon's crested caracara in south-central Florida. Final report to Florida Game and Fresh Water Fish Commission for Project No. NG91-007. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Layne, J.N. 1978. Threatened, Audubon's caracara. Pages 34-36 *in* H.W. Kale II, ed., Rare and endangered biota of Florida. volume 2: Birds. University Press of Florida; Gainesville, Florida.

Layne, J.N. 1985. Audubon's caracara. Florida Wildlife 39:40-42.

Layne, J.N. 1995. Audubon's crested caracara in Florida. Pages 82-83 *in* E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, eds. Our living resources: A report to the nation on the distribution, abundance and health of U.S. plants, animals and ecosystems. U.S. Department of the Interior, National Biological Service, Washington D.C.

Layne, J.N. 1996a. Letter to the U.S. Fish and Wildlife Service, South Florida Ecosystem Office, dated February 22, 1996.

Layne, J.N. 1996b. Audubon's crested caracara. Pages 197-210 *in* J.A. Rodgers, H.W. Kale, and H.T. Smith, eds., Rare and endangered biota of Florida. vol. 5: birds. University Press of Florida; Gainesville, Florida.

Layne, J.N., F.E. Lohrer, and C.E. Winegarner. 1977. Bird and mammal predators on the cattle egret in Florida. Florida Field Naturalist (5):1.1-4.

Lyons, J. 1984. Caracaras in captivity. Pages 69-77 *in* Wildlife rehabilitation, Vol. 2. Exposition Press, Inc.; Smithtown, New York.

Lyons, J. 1985. Caracaras in captivity (revised). Unpublished manuscript. Austin Nature Center; Austin, Texas.

Morrison, J. 1996a. Verbal comments provided to the U.S. Fish and Wildlife Service, South Florida Ecosystem Office at the multi-species recovery meeting. March 6-8, 1996.

Morrison, J. 1996b. Letter to the U.S. Fish and Wildlife Service, South Florida Ecosystem Office, received November 12, 1996.

Morrison, J. 1996c. Crested caracara (*Caracara plancus*) *in* A. Poole and F. Gill, eds. The birds of North America, No. 249. The Academy of Natural Sciences, Philadelphia, PA, and The American Onithologists' Union, Washington, D.C.

Morrison, J. 1997. E-mail message to the U.S. Fish and Wildlife Service, South Florida Ecosystem Office, dated January 7, 1997.

Nicholson, D.J. 1929. The Audubon caracara. Florida Naturalist 2:67-69.

Oberholser, H.C. 1974. The bird life of Texas (vol. 1). University of Texas Press; Austin, Texas.

Palmer, R.S. 1988. Crested caracara. Pages 235-249 *in* R.S. Palmer ed., Handbook of North American birds volume 5. Yale University Press; New Haven, Connecticut.

Sprunt, A., Jr. 1954. Florida bird life. Coward-McCann, Inc. New York and National Audubon Society; New York, New York.

Stevenson, H.M. 1976. Vertebrates of Florida. University Presses of Florida; Gainesville, Florida.

Terres, J.K. 1980. The Audubon Society encyclopedia of North American birds. Alfred A. Knopf; New York, New York.

U.S. Fish and Wildlife Service [FWS]. 1987. Habitat management guidelines for the bald eagle in the southeast region. U.S. Fish and Wildlife Service; Atlanta, Georgia.

U.S. Fish and Wildlife Service [FWS]. 1989. Recovery plan for the Florida population of Audubon's crested caracara. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Recovery for the Audubon's Crested Caracara

Polyborus plancus audubonii

Recovery Objective: DELIST the species once recovery criteria are met.

Recovery Criteria

This objective will be achieved when any further loss, fragmentation, and degradation of habitat in south-central Florida has been prevented; when the number of Audubon's crested caracara territories in the historic range increases from 200 to 300; when Audubon's crested caracara have maintained or exceeded this number of territories for at least 10 years; when these territories are well-distributed throughout the core counties of Glades, DeSoto, Highlands, Okeechobee, and Osceola; when additional breeding pairs have established territories on unoccupied or restored habitat; when those lands have been protected through land acquisition, conservation easements, or cooperative agreements; and when the Audubon's crested caracara population in Florida exhibits an intrinsic rate of increase (r) equal to or greater than 0.0, sustained as a 3-year running average over at least 10 years.

Species-level Recovery Actions

S1. Determine the distribution, status, and abundance of Audubon's crested caracaras. Dry prairie habitats throughout the Kissimmee River valley should be targeted for surveys. Other areas that might support populations of the Audubon's crested caracara should be determined through the use of satellite imagery to locate search areas and other aggregation areas important to juvenile caracaras.

S1.1. Locate active caracara territories in Glades, DeSoto, Highlands, Okeechobee, and Osceola counties. Active territories in these counties should be mapped using digital, spatial information; this information should be maintained as part of a database to facilitate land protection and monitoring efforts for the caracara.

S1.2. Locate and map potential habitat within the former range of the caracara that might be rehabilitated for reintroduction purposes. Caracaras once occurred in prairie habitat from northern Brevard County south to Collier County. Caracara were once reported from as far north as Nassau County and as far south as the lower Keys in Monroe County but have been extirpated over much of their former range. Efforts should be made to locate and map these formerly inhabited areas, to determine if it is feasible to restore habitat and expand the range of the caracara.

S1.3. Develop standardized, systematic censusing procedures. The census should use active territories as a variable.

S2. Protect and enhance existing populations of Audubon's crested caracara.

S2.1. Protect and enhance existing populations of Audubon's crested caracara on public and private land. Caracaras currently occur on several properties managed by the SFWMD in the Kissimmee River valley as well as other publicly owned land in south central Florida; however most pairs occur on private lands. Territories on private lands are critical to the survival and recovery of the caracara.

2.1.1. **Inform landowners of the presence of caracaras on their property**. Appropriate State and Federal authorities should inform landowners that their property contains resident caracaras.

2.1.2. **Encourage landowners to protect caracara nesting sites by providing incentives (awards, credits for mitigation, special recognition, etc.)**. Inform landowners of the amount of habitat needed around each nest and the level of human activity tolerated by each pair during nesting. Encourage landowners to adhere to guidelines derived from item S3.1.4. Investigate options for monetary or tax incentives to encourage lower intensity farming operations or preservation of native habitats in occupied and restorable areas. Encourage the media to focus on these land protectors. Also, provide public recognition for proper land management.

S2.2. **Develop and implement a plan to reintroduce Audubon's crested caracaras into suitable habitats within their historic range.** Caracaras once occurred in prairie habitat from northern Brevard County south to Collier County. Caracara sightings were once reported from as far north as Nassau County and as far south as the lower Keys in Monroe County. Efforts should be made to locate and map these formerly inhabited areas, to determine if it is feasible to restore habitat and expand the range of the caracara. This plan must identify the specific areas that are suitable for such reintroductions, protocols for determining when habitat is suitable for a reintroduction, the size of a reintroduced population, monitoring protocols for reintroduced populations, and land management prescriptions for reintroduction areas.

S2.3. **Encourage natural colonization of restored habitats by Audubon's crested caracaras**. Many areas within the historic range of the caracara are being restored as part of the COE and SFWMD's restoration projects in the South Florida Ecosystem. Other areas are being restored because of a change in land use in the Kissimmee River valley (such as the expansion of Three Lakes WMA). Dispersal of the caracara into restored areas from occupied sites should be encouraged by enhancing areas adjacent to active territories.

S2.4. **Introduce rehabilitated birds into expanded or restored areas whenever and wherever possible**. When caracaras are taken into captivity for rehabilitation purposes, those without permanent disabilities should be considered for release into expanded or restored areas when they have recovered. Myakka River SP has been recommended as a possible location for reintroducing caracaras that have been rehabilitated.

S2.5. **Establish rehabilitation centers for injured or sick caracaras found in the wild**. Lyons (1984, 1985) had considerable success in rehabilitating sick and injured caracaras in Texas. Traumatic injuries in Texas usually involve leg or foot injuries (from leg-hold traps) and gunshot wounds. Lyons found that caracaras quickly adapt to captive conditions, and respond well to medical treatment. By establishing a center in Florida, sick or injured caracaras could be rehabilitated and returned to the wild. This could also be accomplished by developing agreements with a local veterinarian, bird rehabilitation center, or university.

S2.5.1. **Develop an emergency program for removing injured or sick caracaras from the wild including a hotline number for notification of responsible individuals**. When a sick or injured caracara is located, it may be necessary to place the bird into a rehabilitation center where it can receive proper medical treatment. A rehabilitation center should consider such factors as housing, equipment, veterinary expertise, proximity to the present core distribution of caracaras, etc. Key individuals should be appointed to pick up sick or injured birds and transport them to the rehabilitation center. The phone numbers of these individuals should be provided to all wildlife officers within the core range of the caracara.

S2.5.2. **Establish a caracara rehabilitation team, made up of rehabilitation experts, raptor biologists, veterinarians, etc.**

S2.5.3. **Maintain accurate and detailed records on individuals brought in for rehabilitation.**

S2.5.4. **Determine where recovered birds should be released into the wild**. When sick or injured birds have recovered to the point that they can return to the wild, they should be released in expanded or restored habitat areas.

S2.5.5. **Monitor the health and status of Audubon's crested caracara that have returned to the wild**. Monitor rehabilitated birds through radiotelemetry to determine whether they survive. If the introduction of rehabilitated caracaras is successful, more widespread reintroductions could be accomplished with juvenile birds.

S2.5.6 **Conduct section 7 consultations on all Federal activities that may affect caracaras and their habitat.** Federal agencies shall consult with the FWS on any activities (authorized, funded, or carried out) that may affect caracaras. Such activities include: pesticide use, road building, construction of new facilities, training exercises, wetland fill, clearing for new runways, etc.

S3. **Conduct research to determine the basic biological needs of the caracara**. Although considerable research has been done on the biology and ecology of the Audubon's crested caracara, more information is necessary before this species can be properly managed and effects of habitat management actions assessed. Biological studies should be continued to complete our knowledge of the demographics of caracara populations (survivorship, fecundity, mortality, dispersal) and the relationship of these demographic variables to habitat availability and quality, particularly water regimes and fire management.

S3.1. **Determine habitat requirements of the caracara in Florida**. Habitat loss is believed to be the primary cause of caracara decline in Florida. Research to determine precise details are ongoing, but more information is needed on nesting and feeding habitat requirements, the percentage of forest or agricultural encroachment caracaras will tolerate, and their need for water. Precise details are also needed on the extent of caracara movement into other habitats for feeding and drinking purposes.

S3.1.1. **Determine essential habitat components**. Identify all the components that make up prime habitat. Prime habitat is the sum of all essential components, where their absence would make the habitat suboptimal or result in abandonment of the area for nesting and/or feeding. Determine the habitat components necessary for successful nesting and roosting. Determine the need for water in proximity to nests, and the level of tolerance to human disturbance during early and late reproductive stages. This action should involve the use of Geographic Information Systems and remote mapping since much of the occupied caracara territories are present on private lands.

S3.1.2. **Determine the minimum amount of nesting and feeding habitat needed to support a population of caracaras**. Determine the amount of nesting and feeding habitat needed to support a single pair of caracaras. Nesting habitat is relatively restricted, but territories extend over large areas. Therefore, maintaining nesting habitat might be the crucial factor in protecting the birds. Protection of nest sites from predators may be necessary at some nesting sites.

S3.1.3. **Formulate estimates of habitat carrying capacity under optimum conditions**. Determine the carrying capacity of nesting and feeding habitats of the Florida population of Audubon's crested caracara. This will allow scientists to evaluate which habitats are underutilized or overutilized. This knowledge is essential for management of the birds.

S3.1.4. **Establish habitat management guidelines to protect the nests and nesting pairs of Audubon's crested caracaras**. These guidelines should be modeled after the "Habitat Management Guidelines for the Bald Eagle in the Southeast Region" (FWS 1987). Their purpose will be to assist land owners, land managers, and regulatory biologists in avoiding impacts to caracaras.

S3.1.5. **Utilize current information and conduct additional research to develop a Population Viability Analysis for the caracara.** This analysis would be used to evaluate management and regulatory actions as well as other conservation strategies, including the development of reintroduced populations. It would also aid in determining which ecological factors are most critical for the survival and recovery of the species.

S3.2. **Compile caracara data into a central database at one location.** Gather historic data from all researchers. This data would be an important element in determining recovery of the population.

S4. **Develop and implement a program to monitor the status and trends of wild Audubon's crested caracara populations**. It will be necessary to continually monitor the stability and health of existing wild populations to assess recovery efforts.

S4.1. **Develop monitoring protocols and techniques for the Audubon's crested caracara**. Develop a set of monitoring protocols that are able to identify small changes in the size and distribution of Audubon's crested caracara populations over time.

S4.2. **Monitor Audubon's crested caracara populations on public lands to evaluate management actions**. Establish monitoring programs for the Audubon's crested caracara on public lands in south-central Florida to determine if fire management, water management, and other management actions are consistent with the recovery needs of the caracara.

S4.3. **Monitor the success of reintroduced Audubon crested caracara populations**. To determine whether recovery efforts are successful, it will be necessary to conduct periodic censuses and surveys of all introduced populations.

S5. **Increase public awareness of the biology, ecology, status and trends of the Audubon's crested caracara**. The public must be made more aware of the status and trends of the Audubon's crested caracara, its recovery needs, and opportunities to participate in the caracara's recovery. This public awareness program must include an effort to contact owners of lands that support populations of Audubon's crested caracaras; it must also include development and distribution of materials developed specifically to inform the public about the Audubon's crested caracara.

S6. **Assess reclassification criteria based on the results of research projects; revise as necessary.** One condition required to reach the recovery objective for the caracara is to ensure that the amount of nesting and feeding habitat needed to maintain stable or expanding populations remains stable or increases over a 10-year period.

Habitat-level Recovery Actions

H1. **Protect and enhance currently occupied habitat.** Alteration and habitat loss are primary threats to prairie species. As much of the remaining prairie habitat as possible must be secured. State and COE efforts to restore the Kissimmee River floodplain may provide habitat for prairie dependent species.

H1.1. **Protect privately owned, occupied lands wherever possible.** Particular effort should be made to acquire or protect lands on which prairie species reside.

H1.1.1. **Encourage the purchase of unprotected lands that support caracaras**. State, county, and local governments and private organizations can purchase lands. The FWS can consider purchase of land to protect endangered or threatened species through its Land Acquisition Planning System.

H1.1.2. **Use conservation easements and other non fee-title ownership options to maintain habitat**. Conservation easements, recognized under both Federal and State law, may protect habitat while allowing it to remain in private ownership. Non-binding conservation agreements with landowners may also prove useful. Investigating tax and monetary assistance or incentives should be a high priority for willing landowners.

H1.1.3. **Where private lands cannot be acquired, or protected through conservation easements, encourage landowners to maintain suitable habitat for the benefit of prairie species.** The private landowner must be informed of the needs and value of caracaras in order to obtain their cooperation in providing protection.

H1.1.4. **Maintain and enhance habitat on acquired lands or lands under conservation easements or agreements.** Conduct prescribed burns, selective thinning, or mechanical manipulation at periodic intervals to maintain dry prairie and pasture habitat and prevent forest encroachment.

Plant scattered cabbage palms, where needed, to serve as nesting sites for caracaras. Intensive rangeland improvements should be discouraged in prairie areas to maintain as many native vegetative species as possible.

H1.2 **Protect and enhance habitat on public lands**. Occupied caracara territories present on public land should be protected and enhanced for this species. Public lands that are occupied by caracara include Avon Park AFR in Polk and Highlands counties, and the Latt Maxcy property (Kissimmee Prairie State Preserve) in Okeechobee County. Federal land management agencies should try to protect, maintain, and enhance occupied habitat on all lands they manage. Habitat must be maintained in an early stage of succession through selective thinning and prescribed burning. Since caracara nesting is minimal on Avon Park AFR and this site is essential for the survival of the Florida grasshopper sparrow (Ammodramus savannarum floridanus), grazing should not be increased in this area, and prairie management should focus on the grasshopper sparrow. Other public lands should utilize the recommendations obtained from habitat component research on the caracara to determine which management actions are compatible with the survival of this species and the Florida grasshopper sparrow.

H1.2.1. **Conduct prescribed burns at periodic intervals.** Occupied areas should be burned in a mosaic fashion on a periodic rotational basis to maintain early stages of succession.

H1.2.2. **Maintain pastures in native vegetation to the extent possible.** Prairie species may be adversely affected if pasture lands are improved to the point where native vegetation is totally removed.

H1.2.3. **Do not allow reforestation of prairies.** Prairie species prefer unforested areas. Small patches of cabbage palm areas should be maintained to afford nesting sites for caracaras.

H1.2.4. **Establish appropriate burn seasonality.** Fire management should be conducted in all seasons although the majority of natural fire occurs in summer.

H2. **Create, restore, or expand occupied habitat wherever possible.** Habitat loss has occurred throughout the range of the caracara, and has been the primary factor threatening the survival of these animals. Conversion to higher intensity agricultural uses (e.g. sugar cane) may reduce the amount of useable habitat within a territory to the point that caracaras are unable to survive and reproduce. These areas can be enhanced to become suitable again. Mosaics of agriculture and native prairie may afford the landowner best use of their land while maintaining enough suitable habitat for caracaras.

H2.1. **Expand habitat in currently occupied areas.** Wherever possible, enhance prairie habitat in the vicinity of occupied habitat. Use prescribed burning and mechanical treatment or planting of cabbage palms to enhance areas to attract caracaras.

H2.2. **Restore habitat in currently unoccupied areas.** Delineate areas which once supported the caracara but are no longer suitable and restore them to a suitable condition. This may involve cabbage palm plantings and fire management.

H3. **Conduct research on caracara response to habitat modifications.** Little is known concerning the level of tolerance or the extent to which habitat within caracara home ranges may be modified before the birds abandon the site. The response to habitat modification from rangeland to a higher intensity agricultural use should be investigated. A study employing radiotelemetry should be designed and implemented.

H3.1. Determine why certain habitat areas are not used. Certain areas are apparently unsuitable for caracaras since they are not used. The cause(s) for the lack of use should be investigated.

H3.2. Determine which elements need to be modified to make unused areas suitable for the caracara. The unoccupied habitat may lack suitable nest trees or be too wooded. Pesticide contamination, especially in agricultural areas, may be a factor. Water quality analysis should be conducted to determine whether agricultural chemicals are making water unsuitable for caracaras. Blood sampling of individual caracaras should be used to determine levels of various chemicals present in the population. Adverse conditions present on potentially suitable habitat must be recognized and corrected before caracaras can expand their range, or be reintroduced.

H4. Use satellite imagery and updated aerial photographs to monitor changes in land use in the core of the caracara population. This information may be essential in determining the probability of recovery of caracaras, especially in response to agricultural development pressure.

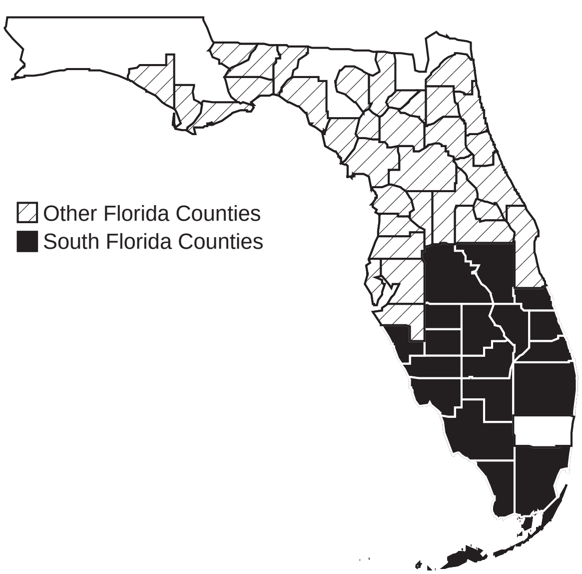
H5. Inform the public. Prairie communities are unique to central Florida and both the caracara and Florida grasshopper sparrow are only found in this community. The general public needs to be informed of the value of prairie, and its management needs.

Bald Eagle

Haliaeetus leucocephalus

Federal Status:	**Threatened (July 12, 1995)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. Florida distribution of the bald eagle.



The bald eagle is the only member of the sea eagle genus commonly found in the western hemisphere. In the eastern U.S., the bald eagle is the largest raptor and is commonly associated with large bodies of water. Bald eagles are considered common in South Florida and are known to breed throughout the state. Nest sites are usually located near large rivers, lakes, or estuaries where the eagle feeds primarily on fish and water-dependant birds. This large raptor was adversely affected by the bioaccumulation of pesticides, principally DDT. These organochlorines interfered with calcium metabolism, which resulted in eggshell thinning. Reduced productivity resulted in population declines and jeopardized the existence of this species. Banning of DDT and other organochlorines during the early 1970s reversed the decline in bald eagle numbers throughout its range. In Florida, overall bald eagle nesting has increased from a few hundred nesting territories in 1973 to 831 in 1995. Similar increases in nesting activity have been documented throughout the remainder of its range. Current threats to the bald eagle include: habitat fragmentation and loss, collisions with cars and powerlines, and shooting. In recognition of increases in the eagle population, efforts are currently underway to reevaluate the management of bald eagles in the southeastern U.S. and to refine conservation recommendations to reduce eagle-human conflict.

This account represents South Florida's contribution to the range-wide recovery plan for the bald eagle (FWS 1989).

Description

The bald eagle is a large raptor with a wingspan of about 2.1m and total body length of 0.9 m. Females are typically larger than males, although distinguishing them can be difficult unless both are side-by-side. Adult plumage is mainly dark brown with a pure white head and tail, while the eyes, feet, and bill are yellow (Palmer 1988). First year juveniles are often chocolate brown to blackish, sometimes with white mottling on the tail, belly, and underwings

(Palmer 1988). They may be confused with turkey vultures (*Cathartes aura*) in flight. The head and tail become increasingly white with age until full adult plumage is reached in the fourth or fifth year of age. During this same period, the legs, bill, and eyes change gradually from black to yellow.

Taxonomy

The bald eagle is in the order Falconiformes, family Accipitridae. Of the 289 species of hawk-like birds, there are 59 species of eagles (Grossman and Hamlet 1964, FWS 1989). The sea and fish eagles account for 11 species comprising 3 genera, of which eight species are in the genus *Haliaeetus*. The bald eagle is the only member of the genus *Haliaeetus* which regularly occurs in North America.

Also our nation's symbol, the bald eagle was first described in 1766 as *Falco leucocephalus* (Linnaeus), and was later renamed the southern bald eagle (*Haliaeetus leucocephalus leucocephalus*, Linnaeus). In 1897, a new northern subspecies was identified as *H. l. alascanus* (Townsend). Although the two subspecies of *leucocephalus* were described based on size and weight, few ornithologists acknowledge these subspecies because there is a continuous gradient in size from north to south throughout the range.

Distribution

The bald eagle was historically found throughout the North American continent from the Aleutian Islands and western Alaska to the Maritime Provinces of Canada and south to the Florida Keys, the Gulf Coast, and Baja California (Curnutt 1996). Apart from Alaska, most nesting bald eagles were found in Florida, the Chesapeake Bay area, the Great Lakes region, Maine, and the Pacific Northwest. In Florida, eagles were historically found throughout the state, although they were probably most abundant along large rivers and lakes. Eagles were probably never numerous in the panhandle of Florida. Currently in South Florida, bald eagle nesting is prevalent along the southwest Gulf Coast and the Kissimmee River valley including Polk and Osceola counties (Curnutt 1996) (Figure 1).

Habitat

Bald eagles are considered a water-dependant species typically found near estuaries, large lakes, reservoirs, major rivers and some seacoast habitats (Robards and King 1966, King *et al*. 1972, Weekes 1974, Whitfield *et al*. 1974, Gerrard *et al*. 1975, Grier 1977, Anthony and Isaacs 1989, Wood *et al*. 1989). Their distribution is influenced by the availability of suitable nest and perch sites near large, open waterbodies, typically with high amounts of water-to-land edge. Throughout their range, bald eagles demonstrate a remarkable ability to tolerate perturbations to their habitat. Their adaptability to a variety of habitat conditions makes generalizations about habitat requirements and nesting behavior difficult. Though variable, eagles have basic habitat requirements that must be met in order to successfully reproduce and survive during the winter or non-nesting season.

Bald eagle.
Photograph is clipart from Corel Corporation (1996).

Nesting Habitat

Nesting habitat includes a nest tree, perch, and roost sites, and adjacent high-use areas but usually does not include foraging areas. The active nest, perch, roost sites, and use areas around the nest, comprise the nesting territory. The size and shape of a defended nesting territory varies greatly depending on the terrain, vegetation, food availability, and eagle density in the area. Generally, bald eagle nesting habitat is adjacent to, or near large bodies of water that are used for foraging (Herrick 1924, Stevenson and Anderson 1994). Nest sites must also provide good visibility, and a clear flight path to the nest (Robards and King 1966, Anthony *et al*. 1982, Anthony and Isaacs 1989, Montana Bald Eagle Working Group 1991).

Most breeding eagles construct nests within several hundred meters of open water (Robards and King 1966, Robards and Hodges 1977, Henney *et al*. 1978), though these distances may increase in areas occupied by humans. Shorelines provide fishing and loafing perches, nest trees, and open flight paths (Whitfield *et al*. 1974). In most studies of nesting bald eagles, at least 90 percent of the nests were less than 200 m from open water. In Florida, most nests were located within 3 km of open water, substantially further than other reported distances (McEwan and Hirth 1979, Wood *et al.* 1989). In extreme southern Florida, nest sites are located principally near the coast, within 50 m of open water (W.B. Robertson, Jr., former NPS and USGS/BRD biologist, personal communication 1998).

Most eagles select nest trees that are larger and taller than surrounding trees (Grubb 1980, Anthony *et al*. 1982, Anthony and Isaacs 1989), except in extreme southern Florida where nests are typically located in mangrove snags (W.B. Robertson, Jr., former NPS and USGS/BRD biologist, personal communication 1998). Forest stands containing the nest site are usually multi-layered, mature, or old-growth stands. Most nest trees are alive, even though mangrove snags are used extensively in extreme southern Florida. (W.B. Robertson, Jr., former NPS and USGS/BRD biologist, personal communication 1998). Nests are usually positioned below the treetop in live conifers, although many tree species have been used for nesting. The structure of the tree appears to be more important to nesting eagles than the species of the tree. Clear flight paths and a good line of sight are essential and nests are often found at or above the surrounding forest canopy in very large trees with open crowns and sturdy horizontal limbs.

Perch sites serve many functions. They may be used to hunt from, consume food, display, or act as sentry posts to advertise and defend the nesting territory (Montana Bald Eagle Working Group 1991). Perches may also be used for loafing, warming, drying, and refuge from the wind or rain. Unlike perches, roost sites are used at night for resting. Some perch sites may serve as roosts, but roost sites need not be near water and foraging sites. Roost trees are usually the tallest, dominant tree in the surrounding forest and are selected to provide protection from the wind and cold (Keister and Anthony 1983, Stalmaster 1987).

In Florida, nests are often in the ecotone between forest and marsh or water, and are constructed in dominant or co-dominant living pines (*Pinus* spp.) or bald cypress (*Taxodium distichum*) (McEwan and Hirth 1979). About 10 percent of eagle nests are located in dead pine trees, while 2 to 3 percent occur in other species such as Australian pine (*Casuarina equisetifolia*) and live oak (*Quercus virginiana*). The stature of nest trees decreases from north to south (Wood 1987, Wood *et al*. 1989) and in extreme southwest Florida eagles nest in black (*Avicennia germinans*) and red mangroves (*Rhizophora mangle*), half of which are snags (Curnutt and Robertson 1994). Nest trees in South Florida are smaller and shorter than reported elsewhere; however, comparatively they are the largest trees available (Wood *et al.* 1989, Hardesty 1991). The small size of nest trees in South Florida relative to other nest sites throughout the eagle's range is due to the naturally smaller stature of *Pinus elliottii*, *P. taeda*, *P. palustris* and *P. clausa* in South Florida, and the lack of pines (*Pinus* spp.) in extreme southern Florida.

Winter Habitat

In southern peninsular Florida, bald eagles breed and nest during the temperate winter. Contrary to changes in habitat use exhibited by northern bald eagle populations, eagles in the south do not substantially alter habitat use throughout the year. Some adults may remain in and defend their nesting territory outside of the breeding season (Palmer 1988), use or defend portions of their territory, or disperse and congregate at predictable food sources such as landfills. Of those adults that do not maintain territories throughout the year, most are not thought to leave the state. Conversely, following fledging, many juvenile eagles disperse north and summer from along the Atlantic Coast west to the Appalachian Mountains and north as far as Canada (Broley 1947, Wood and Collopy 1995).

Behavior

Reproduction

Bald eagles are monogamous and annual courtship behavior reinforces pair bonds (Palmer 1988). Pair bond formation includes dramatic pursuit flights, high soaring, talon locking and cartwheeling (Johnsgard 1990). In establishing territories, eagles may also fly around the perimeter of their nesting areas visually communicating their presence. Pair bond behavior, as well as territory establishment and defense, probably occur concurrently throughout much of the eagle's range. Successful pair bond formation ultimately leads to nest site selection and nest construction for newly formed pairs or established pairs without nests. For pairs which have previously nested, nest repair or construction of an alternate nest may occur concurrent with copulation.

In South Florida, nesting activities generally begin in early September, with egg laying occurring as early as late October, and peaking in the latter part of December. Depending on latitude, incubation may be initiated from as early as October to as late as March. Clutches usually consist of one or two eggs, but occasionally three or four are laid. Incubation takes approximately 35 days and fledging occurs within 10 to 12 weeks of hatching. Parental care may extend 4 to 6 weeks after fledging even though young eagles are fully developed and may not remain at the nest after fledging (FWS 1989).

Foraging

The bald eagle is an opportunistic feeder, but in South Florida the bulk of the diet is fish. Broley (1947) found catfish (*Ictalurus* spp.), mullet, and turtles to be the most common food items found at nests in Florida. He also found that the variety of prey items differs among individual pairs. McEwan (1977) reported 79 percent fish and 17 percent bird prey, by occurrence, based on 788 animal remains recovered from nests. Of these, the dominant items were catfish and the American coot (*Fulica americana*). Eagles in Florida Bay may take birds as large as great white herons (*Ardea herodias*) (J. Ogden, SFWMD, personal communication 1998).

Bald eagles typically hunt from perch sites or by soaring over foraging areas. Most foraging occurs early in the morning with another, less intense feeding period usually occurring late in the afternoon.

Movements

Juvenile birds fledged in Florida are highly migratory, with more than one-third of the recoveries made 1,620 km or more north of Florida, all during the non-nesting season (Broley 1947). Wood and Collopy (1995) found that juvenile Florida eagles tend to move rapidly to northern summering grounds ranging from South Carolina to Prince Edward Island, Canada. Most radio-collared juveniles return each year but a small proportion remain away for 2 to 3 years. The southward migration of juveniles is more dispersed and leisurely.

Little information is available on the dispersal of bald eagles as they approach early adulthood. If paired, it is assumed these birds remain in South Florida as do most other paired adults. If not paired, it is not clear whether these birds continue to migrate north during summer or remain in South Florida with the breeding adults. Similarly, it is not known whether all birds fledged in South Florida ultimately breed in South Florida.

Relationship to Other Species

Throughout their extensive range, bald eagles live sympatrically with many other species, but rarely interact except during the breeding season. Interspecific competition for nests may occur with great horned owls (*Bubo virginianus*), red-tailed hawks (*Buteo jamaicensis*), and several species of crows (*Corvus* spp.). Throughout the year, other bird species may occasionally mob or attack eagles, but these short-term interactions are not considered significant. Raccoons may also depredate eagle nests. Eagles may impact nesting ospreys (*Pandion haliaetus*) by disrupting nesting patterns, and they may also "steal" prey from ospreys (J. Ogden, SFWMD, personal communication 1998).

Interaction between eagles and humans is the single most important factor affecting bald eagles. As discussed in more detail below, anthropogenic affects have been responsible for degradation of nesting, foraging, and wintering habitat throughout the species' range. However, efforts to conserve and manage eagle habitat are resulting in the improvement of the bald eagle population throughout much of its range.

Status and Trends

Bald eagle nesting in Florida, which has traditionally been used to assess population status, has been widely studied, and published accounts are available from a variety of sources. Broley (1947) was the first to document a decline in eagle nesting in the late 1940s. A further decline from 73 to 43 active nesting areas was reported for west central Florida between 1936 and 1956 (Broley 1958). Howell (1937, 1941, 1949, 1954, 1958, 1962, 1968, 1973) reported a decline in nesting around Merritt Island from 24 nests in 1935 to four nests in 1971. McEwan and Hirth (1979) provided additional information on productivity and nest site selection. An excellent summary was provided by Peterson and Robertson (1978), in which they characterized the bald eagle population of the 1970s as less than 50 percent of historic numbers and still slowly decreasing. In contrast, Everglades NP has conducted eagle nest surveys since the early 1960s. These surveys indicate that nesting in Everglades NP remained stable between the 1960s and 1990s at about 45 to 50 nesting pairs (J. Ogden, SFWMD, personal communication, 1998).

Prompted by the work of Broley, State natural resource agencies and conservation organizations initiated surveys for nesting bald eagles in the early 1950s, which have continued in some form to the present day. Unfortunately, many of these studies were short term and covered only portions of the nesting range of the species. These studies did reveal, however, that in many locations, bald eagle numbers had declined from historic numbers. A nationwide survey by the FWS, State wildlife agencies, and conservation groups in 1974 indicated that eagle numbers and their reproductive success in certain areas were low enough to warrant protective actions. As more and more states began systematic surveys for bald eagles, better information became available to assess the status of the bald eagle throughout much of its range.

Since being listed as endangered, bald eagle populations have continuously improved. Improvement in population numbers resulted primarily from the

Table 1. Florida bald eagle nesting trends, 1973-95 (from Nesbitt 1995).

Year	# Active Territories	# Successful Nests	# Young Produced	Young/Active Territory	Young per Successful Nest
1973	88	55	74	0.84	1.35
1974	157	82	117	0.75	1.43
1975	246	145	213	0.87	1.47
1976	241	162	260	1.08	1.61
1977	270	170	265	0.98	1.56
1978	319	182	262	0.82	1.44
1979	353	223	324	0.92	1.45
1980	363	212	345	0.95	1.63
1981	359	234	368	1.03	1.57
1982	340	240	356	1.04	1.48
1983	374	231	351	0.94	1.52
1984	378	247	351	0.93	1.42
1985	387	280	435	1.12	1.55
1986	329	247	429	1.30	1.74
1987	391	251	400	1.02	1.59
1988	399	276	448	1.12	1.62
1989	439	310	474	1.08	1.53
1990	535	366	585	1.09	1.60
1991	601	285	591	0.98	1.54
1992	652	468	729	1.12	1.56
1993	667	447	679	1.02	1.52
1994	779	591	951	1.22	1.61
1995	831	621	982	1.18	1.58
Total	9,498	6,425	9,989	1.05	1.56
10-year Average	**518**	**362**	**572**	**1.11**	**1.59**

banning of DDT and other persistent organochlorines, and has been accelerated by other recovery efforts. In 1963, a National Audubon Society survey reported only 417 active nests in the lower 48 states with an average of 0.59 young produced per active nest. In 1995, about 4,450 occupied breeding areas were reported by the lower 48 states with an estimated average young produced per occupied territory of 1.17 (J. Millar, FWS, personal communication 1996). Compared to 1974, for example, the number of occupied breeding areas in the lower 48 states has increased 4.6 times. Since the late 1970s, the species has doubled its breeding population every 6 to 7 years (FWS 1995).

In Florida, bald eagle nesting and productivity has increased dramatically since the early 1970s (Table 1). Florida currently supports the highest number of breeding bald eagles of any southeastern state, supporting approximately 70 percent of the occupied territories in this region (Nesbitt 1995).

Habitat Alteration

The human population in Florida has grown dramatically over the past several decades. Between 1980 and 1995, the human population grew from an estimated 9.7 million to 14.2 million, making Florida the third most populous state (Florida Commission on Government Accountability to the People 1996). Human population growth in Florida has resulted in extensive alterations in land use. Kautz (1993) estimated that as of 1987, Florida's landscape was composed of 30 percent agricultural land and 13 percent urban development, leaving 57 percent in natural to semi-natural land cover. Intensive conversion of natural plant communities to agricultural, residential, and commercial uses has encroached, and continues to encroach, on bald eagle nesting and foraging habitats (Heinzman 1961, 1962; Wood *et al.* 1989). Adverse effects are particularly evident near water bodies since humans and eagles both prefer waterfront locations (Harris *et al.* 1987, Wood *et al.* 1989).

Habitat alterations affect the quantity, quality, and distribution of essential environmental factors needed to support bald eagles. Changes in the landscape reduce or fragment natural vegetative communities, thereby decreasing the suitability of nest sites. Human population growth and associated land alterations are also responsible for degradation of many of Florida's surface waters, indirectly affecting bald eagle foraging areas. In addition to the direct effects of altering the physical habitat, human growth, and the infrastructure necessary to support that growth, often indirectly result in an increased exposure of nesting bald eagles to human disturbance. New roads, houses, commercial complexes, agriculture, and recreational facilities which result from land conversions may have adverse effects on nesting eagles.

Nesting bald eagles are more sensitive to disturbance than non-nesting or wintering birds, and the early stages of the breeding cycle (nest construction or repair, egg laying, and incubation) are the most critical time (Mathisen 1968, Weekes 1974). Bald eagles are more likely to abandon a nest early in the season before a bond is established or young hatch. The vulnerability of eggs or young to adverse weather is also most critical early in the season. Disturbances later in the nesting cycle may be a problem if eaglets fledge prematurely (Grier 1969).

Human disturbance has been shown to reduce productivity, nest success, and territory use (Newman *et al*. 1977, Grubb 1980, Stalmaster 1987, Anthony and Isaacs 1989, Buehler *et al*. 1991, Montana Bald Eagle Working Group 1991, Steidl 1994, Anthony *et al.* 1995). In Oregon, Anthony and Isaacs (1989) found that nests were constructed further from human disturbances (recreational activities and roads) than were old nests in the same territory. Similarly, Fraser *et al*. (1985) found that nests on developed shorelines tended to be moved further from the water than nests on undeveloped shorelines. Segments of the Chesapeake Bay shoreline historically used for nesting have now become so saturated with human activity that bald eagles no longer use these sites (Buehler *et al.* 1991). Similarly, as shoreline development and human activity increases, eagles often rebuild nests further inland to avoid disturbance (Whitfield *et al*. 1974, Newman *et al.* 1977, Fraser *et al.* 1985). Bald eagles have altered nesting activity to avoid human disturbances in Saskatchewan and Manitoba (Gerrard *et al*. 1975) and forestry operations in western Florida (Broley 1947) and Oregon (Anthony and Isaacs 1989). Grubb (1980) showed that nests closer to human activity were less productive than secluded nests.

The effects of recreational disturbances on wintering and breeding eagles has been extensively researched. Most of this work has focused on eagle habitat along large rivers, lakes, and reservoirs in the Pacific Northwest. In general, it was found that recreational activities usually disrupt eagles temporarily over short time periods. In Florida, Wood and Collopy (1995) indicated that boating use throughout the year limited bald eagle use of foraging areas. Short term disturbance may have a cumulative impact and affect individual fitness through reduced reproductive success (Stalmaster and Newman 1978, Knight and Knight 1984, Harmata and Oakleaf 1992, Anthony *et. al*.1995).

The response of bald eagles to habitat change has not been comprehensively evaluated in Florida. However, as discussed above, research in other portions of the eagle's range indicates that in some situations, nesting bald eagles respond negatively to human disturbance. Florida's bald eagle population has not shown any overt signs of stress (reduced territory occupancy, decreased productivity, increased nest failures, etc.). Recent analyses conducted by the GFC indicate that productivity of nests in urban areas did not differ significantly from nests in more rural areas (S. Nesbitt, GFC, personal communication 1998). However, it is generally believed that the threshold at which the stressors will first be recognized is rapidly approaching, particularly in the urban areas of southwestern and central portions of the State. In these areas, little unoccupied habitat remains and it is expected that eagles will begin nesting in areas more susceptible to disturbance.

Mortality

Within the lower 48 states, shooting has historically been a major source of mortality for bald eagles (Stalmaster 1987). Mortality from shooting is often expressed as a percentage of the total deaths. Published estimates of mortality from shootings are as follows: 62 percent from 1961 to 1965 (Coon *et al.* 1970), 41 percent from 1966 to 1968 (Mulhern *et al.* 1970), 46 percent from 1969 to 1970 (Belisle *et al.* 1972), 35 percent from 1971 to 1972 (Cromartie *et al.* 1975), 25 percent from 1973 to 1974 (Prouty *et al.* 1977), and 20 percent from 1975 to 1977 (Kaiser *et al.* 1980). Since the early 1980s, no systematic analyses of bald eagle mortality have been conducted; however, recent evidence suggests that mortality resulting from shooting is now exceeded by collisions with powerlines and automobiles (S. Nesbitt, GFC, personal communication 1998).

Perhaps the most dramatic declines in bald eagle populations nationwide were caused by environmental contaminants. Organochlorine compounds (DDT and its metabolites) are known to inhibit calcium deposition, which caused eggshell thinning, ultimately reducing reproductive success (Radcliffe 1967, Hickey and Anderson 1968). Mulhern *et al.* (1970) found widespread occurrence of DDT, DDE, and DDD in eagle carcasses; and at least one female had lethal levels of DDT and DDD. Similarly, cyclodiene dieldrin had been documented at lethal levels in eagles (Mulhern *et al.* 1970). Results of measurements from 87 eggshells collected from 1984 to 1987 from Florida nests showed that the shells were only slightly thinner, on average, than pre-1947 eggs. However, there were a few eggs with shells as much as 29 percent thinner indicating that there may still be localized problems with residual contaminants (Wood *et al.* 1989). Since a 1972 ban on the use of DDT in the U.S., increases in eagle productivity has been rapid.

Lead poisoning has been documented as a significant source of mortality in eagles (Pattee *et al.* 1981). The National Wildlife Health Research Center has diagnosed lead poisoning in more than 225 eagles during the last 15 years. Lead poisoning occurs when eagles eat prey that contains lead shot or has assimilated lead into its own tissues. Winter killed waterfowl that have ingested lead shot or were crippled during hunting season are typical sources of lead contamination (Stevenson and Anderson 1994). Chronic low levels of lead increase susceptibility to a variety of mortality factors including: neurological dysfunction, behavioral and learning aberrations, anemia, and increased susceptibility to disease. Restrictions on the use of lead shot for waterfowl hunting has reduced the incidence of lead contamination in bald eagles in the U.S.; however, lead shot is still used in other portions of the eagles' range *(e.g.* Canada and Mexico).

Mercury, in the form of methylmercury, is one of the most toxic naturally occurring substances. Mercury is metabolized at very slow rates and may accumulate in tissues over time resulting in a variety of sublethal effects including: reduced fitness, reproductive impairment, brain lesions, paralysis, and reduced survival of offspring (Fimreite and Darstad 1971, Heinz 1975, Pass 1975, Finley and Stendell 1978, Heinz 1979, Eisler 1987, Wren *et al.* 1995). Elevated mercury levels have been reported in bald eagles in the Northeast and Great Lakes region (Evans 1993); Ontario, Canada (Evans 1993); Oregon (Frenzel and Anthony 1989); and Alaska (Evans 1993). In South Florida, elevated mercury has been found in fish, alligators (*Alligator mississippiensis*), raccoons (*Procyon lotor*), Florida panthers (Puma (=Felis) concolor coryi) and some wading birds (Hord *et al*. 1990, Facemire and Chlebowski 1991, Roelke *et al*. 1991, Spalding and Forrester 1991, Brim *et. al*. 1994, Sundlof *et. al.* 1994).

Limited information is available on the bioaccumulation of mercury in bald eagles in South Florida. Preliminary analysis of blood from eagles in Florida Bay, Everglades NP, showed a mean level of 0.28 parts per million (ppm) in 1993 and a mean level of 0.31 ppm in 1995 (B. Mealy, Miami Museum of Science, personal communication 1996). These data, however, are derived from few samples and over a limited geographical range and may not adequately represent the threat of mercury contamination. Wood *et al*. (1993) collected blood, tissues, and feathers from bald eagles in central and northern Florida and found mercury levels in bald eagles to be above background levels that were considered high enough to elicit sublethal effects. Unfortunately, without extensive monitoring, sublethal effects such as changes in growth, development, reproduction, and behavior are difficult to identify and quantify. However, available information for South Florida indicates that mercury contamination and bioaccumulation in the environment and in other species may already be a problem (Royals and Lange 1990, Facemire and Chlebowski 1991, Spalding *et al*. 1994, Sundlof *et al*. 1994). Since many of the species studied are prey or are representatives of other species that may be prey, it is likely that the transfer of mercury to eagles will remain a conservation problem.

Management

A nationwide recovery program for the bald eagle was established in the mid-1970s. The lower 48 states were divided into five recovery regions: Chesapeake Bay, Pacific, Southeastern, Northern States, and Southwestern. A recovery plan was prepared for each region by separate recovery teams composed of species experts in each geographic area. Each team established recovery goals and identified specific tasks needed to achieve these goals. In the southeastern U.S., the recovery plan established the reclassification criteria from endangered to threatened as 600 or more occupied territories throughout at least 75 percent of the eagle's historical range. In addition, reclassification of the southeastern population required that more than 0.9 young be produced per occupied nest, greater than 1.5 young be produced per successful nest, and at least one young be produced in 50 percent of the nests for each nesting season (FWS 1989). These criteria were based on a 3 year average. Delisting criteria have not been established for the bald eagle in the southeastern U.S.

To help achieve recovery goals for the bald eagle, the FWS, with the assistance of State wildlife resource agencies, produced bald eagle habitat management guidelines that provide recommendations to avoid or minimize detrimental human-related impacts on nesting bald eagles (FWS 1987). These habitat management guidelines provide much of the direction for the management of bald eagles in the U.S. and include measures designed to maintain or improve environmental conditions (FWS 1987). Though the guidelines vary slightly from region to region, they generally provide for the spatial and temporal protection of nesting and foraging sites and flight paths. These guidelines have been widely adopted by Federal and State agencies and are applied to both public and private lands.

A principal component of the guidelines for the southeastern U.S. includes a recommendation that two protective zones be established around bald eagle nests. A primary zone is recommended to encompass an area extending outward from the nest tree between 230 m and 460 m. The exact distance encompassed by this zone is dependent on the location of feeding areas, roosts, and perch sites within a particular nesting territory (FWS 1987). Within the primary zone it is recommended that certain activities be avoided at all times. Activities to be avoided include: residential, commercial, or industrial development, tree cutting, logging, construction, mining, or use of chemicals toxic to wildlife. Activities such as human entry and low-level aircraft flights over the primary zone are not recommended during the nesting season, but may be allowed in some situations during the non-nesting season.

The guidelines recommend a secondary zone extending from the outer boundary of the primary zone outward up to 1.6 km. Restrictions within the secondary zone are recommended to minimize disturbance that might compromise the integrity of the primary zone and to protect areas used by the nesting eagles outside of the primary zone (FWS 1987). Restrictions are recommended on new commercial and industrial development, construction of multi-story buildings or high-density housing developments, construction of roads that increase access to nest sites, and use of chemicals toxic to wildlife. Most other sources of disturbance are allowed within the secondary zone during the non-nesting season.

The guidelines have been used many times in Florida to avoid or minimize adverse effects to nesting bald eagles. Nesbitt *et al.* (1993) evaluated the effectiveness of the guidelines in protecting bald eagle habitat and found that eagle use and productivity was not significantly affected by human encroachment when the guidelines were implemented and adhered to. These results indicate that limited human encroachment was not yet affecting nesting eagles and that no modifications to the guidelines were needed in Florida.

Evaluation of long-term trends in nest success and productivity should provide the information necessary to evaluate continued effectiveness of the guidelines. Data analyses are anticipated to reveal regional differences, principally due to variations in duration, type, and magnitude of threats to bald eagles. If the results indicate decreasing trends either regionally or statewide, guideline modifications will identify more stringent protection of breeding and foraging habitat. Conversely, where trends are increasing, it is expected that the modified guidelines will relax some or all of the protective restrictions.

The effects of disturbance on bald eagles have become apparent over time in portions of the eagles' range. It is clear that bald eagle habitat is slowly being altered or destroyed throughout much of the species' range. The impacts, as described by Stalmaster (1987) are "cumulative and may have few effects on a local and short-term basis, but because it [habitat alteration] is so widespread and long-term in nature, the effects to eagles are tremendous." Stalmaster (1987) was referring to the effects of forest management on bald eagle nesting when he stated that "once altered, forest habitat is rarely allowed to return to the old-growth state that the eagle prefers ...the last vestiges of old growth are now being removed and replaced with fast-growing, economically efficient forest stands." Throughout much of the bald eagles' range, we believe that nesting and wintering habitats are threatened by many other types of anthropogenic factors that will slowly make these areas unsuitable for eagles.

However, by all accounts, the bald eagle population in South Florida has increased dramatically over the last 20 years. The success of eagles in Florida may ultimately be the primary reason for the recovery and delisting of eagles in the southeastern U.S. Even in this time of optimism, there remain concerns about the future of bald eagles in South Florida. Nesbitt *et al*. (1993) indicated that even though the number of nesting eagles in Florida has recovered to one-half to two-thirds of historic numbers, the amount of feeding and nesting habitat remaining in Florida may not be sufficient to support the eagle population that existed in the early 1900s. Wood *et al*. (1989) indicated that Florida eagles are faced with significant disturbances from human land-use patterns, especially land alterations associated with urban development. In combination, these and other factors may be working synergistically to reduce the value of bald eagle habitat in Florida. Currently, however, the threshold of human disturbance which triggers large-scale observable adverse effects has not yet been reached or is not detectable under current monitoring programs.

In Florida, only the total number of nesting eagles and statewide reproductive success have been used as the benchmarks for assessing the health of the bald eagle population. Undoubtedly, many of the same cumulative effects noted elsewhere are affecting eagles in South Florida. Whether bald eagles in South Florida respond adversely to these cumulative effects is a question that must be answered before we proclaim South Florida's eagle population to be recovered.

Literature Cited

Anthony, R.G., R.L. Knight, G.T. Allen, B.R. McClelland, and J.I. Hodges. 1982. Habitat use by nesting and roosting bald eagles in the Pacific Northwest. Transactions of the North American wildlife natural resources conference, 47:332-342.

Anthony, R.G. and F.B. Isaacs. 1989. Characteristics of bald eagle nest sites in Oregon. Journal of Wildlife Management 53(1):148-159.

Anthony, R.G., R.J. Steidl, and K. McGarigal. 1995. Recreation and bald eagles in the Pacific Northwest. Pages 223-241 *in* R.L. Knight and K.J. Gutzwiller, eds. Wildlife and recreationists coexistence through management and research. Island Presses; Washington, D.C.

Belisle, A.A., W.L. Reichel, L.N. Locke, T.G. Lamont, B.M. Mulhern, R.M. Prouty, R.B. DeWolf, and E. Cromartie. 1972. Residues of organochlorine pesticides, polychlorinated biphenyls, and mercury and autopsy data for bald eagles, 1969 and 1970. Pesticide Monitoring Journal 6:133-138.

Brim, M.S., D. Bateman, R. Jarvis, and G. Carmody. 1994. Mercury in fishes of the J.N. “Ding” Darling National Wildlife Refuge. U.S. Fish and Wildlife Service Publication PCFO-EC 94-03; Washington, D.C.

Broley, C.L. 1947. Migration and nesting of Florida bald eagles. Wilson Bulletin 59:3-20.

Broley, C.L. 1958. Plight of the American bald eagle. Audubon 60(4):162-163, 171.

Buehler, D.A., T.J. Mersmann, J.D. Fraser, and J.K.D. Seegar. 1991. Effects of human activity on bald eagle distribution on the northern Chesapeake Bay. Journal of Wildlife Management 55(2):282-290.

Coon, N.C., L.N. Locke, E. Cromartie, and W.L. Reichel. 1970. Causes of bald eagle mortality, 1960-1965. Journal of Wildlife Disease 6:72-76.

Cromartie, E., W.L. Reichel, L.N. Locke, A.A. Belisle, T.E.G. Kaiser, T.G. Lamont, B.M. Mulhern, R.M.S. Prouty, and D.M. Swineford. 1975. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for bald eagles, 1971-72. Pesticide Monitoring Journal 9:11-14.

Curnutt, J.L. 1996. Southern bald eagle. Pages 179-187 *in*: J.A. Rodgers Jr., H.W. Kale II, H.T. Smith, eds. Rare and endangered biota of Florida, University Press of Florida; Gainesville, Florida.

Curnutt, J.L and W.B. Robertson, Jr. 1994. Bald eagle nest site characteristics in south Florida. Journal of Wildlife Management 58(2):218-221.

Eisler, R. 1987. Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service biological report No. 85(1.10); Washington, D.C.

Evans, E. 1993. Mercury and other metals in bald eagle feathers and other tissues from Michigan, nearby areas of Minnesota, Wisconsin, Ohio, Ontario, and Alaska 1985-89. Michigan Department of Natural Resources report number 3200.

Facemire, C.F. and L. Chlebowski. 1991. Mercury contamination in a wood stork (*Mycteria americana*) from west-central Florida. U.S. Fish and Wildlife Service, publication number VBFO-91-CO3; Vero Beach, Florida.

Fimreite, N. and L. Darstad. 1971. Effects of dietary methlymercury on red-tailed hawks. Journal of Wildlife Management 35:293-300.

Finley, M.T. and R.C. Stendell. 1978. Survival and reproductive success of black ducks fed methylmercury. Environmental Pollution 16:51-64.

Florida Commission on Government Accountability to the People. 1996. Benchmarks report. Executive Office of the Governor; Tallahassee, Florida.

Fraser, J.D., L.D. Frenzel, and J.E. Mathisen. 1985. The impact of human activities on breeding bald eagles in north-central Minnesota. Journal of Wildlife Management 49:585-592.

Frenzel, R.W. and R.G. Anthony. 1989. Relationship of diets and environmental contaminants in wintering bald eagles. Journal of Wildlife Management 53:792-802.

Gerrard, J.M., P.N. Gerrard, W.J. Maher, and D.W.A. Whitfield. 1975. Factors influencing nest site selection of bald eagles in northern Saskatchewan and Manitoba. Blue Jay 33(3):169-176.

Grossman, M.L., and J. Hamlet. 1964. Birds of prey of the world. Bonanza Biological Books; New York, New York.

Grier, J.W. 1969. Bald eagle behavior and productivity responses to climbing nests. Journal of Wildlife Management 33(4):961-966.

Grier, J.W. 1977. Quadrat sampling of a nesting population of bald eagles. Journal of Wildlife Management 41:438-443.

Grubb, T.G. 1980. An evaluation of bald eagle nesting in western Washington. Pages 87-103 *in* R.L. Knight, G.T. Allen, M.V. Stalmaster, and C.W. Servheen, eds. Proceedings of the Washington bald eagle symposium. Washington Department of Game; Olympia, Washington.

Hardesty, J.L. 1991. Conservation of coastal nesting bald eagles in Florida: history, demography, and habitat use. Unpublished Masters Thesis, University of Florida; Gainesville, Florida.

Harmata, A. and B. Oakleaf. 1992. Bald eagles in the greater Yellowstone ecosystem: an ecological study with emphasis on the Snake River, Wyoming. Final report to the Wyoming Game and Fish Department; Cheyenne, Wyoming.

Harris, J. O., P. J. Zwank, and J. A. Dugoni. 1987. Habitat selection and behavior of nesting bald eagles in Louisiana. Journal of Raptor Research 21:27-31.

Heinz. G.H. 1975. Effects of methylmercury on approach and avoidance behavior of mallard ducklings. Bulletin of Environmental Contamination and Toxicology 13:554-564.

Heinz. G.H. 1979. Methylmercury: reproductive and behavioral effects on three generations of mallard ducks. Journal of Wildlife Management 43:394-401.

Heinzman, G. 1961. The American bald eagle. Natural History 70(6):18-21.

Heinzman, G. 1962. American bald eagle a last stand in Florida? Florida Wildlife 15(8):14-17.

Henney, C.J., D.W. Anderson, and C.E. Knoder. 1978. Bald eagles nesting in Baja, California. The Auk. 95(2):424.

Herrick, F. H. 1924. Nests and nesting habits of the American eagle. The Auk. 41(2):213-231.

Hickey, J.J., and D.W. Anderson. 1968. Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. Science 162(3850):271-273.

Hord, L.J., M.L. Jennings, and A. Brunnell. 1990. Mercury contamination of Florida alligators. Pages 229-240 *in* Proceedings of the tenth annual meeting of the Species Survival Commission, International Union for the Conservation of Nature and Natural Resources, Crocodile Specialist Group; Gainesville, Florida.

Howell, J.C. 1937. The nesting of bald eagles of southeastern Florida. Auk 54:296-299.

Howell, J.C. 1941. Comparisons of 1935 and 1940 populations of nesting bald eagles in east central Florida. Auk 58:402-403.

Howell, J.C. 1949. Comparisons of 1935, 1940, and 1946 populations of nesting bald eagles in east-central Florida. Auk 66:84.

Howell, J.C. 1954. A history of some bald eagle nest sites in east-central Florida. Auk 71:306-309.

Howell, J.C. 1958. Further history of some bald eagle nest sites in east-central Florida. Auk 75:96-98.

Howell, J.C. 1962. The 1961 status of some bald eagle nest sites in east-central Florida. Auk 79:716-718.

Howell, J.C. 1968. The 1966 status of 24 nest sites of the bald eagle in east-central Florida. Auk 85: 680-681.

Howell, J.C. 1973. The 1971 status of 24 bald eagle nest sites in east-central Florida. Auk 90:678-680.

Johnsgard, P.A. 1990. Hawks, eagles, and falcons of North America. Smithsonian Institution Press; Washington, D.C.

Kaiser, T.E.G., W.L. Reichel, L.N. Locke, E. Cromartie, A.J. Krynitsky, T.G. Lamont, B.M. Mulhern, R.M.S. Prouty, C.J. Stafford, and DM Swineford. 1980. Organochlorine pesticide, PCB, and PBB residues and necropsy data for bald eagles from 29 states 1975-77. Pesticide Monitoring Journal 13:145-149.

Kautz, R.S. 1993. Trends in Florida wildife habitat 1936-1987. Florida Scientist 56:7-24.

Keister, G.P. and R.G. Anthony. 1983. Characteristics of bald eagle communal roosts in the Klamath Basin, Oregon and California. Journal of Wildlife Management 47(4):1072-1079.

King, J., F. Robards, and C. Lensink. 1972. Census of the bald eagle breeding population in southeast Alaska. Journal of Wildlife Management 36:1292-1295.

Knight, R.L. and S.K. Knight. 1984. Responses of wintering bald eagles to boating activity. Journal of Wildlife Mangement 48:999-1004.

Mathisen, J.E. 1968. Effects of human disturbance on nesting bald eagles. Journal of WildlifeManagement 32(1):1-6.

McEwan L. C. 1977. Nest site selection and productivity of the southern bald eagle. Unpublished Masters Thesis, University of Florida, Gainesville, Florida.

McEwan, L. C., and D. H. Hirth. 1979. Southern bald eagle productivity and nest site selection. Journal of Wildlife Management 43:585-594.

Mealy, B. 1996. Telephone conversation. 17 September 1996.

Millar, J. 1996. Telephone conversation. 21 November 1996.

Montana Bald Eagle Working Group. 1991. Habitat management guide for bald eagles in northwestern Montana. Bureau of Land Management; Billings, Montana.

Mulhern, B. M., W. L. Reichel, L. N. Locke, T. G. Lamont, A. A. Belisle, E. Cromartie, G. E. Bagley, and R. M. Prouty. 1970. Organochlorine residues and autopsy data from bald eagles 1966-68. Pesticide Monitoring Journal 4:141-144.

Nesbitt, S.A. 1995. Bald eagle population monitoring. Annual performance report, Florida Game and Fresh Water Fish Commission; Gainesville, Florida.

Nesbitt, S.A. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. October 1998.

Nesbitt, S.A., M.J. Folk and D.A. Wood. 1993. Effectiveness of bald eagle habitat protection guidelines in Florida. Proceedings of the 47th annual conference Southeastern Association of Fish and Wildlife Agencies 47:333-338.

Newman, J.R., W.H. Brennan, and L.M. Smith. 1977. Twelve-year changes in nesting patterns of bald eagles on San Juan Island, Washington. The Murrelet 58(2):37-39.

Ogden, J. C. 1998. Comments on draft species accounts. January 27, 1998.

Palmer, R.S. 1988. Handbook of North American birds, volume 4. Yale University Press; New Haven, Connecticut.

Pass, D.A. 1975. The pathology of subacute and chronic methylmercury poisoning of the mallard duck. Journal of Comparative Pathology 85:7-21.

Pattee, O. H., S. N. Wiemeyer, B. M. Mulhern, L. Sileo, and J. W. Carpenter. 1981. Experimental lead-shot poisoning in bald eagles. Journal of Wildlife Management 45:806-810.

Peterson, D.W. and W.B. Robertson, Jr. 1978. Threatened southern bald eagle. Pages 27-30 *in* H.W. Kale II, ed. Rare and endangered biota of Florida: volume two, birds. University Presses Florida; Gainesville, Florida.

Prouty, R. M., W. L. Reichel, W. N. Locke, A. A. Belisle, E. Cromartie, T. E. Kaiser, T. G. Lamont, B., M. Mulhern, and D. M. Swineford. 1977. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for bald eagles, 1973-74. Pesticide Monitoring Journal 11:134-137.

Radcliffe, D. A. 1967. Decrease in eggshell weight in certain birds of prey. Nature 215:208-210.

Robards, R.C. and J. G. King. 1966. Nesting and productivity of bald eagles, southeast Alaska, 1966. U.S Fish and Wildlife Service; Juneau, Alaska.

Robards, R.C. and J.I. Hodges. 1977. Observations from 2,760 bald eagle nests in ssoutheast Alaska, 1969-1976. Progress report to the U.S. Fish and Wildlife Service; Anchorage, Alaska.

Robertson, W. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. August 1998.

Roelke, M.E., D.P. Schultz, C.F. Facemire, S.F. Sundlof, and H.E. Royals. 1991. Mercury contamination in Florida panthers. Report to the Florida Panther Technical Subcommittee, Florida Panther Interagency Committee.

Royals, H. and T. Lange. 1990. Mercury in Florida fish and wildlife. Florida Wildlife 44(2):3-6.

Spalding, M.G. and D.J. Forrester. 1991. Effects of parasitism and disease on the nesting success of colonial wading birds (*Ciconiiformes*) in southern Florida. Final report no. NG88-008 to Nongame Program, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Spalding, M.G., R.D. Bjork, G.V.N. Powell, and S.F. Sundlof. 1994. Mercury and cause of death in great white herons. Journal of Wildlife Management 58:735-739.

Stalmaster, M.V. 1987. The bald eagle. Universe Books; New York, New York.

Stalmaster, M.V. and J.R. Newman. 1978. Behavioral responses of wintering bald eagles to human activity. Journal of Wildlife Management 42:506-513.

Steidl, R.J. 1994. Human impacts on the ecology of bald eagles in interior Alaska. Unpublished dissertation, Oregon State University; Corvalis, Oregon.

Stevenson, H.M. and B.H. Anderson. 1994. The birdlife of Florida. University Presses Florida; Gainesville, Florida.

Sundlof, S.F., M.G. Spalding, J.D. Wentworth, and C.K. Steible. 1994. Mercury in livers of wading birds (*Ciconiiformes*) in southern Florida. Archives of Environmental Contamination and Toxicology 27:299-305.

U.S. Fish and Wildlife Service [FWS]. 1987. Habitat management guidelines for the bald eagle in the southeastern region. U.S. Fish and Wildlife Service; Atlanta, Georgia.

U.S. Fish and Wildlife Service [FWS]. 1989. Southeastern states bald eagle recovery plan, U.S. Fish and Wildlife Service; Atlanta, Georgia.

U.S. Fish and Wildlife Service [FWS]. 1995. Final rule to reclassify the bald eagle from endangered to threatened in all of the lower 48 states. Federal Register volume 60, No.133, 36000-36010.

Weekes, F.M. 1974. A survey of bald eagle nesting attempts in southern Ontario, 1969-1973. Canadian Field Naturalist 88(4):415-419.

Whitfield, D.W.A., J.M. Gerrard, W.J. Maher, and D.W. Davis. 1974. Bald eagle nesting habitat, density and reproduction in central Saskatchewan and Manitoba. Canada Field Naturalist 88(4):399-407.

Wood, P.B. 1987. Distribution, ownership status, and habitat characteristics of bald eagle nest sites in Florida. Final report Nongame Wildlife Project 85-020, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Wood, P.B., T.C. Edwards, and M.W. Collopy. 1989. Characteristics of bald eagle nesting habitat in Florida. Journal of Wildlife Management 53(2):441-449.

Wood, P.B., J. White, A. Steffer, J.M. Wood, and H.F. Percival. 1993. Mercury concentrations in tissues of Florida bald eagles. Final project report to the U.S. Fish and Wildlife Service; Vero Beach, Florida.

Wood, P.B. and M.W. Collopy. 1995. Population ecology of subadult southern bald eagles in Florida: post-fledging ecology, migration patterns, habitat use, and survival. Final report to Florida Game and Fresh Water Fish Commission, Nongame Wildlife Program, Tallahassee, Florida.

Wren C.D., S. Harris, and N. Harttrup. 1995. Pages 392-423 *in* D.J. Hoffman, B.A. Rattner, G.A. Burton, Jr., and J. Cairns, Jr., eds. Handbook of ecotoxicology. CRC Press, Inc.; Boca Raton, Florida.

Recovery for the Bald Eagle

Haliaeetus leucocephalus

Recovery Objective: **DELIST** the species once recovery criteria are met.

South Florida Contribution: South Florida's contribution to meeting this recovery objective will be achieved by maintaining or increasing the number of successful nests and the average annual productivity.

Recovery Criteria

Delisting criteria for the bald eagle in the southeast region are currently being developed. Until this species is delisted, South Florida's contribution to recovery of the bald eagle in the southeast is in accordance with the recovery criteria as indicated in the current approved Southeastern States Bald Eagle Recovery Plan. Specifically, South Florida can contribute to the recovery of the bald eagle in the southeast by furthering the goals of: nesting productivity of at least 0.9 chicks per occupied nest, greater than 1.5 young per successful nest, and at least 50 percent success in raising at least one young. These criteria must be accompanied by three years of data.

Species-level Recovery Actions

S1. **Determine distribution of the bald eagle in South Florida**. This task is covered by the bald eagle monitoring program performed by GFC described below in task 3.

S2. **Protect and manage bald eagle populations in South Florida**.

S2.1. **Prevent or mitigate the effects of behavioral degradation**. Behavioral degradation is the modification of normal eagle activity by any disturbance which reduces an area's ability to support eagles. These disturbances may result in increased energy expenditures, decreased feeding efficiencies, reduced reproductive potential, or decreased habituation by eagles.

S2.1.1. **Identify and quantify effects of disturbance on nesting eagles and incorporate into management plans**. Quantifying disturbance effects must focus on increases or decreases in annual productivity.

S2.1.2. **Identify and quantify the effect of disturbance on bald eagle feeding sites and incorporate into management plans as indicated in task H1.2.5**. The impact of disturbance to foraging eagles is not clear, but reduced feeding efficiency and increased energy expenditures are likely. The effect of these factors on productivity must be examined.

S2.1.3. **Continue to require permits for all research activities which have the potential to negatively impact eagles**. The effects of disturbance from research projects should be evaluated against the information to be gained and the project's enhancement of the recovery potential of eagles.

S2.1.4. **Help the Department of Defense develop and implement bald eagle guidelines for use on Military Areas of Operation in South Florida.**

S2.2. **Reduce bald eagle mortalities in South Florida**. Minimizing mortality will involve documenting the type, amount, source, and location of mortality and providing effective enforcement of existing laws.

S2.2.1. **Enforce laws protecting bald eagles**. Maintain and/or augment active enforcement of existing laws and preventive actions designed to reduce the number of violations. Law enforcement personnel at the State and Federal levels should be made aware of the potential sources of harm to bald eagles.

S2.2.2. **Establish and maintain adequate rehabilitation facilities**. Mortality may be reduced through the use of rehabilitation facilities. Existing emergency care protocols should continue at established, permitted rehabilitation facilities.

S2.2.3. **Reduce mortality from aerial collisions**. Structural modifications and project planning modifications in documented problem areas can reduce potential sources of mortality for bald eagles. The frequency of collisions between eagles and towers or powerlines may be reduced by locating structures away from eagle habitat and increasing structure visibility *(i.e.* installing marker balls or other marker models).

S2.2.4. **Reduce eagle mortality due to collisions with automobiles**. Increasing roadway clear zones and minimizing access to carrion may reduce collision mortality. Cooperation with DOT is essential to completing this task.

S2.2.5. **Work with utility companies and municipal governments to reduce mortality from electrocution**. Appropriate design and location of power lines can reduce mortality due to electrocution. Poles and lines should be designed to prevent electrocutions in areas of high eagle use.

S2.2.6. **Prevent mortality due to poisoning**. Prohibit the use of poisons for predator control in areas used by feeding eagles. This would alleviate the problem of secondary or unintentional ingestion of poisons which are being used for the control of other species.

S2.2.7. **Prevent poisoning mortality due to secondary ingestion of euthanized domestic animals**. Educate veterinarians and municipalities of the dangers of depositing euthanized domestic animals in landfills. Develop landfill management recommendations to reduce likelihood of secondary ingestion of barbiturates.

S3. **Continue to monitor bald eagle nesting activities in South Florida**. Population monitoring is necessary in order to determine the status and distribution of the species. The GFC currently monitors eagle nests twice per nesting season. This activity should be continued and expanded, as necessary, to provide important information on nesting success and the success of the habitat management guidelines, in addition to providing essential information on the population status throughout the state. If the bald eagle is to be delisted in the future, this information is essential to ensuring delisting criteria, once developed, are met.

S4. Develop public information and education materials to inform the public of the recovery needs of the bald eagle in South Florida. Public information programs should provide updated, accurate information on the status and needs of eagles and the relationship between eagle recovery and the well-being of man. While support must be evoked from the general public, specific problems such as indiscriminate shooting of eagles must be resolved by focusing efforts at specific user groups.

S4.1. Continue to use permanently incapacitated eagles for educational presentations. Exhibiting disabled eagles during lectures is an effective method of teaching. Such activities should, however, be carefully limited to qualified, permitted, individuals and employ only eagles which may not be returned to the wild.

S4.2. Prepare general informational brochures for distribution in South Florida. This should include life history information relative to the southeast since many general accounts depict only characteristics of northern populations. This brochure should present accurate status information as well as recovery needs. It should also give sources for additional informational materials.

S4.3. Develop and distribute information to pilots concerning the potential for disturbance of nesting eagles by aircraft. A poster should be developed and distributed to all public, private, and military airports. Information on eagle and eagle nest protection should also be included in the Airman's Information Manual in the section on bird strike hazard.

S5. Develop delisting criteria for the bald eagle in South Florida. Delisting criteria for the bald eagle will be developed on a regional basis by the Southeastern Bald Eagle Recovery Team.

Habitat-level Recovery Actions

H1. Prevent further loss and degradation of bald eagle habitat in South Florida. Despite the amount of habitat loss and degradation throughout South Florida, the number of bald eagles with breeding territories in South Florida has increased. Nevertheless, the continued loss and degradation of bald eagle habitat in South Florida is expected to cause population declines in the long-term if it continues unabated or unmitigated. In the long-term the persistence of bald eagles in South Florida will require protection of their nests, foraging areas, migratory corridors, and juvenile dispersal areas.

H1.1. Continue to gather information on the effects of habitat loss and degradation of habitat on bald eagles in South Florida. One of the challenges to protecting habitat for bald eagles in South Florida is the different responses of individual pairs to habitat loss and degradation within their territories. Some pairs will abandon their territories when minimal amounts of disturbance occur, while other bald eagle pairs will ignore seemingly significant disturbance. Future efforts to conserve bald eagles in South Florida will require better information on how different types of habitat loss affect bald eagle pairs and identification of biological effects (such as reduced productivity) that occur regardless of the behavioral responses of nesting adults.

H1.1.1. Identify alterations to terrestrial and aquatic habitats that adversely affect bald eagles in South Florida. Alterations of aquatic habitat have affected eagles in a variety of ways. Altered hydrology due to channelization for flood protection and water storage and agricultural, commercial, and residential uses of surface and groundwater affect the amount of surface water available to support forage fish and other terrestrial prey. Agricultural, commercial, and residential development also affect water quality and the ability of aquatic resources to provide suitable foraging sites for bald eagles.

H1.1.2. **Quantify essential characteristics of occupied bald eagle habitat**. Quantification of the characteristics of habitats, undertaken in a systematic and uniform format, is needed. Such characteristics should be determined by comparing differences between historic and currently occupied territories. In addition, areas of high productivity should be compared and contrasted to areas of low productivity. This should provide for the accurate prediction of impacts during early planning stages and allow for the protection of potential as well as occupied habitat.

H1.1.3. **Quantify responses of bald eagles in South Florida to habitat alteration**. Individual eagles, pairs, or groups of eagles vary widely in their response to alteration of habitat. Information is needed to address the effects of disturbance, including the duration, frequency, and intensity as they relate to each stage of reproduction.

H1.2. **Protect bald eagle habitats in South Florida through site management**. Management of occupied territories in South Florida is the first priority of recovery. Nowhere else in its range is the eagle under greater threat from habitat changes than in the South Florida Ecosystem.

H1.2.1. **Continue to implement and adhere to "Habitat Management Guidelines for the Bald Eagle in the Southeast Region"**(op cit). The current level of knowledge for bald eagle habitat management is reflected in these guidelines and they should be used in resource planning. They should also be reviewed and revised as new information becomes available.

H1.2.2. **Develop specific management plans for each breeding territory**. Individual management plans should be developed for each breeding area whenever possible. This should include occupied, recently occupied, and historic nesting areas. The plans should be designed to accommodate local factors of habitat use, use-area configuration, nesting success, and level of tolerance to disturbance.

H1.2.3. **Protect eagle habitat through cooperative agreements, easements, acquisition or other appropriate means**. Funding for habitat management should be sought from a multitude of sources including Federal, State, local, and private sources.

H1.2.4. **Identify and incorporate important bald eagle habitat in land use plans and planning**. Identify important habitat in order to ensure that accurate information is available for the development of land use plans.

H1.2.5. **Use section 7 of the ESA to protect bald eagles and their habitats**. Interagency consultations on permits issued by the U.S. COE pursuant to section 10 of the Rivers and Harbors Act and section 404 of the Clean Water Act are important for the conservation of bald eagles in South

Florida. With the human population in South Florida expected to almost double over the next 15 years, these interagency consultations will become increasingly important to prevent bald eagles in South Florida from declining.

H1.3. **Prevent or mitigate the degradation of eagle habitat from environmental contaminants**. Mercury occurs throughout South Florida and may reduce recovery opportunities for eagles in South Florida. The numbers, nesting effort, and fecundity of bald eagles that nest in areas where high levels of mercury are known or suspected should be monitored to detect possible mercury contamination. Similarly, addled bald eagle eggs, carcasses and prey from areas where high levels of mercury are known or suspected should be tested for mercury contamination.

H2. **Develop methods to restore previously occupied habitat or to establish new territories**. In South Florida, an increasing number of bald eagles, territories occur in areas that are being cleared for residential housing or for industrial sites. In some instances, individuals have applied for permits to take bald eagles incidental to land clearing for residential housing. At the same time, several managers of wetland mitigation banks have included bald eagles as beneficiaries of their mitigation banks without demonstrating opportunities to restore or enhance the value of bald eagle territories. In the past, the FWS and GFC have had no information on opportunities to restore previously occupied bald eagle territories or to establish new territories. This information, which would require some experimentation, would help establish measures to minimize or mitigate the effects of habitat loss or degradation on bald eagles associated with land clearing for residential housing construction in South Florida.

H3. **Increase public awareness of habitat-related issues that affect the recovery of the bald eagle in South Florida**.

H3.1. **Produce an information brochure for landowners**. Land management information and guidelines should be prepared for landowners including information on where to obtain additional professional assistance. State foresters should be included in this effort since they provide silvicultural expertise to private landowners.

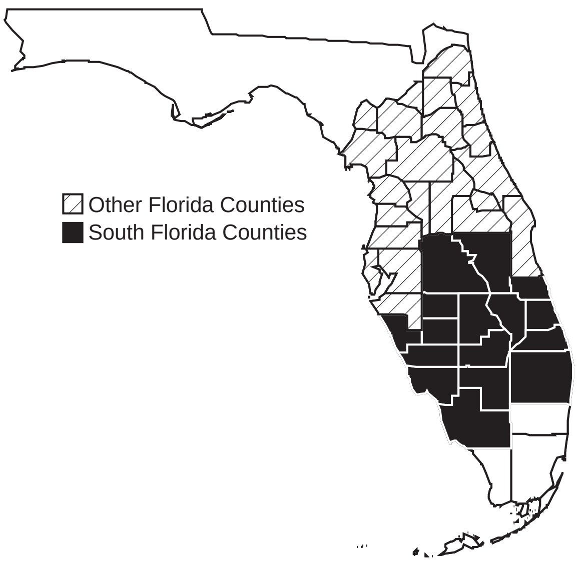
H3.2. **Establish displays at public boat landings to provide information on laws, penalties, rewards, and identification of eagles**. Many boaters utilize public landings for access to aquatic habitat used by eagles. This includes use by hunters and fishermen as well as by recreational and commercial boaters. These user groups should be provided with information on identification and legal protection of eagles. Local phone numbers where violations may be reported should also be included.

Florida Scrub-jay

Aphelocoma coerulescens

Federal Status:	**Threatened (June 3, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. County distribution of the Florida scrub-jay.



The Florida scrub-jay is a relict species of fire-dominated oak scrub habitat that occurs on well-drained sandy soils in peninsular Florida. Scrub-jays are extremely habitat-specific, sedentary, and territorial. Florida scrub-jays form family groups; fledglings remain with their parents in their natal territory as helpers. The Florida scrub-jay was listed as a threatened species because of loss, fragmentation, and degradation of scrub habitats throughout Florida, due primarily to urbanization, agriculture, and fire suppression. During the last 10 to 12 years, the population has declined by an estimated 25 to 50 percent, and they have been extirpated from seven counties statewide. The most recent estimate of the scrub-jay population (1993) is 11,000 birds. Conservation measures for Florida scrub-jays will involve protection and long-term management of suitable scrub habitat.

This account represents South Florida's contribution to the range-wide recovery plan for the Florida scrub-jay (FWS 1990).

Description

Florida scrub-jays are about 25 to 30 cm long and weigh about 77 grams. They are similar in size and shape to the blue jay (*Cyanocitta cristata*), but differ significantly in coloration (Woolfenden and Fitzpatrick 1996a). Unlike the blue jay, scrub-jays lack a crest. They also lack the conspicuous white-tipped wing and tail feathers, black barring and bridle of the blue jay. The Florida scrub-jay's head, nape, wings and tail are pale blue, and it is pale grey on its back and belly. Its throat and upper breast are lightly striped and bordered by a pale blue-gray "bib." The sexes of Florida scrub-jays are not distinguishable by plumage, and males average only slightly larger than females (Woolfenden 1978). The sexes may be differentiated by a distinct "hiccup" call vocalized only by females (Woolfenden and Fitzpatrick 1986). Scrub-jays less than about 5 months of age are easily distinguishable from adults; their plumage is smokey gray on the head and back, and they lack the blue crown and nape of adults. Molting occurs between early June and late November, and peaks between mid-July and late September (Bancroft and Woolfenden 1982). During late summer and early fall, when the first basic molt is nearly complete, fledgling scrub-jays may be indistinguishable from adults in the field (Woolfenden and Fitzpatrick 1984). The wide variety of vocalizations of Florida scrub-jays are described in detail by Woolfenden and Fitzpatrick (1996b).

Taxonomy

Scrub-jays (*Aphelocoma coerulescens*) are in the order Passeriformes and the family Corvidae. They have been called a "superspecies complex," and described in four groups that differ in geographic distribution within the United States and Mexico: *A. californicus*, from southwestern Washington through Baja California; *A. insularis*, on Santa Cruz in the Channel Islands, California; *A. woodhousii*, from southeastern Oregon and the Rocky Mountains and Great Plains to Oaxaca, Mexico; and *A. coerulescens* in peninsular Florida (AOU 1983). Other congeners are the Mexican jay or gray-breasted jay (*A. ultramarina*) and the unicolored jay (*A. unicolor*) of southern Mexico and northern Central America (Woolfenden and Fitzpatrick 1996b).

The Florida scrub-jay, which was originally named *Corvus coerulescens* by Bosc in 1795, was transferred to the genus *Aphelocoma* in 1851 by Cabanis. In 1858, Baird made *coerulescens* the type species for the genus, and it has been considered a subspecies (*A. c. coerulescens*) for the past several decades (AOU 1957). It recently regained recognition as a full species (Florida scrub-jay, *Aphelocoma coerulescens*) from the American Ornithologists' Union (AOU 1995) because of genetic, morphological and behavioral differences between the other members of this group: the western scrub-jay (*A. californicus*) and the island scrub-jay (*A. insularis*). The group name is retained for species in this complex; however, it is now hyphenated to "scrub-jay" (AOU 1995).

Distribution

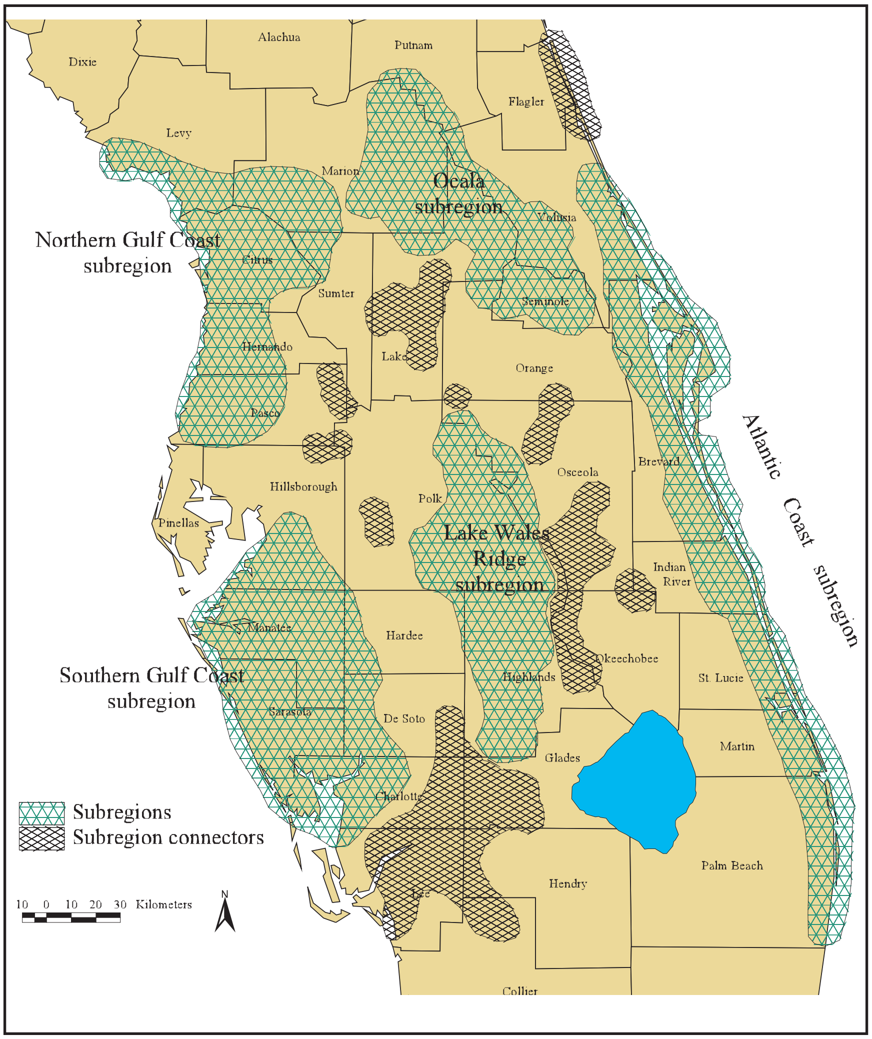
Florida scrub-jays historically were distributed throughout the Florida peninsula in suitable scrub habitat in 39 of the 40 counties south of, and including, Levy, Gilchrist, Alachua, Clay, and Duval counties (Fitzpatrick *et al*. 1991). Historically, the only county on the peninsula that lacked scrub-jays was Monroe, although they were never considered abundant on the Atlantic coast south of Martin County, and occurred only in a narrow coastal band there. The current county distribution of Florida scrub-jays is shown in Figure 1. On the Atlantic coast, scrub-jays extend from Flagler to Palm Beach counties. On the Gulf coast, scrub-jays persist patchily from Levy, Citrus, western Marion, and northwestern Sumter counties south to Sarasota, western DeSoto, Charlotte, Lee, and northwestern Collier counties. In central Florida, scrub-jays range from southwestern Clay through Putnam and Marion counties, south through Polk, Highlands, and Glades counties. Florida scrub-jays have been extirpated from Broward, Dade, Duval, Gilchrist, Pinellas, and St. Johns counties.

Florida scrub-jay.
Original photograph by Brian Toland.

The distribution and status of the Florida scrub-jay across its entire range was updated during 1992 and 1993 (Fitzpatrick *et al*. 1994b). Based upon that survey, the overall Florida population of scrub-jays was divided into five subregions, corresponding to the major sand deposits located on the peninsula (Figure 2). Three of these subregions are considered "core populations" because they contain well over half of the state's remaining scrub-jays. These population cores occur at Merritt Island/Cape Canaveral Complex, Ocala NF, and on the southern Lake Wales Ridge, and are respectively named the Atlantic Coast Subregion, the Ocala Subregion, and the Lake Wales Ridge Subregion (Fitzpatrick *et al*. 1994a).

All extant scrub-jay populations outside of the three core population subregions consist of smaller subpopulations that are isolated to varying degrees (Fitzpatrick *et al*. 1994b). Along the Gulf coast from Levy County south to Lee County, scrub-jays historically occurred in a contiguous fourth major population: the Gulf Coast Subregion. Today, however, this population is divided into two subregions: the Northern Gulf Coast Subregion and the Southern Gulf Coast Subregion, because of the extensive amount of habitat fragmentation and loss that has occurred in Pinellas, Hillsborough, Pasco, and Hernando counties (Fitzpatrick *et al*. 1994b).

Figure 2. Location of Florida scrub-jay subregions and the habitats connecting the sub-regions (adapted from Fitzpatrick *et al*. 1994a).



Habitat

The Florida scrub-jay has extremely specific habitat requirements. It is endemic to peninsular Florida's ancient dune ecosystems or scrubs, which occur on well-drained to excessively well-drained sandy soils (Laessle 1958, 1968, Fitzpatrick *et al*. 1994b). This relict oak-dominated scrub, or xeric oak scrub, is essential habitat to the Florida scrub-jay. This community type is adapted to nutrient-poor soils, periodic drought, high seasonal rainfall and frequent fires (Abrahamson 1984). Xeric oak scrub on the Lake Wales Ridge is predominantly comprised of four species of stunted, low-growing oaks: sand live oak (*Quercus geminata*), Chapman oak, (*Q. chapmanii*), myrtle oak, (*Q. myrtifolia*), and scrub oak, (*Q. inopina*) (Myers 1990). In optimal habitat for scrub-jays, these oaks are 1 to 3 m high, interspersed with 10 to 50 percent unvegetated, sandy openings, and a sand pine (*Pinus clausa*) canopy of less than 20 percent (Woolfenden and Fitzpatrick 1990). Trees and dense herbaceous vegetation are rare. Other vegetation noted along with the oaks includes saw palmettos (*Serenoa repens*) and scrub palmetto (*Sabal etonia*), as well as woody shrubs such as Florida rosemary (*Ceratiola ericoides*) and rusty lyonia (*Lyonia ferruginea*). Although there is more species diversity in the Lake Wales Ridge oak scrub, the Atlantic Coastal Ridge oak scrub is similar in structural composition.

On the Merritt Island/Cape Canaveral Complex and in southwest Florida, scrub-jays occupy areas with less scrub oak cover and fewer openings than xeric oak scrub habitat on the Lake Wales Ridge (Breininger 1981, Thaxton and Hingtgen 1996). The predominant communities here are oak scrub and scrubby flatwoods. Scrubby flatwoods differ from scrub by having a sparse canopy of slash pine (*P. elliottii*); sand pine are rare. Although *Q. inopina* and *S. etonia* are restricted to the Lake Wales Ridge, the other species mentioned above are predominant in these areas as well. In addition, runner oak (*Q. minima*), turkey oak (*Q. laevis*), bluejack oak (*Q. incana*), and longleaf pine (*P. palustris*) have been reported.

Kennedy Space Center, in Brevard County, has one of the largest contiguous populations of the Florida scrub-jay. Studies conducted there provide good descriptions of this habitat type (Schmalzer and Hinkle 1992). Although Kennedy Space Center is geographically located just north of the ecosystem boundaries for South Florida, habitat data for scrub-jays are included for comparative purposes with xeric oak scrub on the Lake Wales Ridge. In a recent study, Breininger *et al*. (1995) reported that scrub-jays occupied all areas at Kennedy Space Center that were more than 136 m from a forest, and that supported more than 29 percent scrub oak cover and more than 4 percent open space. Areas closer to forested habitat, or with greater than 20 percent pine cover, were used infrequently by scrub-jays, even when the percentages of scrub oak cover and open space were suitable. Highest densities of scrub-jays, as an indication of habitat preference, were in areas greater than 136 m from forested habitat, where scrub oak cover exceeded 60 percent, open space exceeded 10 percent, and pine cover was less than 20 percent.

Behavior

Social Structure

Florida scrub-jays have a social structure that involves cooperative breeding, a trait that the western North American populations of scrub-jays do not exhibit (Woolfenden and Fitzpatrick 1984). Florida scrub-jays live in groups ranging from two (a single mated pair) up to large, extended families of eight adults and one to four juveniles. Fledgling scrub-jays remain with the breeding pair in their natal territory as “helpers,” forming a closely-knit, cooperative family group. Pre-breeding numbers are generally reduced to either a pair with no helpers or families of three or four individuals (a pair plus one or two helpers).

Florida scrub-jays have a well-developed intrafamilial dominance hierarchy, with breeder males most dominant, followed by helper males, breeder females, and, finally, female helpers (Woolfenden and Fitzpatrick 1977). Helpers participate in sentinel duties (McGowan and Woolfenden 1989), territorial defense, predator-mobbing, and the feeding of both nestlings (Stallcup and Woolfenden 1978) and fledglings (McGowan and Woolfenden

1990). The well-developed sentinel system involves having one individual occupying an exposed perch watching for predators or territory intruders. When a predator is observed, the sentinel jay gives a distinctive warning call and all group members seek cover in dense shrub vegetation (Fitzpatrick *et al*. 1991).

The only other population of scrub-jays that exhibits cooperative breeding is the southernmost form in Oaxaca, Mexico (Burt and Peterson 1993). Although it is well known that delayed dispersal by juvenile Florida scrub-jays is caused by limitations in the availability of breeding habitats, this does not appear to be the reason for cooperation among the southern Mexico population. It is still unclear why the Mexican population exhibits this social behavior; however, Burt and Peterson (1993) offer several possible explanations for this difference that will require further investigation.

Florida scrub-jay pairs occupy year-round, multi-purpose territories (Woolfenden and Fitzpatrick 1984; Fitzpatrick *et al*. 1991, 1994b). Territory size averages 9 to 10 ha, with a minimum size of about 5 ha. The availability of territories is a limiting factor for scrub-jay populations. Because of this limitation, non-breeding adult males may remain at the natal territory as helpers for up to five years, waiting for either a mate or territory to become available (Fitzpatrick *et al*. 1991). New territories are established several ways: by replacing a lost breeder on a territory (Woolfenden and Fitzpatrick 1984); through "territorial budding," where a helper male becomes a breeder in a segment of its natal territory (Woolfenden and Fitzpatrick 1978); by inheriting a natal territory following the death of a breeder; by establishing a new territory between existing territories (Woolfenden and Fitzpatrick 1984); or through "adoption" of an unrelated helper by a neighboring family followed by resident mate replacement (B. Toland, FWS, personal communication 1996). Territories can also be obtained by creating suitable habitat in areas that were previously unsuitable through effective habitat management efforts (Thaxton and Hingtgen 1994).

Reproduction and Demography

To become a breeder, a scrub-jay must acquire a territory and a mate. Evidence presented by Woolfenden and Fitzpatrick (1984) suggests that Florida scrub-jays are permanently monogamous. The pair retain ownership and sole breeding-privileges in their particular territory year after year. Courtship to form the pair is lengthy and ritualized, and involves posturing and vocalizations made by the male to the female (Woolfenden and Fitzpatrick 1996b). Copulation between the pair is generally out of sight of other jays (Woolfenden and Fitzpatrick 1984). These authors also reported never observing copulation between unpaired jays, nor courtship behavior between a female and a jay other than her mate. Age at first breeding in the Florida scrub-jay varies from 1 to 7 years, although most individuals become breeders between 2 and 4 years of age (Fitzpatrick and Woolfenden 1988). Persistent breeding populations of Florida scrub-jays exist only where there are scrub oaks in sufficient quantity to provide an ample winter acorn supply, cover from predators, and nest sites during the spring (Woolfenden and Fitzpatrick 1996).

Florida scrub-jay nests are typically placed in shrubby oaks, at a height of 1 to 2 m. *Quercus inopina* and *Q. geminata* are the preferred shrub on the Lake Wales Ridge (Woolfenden and Fitzpatrick 1984) and *Q. myrtifolia* is favored on the Atlantic Coastal Ridge and southern Gulf coast (Toland 1991, J. Thaxton Uplands Inc., personal communication 1998). In suburban areas, scrub-jays nest in the same evergreen oak species as well as in introduced or exotic trees; however they construct their nests in a significantly higher position in these oaks than when in natural scrub habitat (Bowman *et al*. 1996). Florida scrub-jay nests are an open cup, about 18 to 20 cm outside diameter, and 8 to 9 cm inside diameter. The outer basket is bulky and constructed of coarse twigs from oaks and other vegetation, and the inside is lined with tightly wound palmetto or cabbage palm fibers. There is no foreign material as may be present in a blue jay nest (Woolfenden and Fitzpatrick 1996b).

Nesting is synchronous, normally occurring from 1 March through 30 June (Woolfenden and Fitzpatrick 1990, Fitzpatrick *et al*. 1994b). On the Atlantic Coastal Ridge and southern Gulf coast, nesting may be protracted through the end of July (B. Toland, FWS, personal communication 1996; J. Thaxton, Uplands Inc., personal communication 1998). In suburban habitats, nesting is consistently initiated earlier (March) than in natural scrub habitat (Fleischer 1996), although the reason for this difference is unknown. Nesting failures are almost always caused by predation, most frequently by ground-based predators including eastern coachwhip (*Masticophis flagellum*), eastern indigo snake (*Drymarchon corais*), rat snake (*Elaphe obsoleta*), corn snake (*E. guttata*), raccoon *(Procyon lotor*), and domestic cat (*Felis catus*) (Fitzpatrick *et al*. 1991, Schaub *et al*. 1992).

Clutch size ranges from one to five eggs, but is typically three or four eggs. Clutch size is generally larger (up to six eggs) in suburban habitats, and the birds attempt to rear more broods (Fleischer 1996). Double brooding by as much as 20 percent has been documented on the Atlantic Coastal Ridge and in suburban habitat within the southern Gulf coast, compared to about 2 percent on the Lake Wales Ridge (B. Toland, FWS, personal communication 1996, J. Thaxton, Uplands Inc., personal communication 1998). Scrub-jay eggs measure 27.08 mm x 20.18 m (length x breadth) (Woolfenden and Fitzpatrick 1996b), and coloration "varies from a pea green to pale glaucous green, blotched and spotted with irregularly shaped markings of cinnamon rufous and vinaceous cinnamon, these being heaviest about the larger end" (Bendire in Bent 1946). Eggs are incubated for 17 to 18 days, and fledging occurs 16 to 21 days after hatching (Woolfenden 1974, 1978; Fitzpatrick *et al*. 1994b). Only the breeding female incubates and broods eggs and nestlings (Woolfenden and Fitzpatrick 1984). Average production of young is two fledglings per pair, per year (Woolfenden and Fitzpatrick 1990, Fitzpatrick *et al*. 1994a), and the presence of helpers improves fledging success (Mumme 1992). Annual productivity must average at least two young fledged per pair for a population of scrub-jays to maintain long-term stability (Fitzpatrick *et al*. 1991).

Fledglings depend on adults for food for about 10 weeks, during which time they are fed by both breeders and helpers (Woolfenden 1975, McGowan and Woolfenden 1990). In optimal scrub, survival of scrub-jay fledglings to yearling age class averages about 35 percent, while annual survival of adult males and females is equal and averages around 80 percent (Fitzpatrick *et al*. 1994b). Data from Archbold Biological Station, however, suggest that survival and reproductive success of scrub-jays is substantially lower than these values under

Table 1. Mean survivorship and reproduction of Florida scrub-jays in several habitats at Archbold Biological Station, 1969-86 (taken from Woolfenden and Fitzpatrick 1991).

	Optimal Habitat	**Suboptimal Habitat**		
	Periodically burned, open oak scrub	Unburned, overgrown scrubby flatwoods	Unburned southern ridge sandhill (slash pine-turkey oak)	Mature citrus bordering unburned scrub
N (pair-years)	429	74	8	21
Seasonal nest attempts	1.38 (593/429)	1.49 (110/74)	1.50 (12/8)	1.11 (20/18)
Fledglings/pair	1.97 (843/429)	1.58 (117/74)	1.38 (11/8)	2.00 (38/18)
Independent young/pair	1.17 (500/429)	0.80 (59/74)	1.13 (9/8)	1.56 (28/18)
Yearlings/pair	0.60 (259/429)	0.36 (27/74)	0.50 (4/8)	0.61 (11/18)
First-year survival	0.307 (259/843)	0.231 (27/117)	0.364 (4/11)	0.289 (11/38)
Breeder survival	0.789 (697/883)*	0.723 (107/148)	0.688 (11/16)	0.619 (26/42)
Expected lifetime success/individual				
Breeding seasons	4.4	3.5	3.2	2.6
Fledglings	4.3	2.8	2.2	2.6
Independent young	2.6	1.4	1.8	2.0
Yearlings	1.3	0.6	0.8	0.8

*N=883 breeder years for calculating breeder survival

suboptimal habitat conditions (Woolfenden and Fitzpatrick 1991) (Table 1). The data help explain why local populations inhabiting unburned, late successional habitats become extirpated.

Similarly, data from Indian River County show that mean annual productivity declines significantly in suburban areas. Toland (1991) reported that productivity averaged 2.2 young fledged per pair in contiguous, optimal scrub, 1.8 young fledged per pair in fragmented, moderately developed scrub, 1.2 young per pair fledged in highly fragmented, suboptimal scrub, and only about 0.5 young per pair in residential lawns. Overall nest success (probability of fledging at least one young) is about 50 percent on the Lake Wales Ridge and about 70 percent on the Atlantic Coastal Ridge in Indian River County (B. Toland, FWS, personal communication 1996). The maximum observed lifespan of a Florida scrub-jay is 15.5 years (Woolfenden and Fitzpatrick 1996b).

Dispersal

Scrub-jays are nonmigratory, extremely sedentary, and permanently territorial. Juveniles remain in their natal territory for up to 5 years before dispersing to become breeders (Woolfenden and Fitzpatrick 1984). Once they pair and become breeders, generally within two territories of their natal ground, they remain on their breeding territory until death. In suitable habitat, fewer than 5 percent of scrub-jays disperse more than 8 km (Fitzpatrick *et al*. 1994b). All documented long-distance dispersals have been in unsuitable habitat such as woodland, pasture, or suburban plantations. Scrub-jay dispersal behavior is affected by the intervening landscape matrix. Protected scrub habitats will most effectively sustain scrub-jay subpopulations if they are located within a matrix of surrounding habitats that can be utilized and traversed by scrub-jays. Brushy pastures, scrubby corridors along railway, utility, and country road rights-of-way, and open, burned flatwoods provide links for colonization among scrub-jay subpopulations. Stith *et al*. (1996) believe that a dispersal distance of 8 km is close to the biological maximum for Florida scrub-jays. Table 2 provides estimated distances across which scrub-jays normally disperse in the wild.

In suburban habitats in southwest Florida, however, average dispersal distances for scrub-jays is much greater than in natural habitat (Thaxton and Hingtgen 1996). In their study, these authors also noted that no dispersals were made from preserves to suburban territories, and attributed this to habitat degradation. Scrub-jays are known to disperse up to 94 km in suburban habitats in southeastern Florida and are thought to frequently disperse further than the 8 km average found in more natural conditions (G. Iverson, personal communication 1998).

Table 2. Dispersal distances of Florida scrub-jays in relation to habitat type (from Fitzpatrick *et al.* 1994)

Habitat Type	Normal Dispersal Distance (km)	Maximum Dispersal Distance (km)
Open Water	2	2
Urban areas	2	2
Dense pine forest	2	3
Unbroken, open pasture	3	7
Cropland	3	7
Unbroken citrus groves	5	8
Densely wooded suburbs	5	8
Suburbs with few trees	5	13
Flatwoods	5	17
Broken pasture, fence rows, roadsides	8	24
Overgrown scrub with some clearings	8	24

Foraging

Florida scrub-jays forage mostly on or near the ground, often along the edges of natural or man-made openings. They visually search for food by hopping or running along the ground beneath the scrub, or by jumping from shrub to shrub. Insects, particularly orthopterans and lepidopteran larvae, comprise the majority of the animal diet throughout most of the year (Woolfenden and Fitzpatrick 1984). Acorns are by far the most important plant food (Fitzpatrick *et al*. 1991). From August to November each year scrub-jays harvest and cache thousands of scrub oak acorns throughout their territory. Each scrub-jay may cache 6,000 to 8,000 acorns per year (DeGange *et al*. 1989). Acorns are typically buried 1 to 2 cm beneath the surface of bare sand in openings in the scrub during fall, and retrieved and consumed in winter and early spring. On the Atlantic Coastal Ridge, acorns are frequently cached in pine trees, either in forks of branches, in distal pine boughs, under bark, or on epiphytic plants, between 0.3 to 9 m in height (B. Toland, FWS, personal communication 1996). Other small nuts, fruits, and seeds are also eaten.

Vertebrate prey items comprise the minority of the diet, but may include a wide array of species weighing up to 25 g (B. Toland, FWS, personal communication 1996). Notable vertebrate prey species documented for scrub-jays on both the Lake Wales Ridge and the Atlantic Coastal Ridge include, green treefrog (*Hyla cinerea*), squirrel treefrog (*H. squirella*), green anole (*Anolis carolinensis*), brown anole (*A. sagrei*), Florida scrub lizard (*Sceloporus woodi*), six-lined racerunner (*Cnemidophorus sexlineatus*), black racer (*Coluber constrictor*), peninsula crowned snake (*Tantilla relicta relicta*), rough green snake (*Opheodrys aestivus*), house mouse (*Mus musculus*), cotton mouse (*Peromyscus gossypinus*), oldfield mouse (*P. polionotus*), and Florida mouse (*Podomys floridanus*) (Woolfenden and Fitzpatrick 1984).

In suburban areas, scrub-jays will accept supplemental foods offered by humans, such as peanuts, corn, and sunflower seeds.

Relationship to Other Species

Because Florida scrub-jays are endemic to oak scrub habitat in peninsular Florida, it occurs with many other species also endemic to this community type. As mentioned previously, the scrub-jays are dependent upon the species of evergreen oaks in the scrub. This oak scrub habitat is also essential to at least 21 federally listed plant species on the Lake Wales Ridge and at least two others on the Atlantic Coastal Ridge. The threatened blue-tailed mole skink (*Eumeces egregius lividus*) and sand skink (*Neoseps reynoldsi*) also occur on the Lake Wales Ridge, and the threatened eastern indigo snake (*Drymarchon corais couperi*) and state-listed gopher tortoise (*Gopherus polyphemus*) are also known to occur with scrub-jays. It is critical that management for scrub habitat and for the Florida scrub-jay consider possible effects on these and other scrub-endemic species.

Scrub-jays occasionally interact with blue jays in scrub and scrubby flatwoods habitats. It has been suggested that the presence of blue jays may limit use of woodland habitat by scrub-jays; however, B. Toland (FWS, personal communication 1996) reports successful fledging by both species nesting in close proximity to one another in Indian River, Polk, and Brevard counties. He also reports that in all cases, Florida scrub-jays were dominant over blue jays in agonistic encounters.

There are relatively few predators on adult Florida scrub-jays; however, the most dangerous native predators are the Cooper's hawk (*Accipiter cooperii*), sharp-shinned hawk (*A. striatus*), merlin (*Falco columbarius*), northern harrier (*Circus cyaneus*), and peregrine falcon (*F. peregrinus*) in descending magnitude of threat. House cats and bobcats (*Felis rufus*) have been documented to prey on scrub-jays (Fitzpatrick *et al*. 1994b). Eastern coach whips, eastern indigo snakes, and great horned owls (*Bubo virginianus*) also occasionally prey on adult scrub-jays (Fitzpatrick *et al*. 1994b).

Status and Trends

The Florida scrub-jay was federally listed as threatened in 1987 primarily because of habitat fragmentation, degradation, and loss (52 FR 20719). Scrub habitats associated with Florida's barrier islands, mainland coasts, and Lake

Wales Ridge are some of the most imperiled natural communities in the United States, with estimates of habitat loss since pre-settlement times ranging from 70 to more than 80 percent (Bergen 1994, Fitzpatrick *et al*. 1994b). Historically, this vegetative community type occurred as large, contiguous patches, some of them over hundreds of miles (Cox 1987). Today, only relict patches of xeric oak scrub remain. Throughout the northern part of the range, population declines of scrub-jays are attributed to scrub fragmentation and degradation, due primarily to widespread fire suppression. Citrus conversion and residential development continue to be the most important factors causing the decline of scrub-jay populations in the southern extremes of their range (Fernald 1989, Fitzpatrick *et al*. 1991).

The decreasing trend of the Florida scrub-jay population is closely correlated with loss of scrub habitat. A statewide survey of Florida scrub-jays conducted during 1992 and 1993 documented about 11,000 Florida scrub-jays (~4,000 pairs) as of 1993, extrapolating from the average scrub-jay group size of 2.8 individuals, and estimated that at least two-thirds of the population inhabits federal lands (Fitzpatrick *et al*. 1994a). This population estimate is no more than 15 percent of the pre-settlement population estimate, and corresponds to a similar reduction in the distribution of scrub habitat. As of 1993, half of all remaining Florida scrub-jays occurred in Brevard County (1,232 families) and Highlands County (890 families) (Fitzpatrick *et al*. 1994a). A total of 19 occupied counties contained 30 or fewer groups of scrub-jays. Cox (1987) estimated that 15,600 to 22,800 jays comprised the statewide population as of 1984. Even a conservative assumption that Cox found all of the breeding pairs of scrub-jays illustrates that the Florida scrub-jay has declined by an estimated 25 to 50 percent during the last 10 years (Fitzpatrick *et al*. 1994a).

Stith *et al*. (1996) used a buffering procedure and 3.5 km dispersal buffer to delineate 191 separate Florida scrub-jay subpopulations. Of these, 152 subpopulations (over 80 percent) contained fewer than 10 pairs of scrub-jays, 33 subpopulations contained between 10 and 99 pairs, and only six contained at least 100 pairs. When a 12 km dispersal buffer was applied to these data, 42 separate scrub-jay subpopulations were delineated; half of these subpopulations contained fewer than 10 pairs. Results from their population viability analysis indicate that a population of jays with fewer than 10 breeding pairs has a 50 percent probability of extinction over 100 years. This improves to a 2 to 3 percent chance of extinction for populations with at least 100 pairs. Only the three core subpopulations currently have enough breeding pairs each to provide a 99 percent probability of survival over 100 years (Fitzpatrick *et al*. 1994b).

To prepare this species account, the FWS conducted additional analyses of these data. Instead of the buffers Stith *et al*. (1996) used, we applied an 8.2 km buffer around occupied scrub-jay territories because this is considered the maximum dispersal distance for scrub-jays (Stith *et al*. 1996). Our analyses (Figure 3) revealed 55 distinct subpopulations instead of the 191 and 42 subpopulations Stith *et al*. (1996) identified. Thirty-six of our subpopulations contained fewer than 10 breeding pairs, 13 contained between 10 and 99 breeding pairs, and six contained more than 100 breeding pairs (the latter result was the same Stith *et al*.reached).

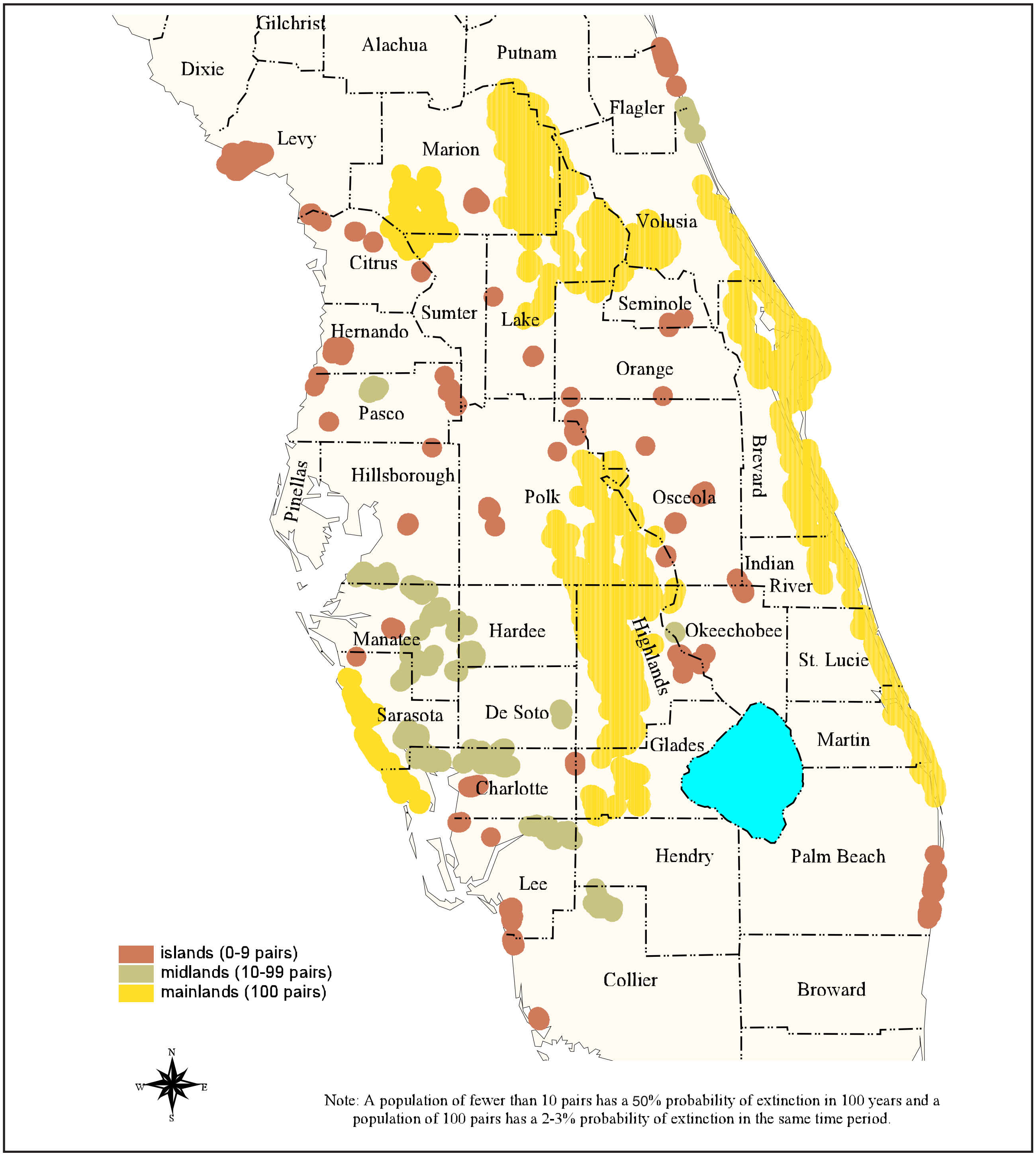


Figure 3. Distribution of Florida scrub-jay subpopulations with an 8.2 km dispersal buffer.

Based on these analyses, about 8.0 percent (324 pairs) of the remaining scrub-jay families have a 50 percent probability of extinction within 100 years. We believe this is a minimum extinction probability because it only addresses extinction risk caused by genetic and demographic phenomena, it does not incorporate the additional extinction risk caused by habitat loss and fragmentation in these territories. These families are important because they occur in the areas that historically connected core populations (see Figure 2); the loss of these birds and their habitat will effectively eliminate any connections between the core populations.

About 16 percent (about 650 pairs, assuming an average of 50 pairs per subpopulation) of the remaining scrub-jay families have an extinction probability ranging between 3 and 50 percent. These subpopulations, which occur primarily in southwestern Florida, particularly in Manatee and Sarasota counties, once comprised the southern part of the Gulf Coast Subregion. Since the 1992-1993 survey that produced these data, this area has experienced extensive habitat loss and fragmentation because of urbanization. Consequently, many (if not most) of these subpopulations have been reduced in area and fragmented, with a commensurate decline in the number of breeding pairs these subpopulations support.

The remaining breeding pairs occur in six subpopulations. Of those, the subpopulations centered in the Ocala NF, Lake Wales Ridge, and Merritt Island/Cape Canaveral Complex represent the “core subpopulations,” which are large enough to have only a 1 percent probability of extinction over 100 years. Of more concern are the two subpopulations along the Atlantic coast from Brevard County to Palm Beach County and along the Gulf coast in Sarasota and Charlotte counties. Since the 1992-1993 survey, these areas have also experienced extensive habitat loss and fragmentation because of urbanization. Consequently, these subpopulations have also been reduced in area with a commensurate decline in the number of breeding pairs they support. We feel these areas, in particular, warrant immediate management actions to preclude the extirpation of the scrub-jay.

In South Florida, the only core population that remains exists on the Lake Wales Ridge. This core population is also experiencing extensive habitat loss and fragmentation because of urbanization; the effects of continued urbanization raises concerns about the current status and trends of this population. We feel the Lake Wales Ridge population is critical to the survival and recovery of the Florida scrub-jay in South Florida; any further declines in the size and distribution of this core population places the Florida scrub-jay at a greater risk of extinction in South Florida.

Florida scrub-jays will also inhabit suburban areas where patches of scrub remain. In central Florida, the highest densities of scrub-jays are in areas where development is 33 percent or less (R. Bowman, Archbold Biological Station, personal communication 1995). Scrub-jay increases in habitats altered by human actions probably result from supplemental food sources (primarily peanuts) and the initial creation of openings in the scrub and visual buffers (buildings) to neighboring jay families. However, as the degree of habitat destruction and fragmentation increases, the survival of fledgling scrub-jays declines and failed nesting attempts increase (Toland 1991). Females from suburban territories may have fewer opportunities to pair with single males, because most males in suburban areas gain territories through breeder replacement (Thaxton and Hingtgen 1996). In addition, the potential for males remaining as helpers to inherit suitable habitat in suburban areas is greatly reduced when compared to protected areas. Resident males may be less likely to maintain any natal territory as a breeder in suburban areas (Thaxton and Hingtgen 1996).

Scrub-jay population numbers are also affected by the frequency and severity of catastrophic mortalities. Epidemic disease is the only known catastrophe that affects Florida scrub-jay populations (Fitzpatrick *et al*. 1991). Archbold Biological Station experienced an epidemic between September 1979 and February 1980 that killed 70 percent of the scrub-jays on that site; the population was not recovered to pre-epidemic numbers as of 1991. The probability of such an epidemic occurring in the future should be considered, along with habitat quality and management, to better predict the future status of scrub-jay populations in Florida. Root (1996) used spatially explicit models to show that an annual epidemic rate of 0.001 (one in a thousand years) produced quasi-extinction probabilities of at least 66 percent for Florida scrub-jays in Brevard County, Florida under optimal habitat conditions and no dispersal, and at least 52 percent when dispersal was allowed among her modeled populations. The addition of connectivity between populations can mitigate the effects of epidemics, and should be an important component of reserve designs for conservation of Florida scrub-jays.

Management

Overall conservation measures for the Florida scrub-jay should include an understanding of the demography and behavior of the species as well as the long-term management needs of oak-dominated scrub habitat. All Florida scrub-jays reside within territories, and each territory must contain sufficient habitat to sustain a family throughout the year. Given that, it is critical to know the total area of suitable habitat needed, the density of territories supported by the habitat, and the long-term management needs for that habitat to maintain its suitability for scrub-jays.

Effective management of the remaining Florida oak scrub habitat, both on public and private lands, will ultimately determine the fate of the Florida scrub-jay. Management to maintain or increase numbers of scrub-jays is directly correlated with maintaining or increasing the amount of habitat available to support territorial pairs of these birds (Fitzpatrick *et al*. 1994b). Maintenance of suitable habitat not only requires management of the patches of scrub occupied by scrub-jays, it also necessitates maintenance of the landscape matrix within which scrub occurs (D. Breininger, DYN-2, personal communication 1998). Periodic fire maintains landscape diversity and reduces likelihood of fragmentation of scrub patches.

Florida scrub-jays will not persist in habitat that is not burned regularly. Natural fires, which typically occur from lightening strikes between May and September, are a frequent influence on scrub habitat succession. These fires probably occurred at intervals of 10 to 100 years in various types of scrub during presettlement times (Myers 1990). Fire does not alter the vegetative species composition of scrub communities; most of the dominant plants either resprout from underground rhizomes, or recruit from seeds in the soil or released above ground after fire (Schmalzer and Hinkle 1987). Oak scrub revegetates to its preburn structure and species composition about 4 to 5 years after a fire (Abrahamson 1984, Schmalzer and Hinkle 1987, Breininger and Schmalzer 1990).

Fire frequencies necessary to maintain scrub and the surrounding landscape matrices vary depending on whether conditions are mesic or xeric. Within the xeric Lake Wales Ridge, fire return intervals averaging about once every 10 to 20 years is optimal for scrub-jays (Fitzpatrick *et al*. 1991). In more mesic conditions such as those found along the Gulf and Atlantic coasts, more frequent fires (every 6 to 12 years) are required to maintain suitable scrub-jay habitat. In mesic scrubs, more frequent fires may be needed initially to restore overgrown scrub and maintain the functions and values of adjacent ecosystems (D. Breininger, DYN-2, personal communication 1998). However, too frequent fires in scrub tend to maintain the principal oak species below acorn-bearing height and may encourage the spread of palmettos at the expense of oaks. Less frequent fires produce tall, dense oak understories and pine forests (also known as "overgrown scrub") which are unsuitable to scrub-jays.

In the absence of natural fires the oak scrub community requires specific management prescriptions, including controlled burns and/or mechanical renovation, to maintain habitat suitability for scrub-jays (Myers 1990, Woolfenden and Fitzpatrick 1991, Breininger 1992, Fitzpatrick *et al*. 1994b). Prescribed burning is the preferred method of scrub management. Mechanical treatments, such as rollerchopping, are short-term alternatives but may be less effective in the long term. Studies conducted at Archbold Biological Station during the past 25 years conclude that small, isolated populations of Florida scrub-jays are more likely to become extinct due to normal demographic fluctuations if their habitat is not maintained by periodic burning (Fitzpatrick *et al*. 1991). Root (1996) also showed, through the use of various population models, that reserve designs for Florida scrub-jays must incorporate restoration of habitat quality for successful conservation of the species.

According to Fitzpatrick *et al*. (1991), habitat management prescriptions for scrub-jays should include rotations of prescribed burns, each covering relatively small portions of a preserved tract of scrub. Each point in the tract should be burned once every 10 to 20 years, on average; the shorter intervals are applicable to faster-growing coastal scrubs while the longer intervals are correlated to the slow-growing central ridge scrubs (Woolfenden and Fitzpatrick 1991). Small patches left unburned will provide cover and foraging sites as the scrub regenerates. No more than 25 percent of an area occupied by scrub-jays should be burned at any one time (Fitzpatrick *et al.* 1991). Again, it is critical to maintain or make connections between patches of suitable habitat to facilitate dispersal, and to include buffer habitat around scrub patches (Root 1996).

When creating or managing reserves for scrub-jays, consideration must be given to habitat composition, size, shape, and location (Fitzpatrick *et al*. 1991). Effective reserve design to support an adequate protected population of Florida scrub-jays in average habitat should include about 304 ha of periodically burned oak scrub (Fitzpatrick *et al*. 1991). This assumes that an adequate protected population of scrub-jays consists of 15 to 30 territories located within 4 km of at least one other population containing more than 30 territories, and the need for 10 ha per territory. Florida scrub-jay populations containing fewer than 30 territories cannot be considered safe from extinction over the long term. Reserves separated by more than 12 km with no connecting scrub patches or corridors can cause isolation of populations by not allowing for dispersal and colonization (Woolfenden and Fitzpatrick 1996b). Small patches or corridors of scrub between larger tracts will reduce the probability that scrub-jays in any one patch will become extirpated. Fitzpatrick *et al*. (1991), therefore, recommend preservation of large tracts of oak scrub habitat over a number of smaller tracts for reserve design. In suburban areas, it has been shown that Florida scrub-jays may not disperse from natural to suburban territories (Thaxton and Hingtgen 1996). Therefore, it is critical to consider maintaining natural preserves for resident birds within dispersal distance; without these, the resident birds are extremely vulnerable to extirpation.

Although a majority of the population of Florida scrub-jays currently resides on public lands, overall numbers of the species are in decline. Management practices on public lands should focus on enhancing and creating scrub habitat to assist with scrub-jay recovery. Conservation on private lands includes acquisition programs for scrub habitat, through State efforts such as the CARL program, and the implementation of habitat conservation plans to protect large tracts of suitable scrub habitat. The FWS is using the digital data presented by Fitzpatrick *et al*. (1994b) to evaluate the amount of occupied scrub habitat as well as unoccupied but restorable scrub throughout Florida, and to identify areas suitable for creating reserves on both public and private lands, including establishing connections between existing protected habitat. In addition, we will be using spatially explicit models to predict results of various alternative reserve designs and help us implement the most optimal conservation measures for long-term protection of the Florida scrub-jay.

There are cases, however, where long-term management of scrub habitat is not possible, such as in rapidly expanding urbanized areas. Fitzpatrick *et al*. (1991) outline procedures to inventory habitat and protocols to survey for scrub-jays, intended as guidance for determining if proposed development projects will adversely affect Florida scrub-jays or their habitat. These authors also provide instruction on implementing preservation measures for agencies or individuals who believe scrub-jays or their habitat will be negatively affected by land clearing or related activities.

To address potential negative effects of land-use practices on scrub-jays and their habitat, we are adopting the terminology recommended by Fitzpatrick *et al*. (1994b). A subpopulation of scrub-jays consists of a number of territories, where each territory is not separated by more than 3.2 km. Clusters of subpopulations that are separated by more than 8 km are considered satellite systems. Satellite systems are also isolated from the core populations and from each other by this same distance. A subpopulation or satellite system is considered isolated if it is separated from the next nearest one by more than 24 km, the maximum documented dispersal distance for the species.

For projects where adverse effects to Florida scrub-jays and their habitats are likely, on-site minimization measures, as well as off-site habitat compensation may be required. Habitat compensation results in the protection and management of suitable scrub-jay habitat in another area. The FWS generally recommends that areas used as habitat compensation be located in the same subregion of the affected habitat to enhance existing subpopulations and satellite systems, and maintain any subregion-specific characteristics among the birds. It has been shown that genetic, ecological and behavioral differences exist among Florida scrub-jays within the different subregions (Fitzpatrick *et al*. 1994b). It is also important to understand the aforementioned dispersal distances to avoid further fragmentation and isolation of existing scrub-jay subpopulations and satellite systems. For compensation, the FWS also generally recommends conservation and management of two acres of occupied habitat for every one acre of occupied habitat affected. This recommendation is currently under review to determine whether adequate long-term protection to the Florida scrub-jay is afforded. Although the 2:1 ratio may result in scrub-jay persistence in many areas, it does not protect enough habitat to ensure long-term recovery of the species.

In areas where scrub habitat is threatened so that scrub-jays would not be able to survive, translocation of birds to protected areas of suitable habitat may be an alternative to salvage birds that would otherwise be lost. Translocation may also be useful to re-establish populations of scrub-jays from areas where they were extirpated, following habitat restoration. In 1989-90, Mumme and Below (1995) conducted an experimental translocation of 18 scrub-jays (12 helpers and 3 breeding pairs) into unoccupied protected scrub habitat in Collier County. Half of these birds disappeared or emigrated and half remained to eventually establish territories. As of December, 1996, this population consisted of six adults (1 female, 5 males) and three first-year birds (at least 1 female). Because of the apparent shortage of females, supplemental translocation may be needed (Mumme and Below 1996). Further research is still needed to assess translocation as a viable management option for these exceptional circumstances.

Literature Cited

American Ornithologists' Union [AOU]. 1957. Check-list of North American Birds. Fifth edition. Allen Press; Lawrence, Kansas.

American Ornithologists' Union [AOU]. 1983. Check-list of North American Birds. Sixth edition. Allen Press; Lawrence, Kansas.

American Ornithologists' Union [AOU]. 1995. Fortieth supplement to the North American Ornithologists' Union check-list of North American Birds. Auk 112(3):819-830.

Abrahamson, W.G. 1984. Post-fire recovery of the Florida Lake Wales Ridge vegetation. American Journal of Botany 71: 9-21.

Bancroft, G.T., and G.E. Woolfenden. 1982. The molt of scrub jays and blue jays in Florida. Ornithological Monograph Number 29. American Ornithologists' Union; Washington, D.C.

Bent, A.C. 1946. Life histories of North American jays, crows and titmice. U.S. National Museum Bulletin number 191. U.S. Government Printing Office; Washington, D.C.

Bergen, S. 1994. Characterization of fragmentation in Florida scrub communities. Unpublished M.S. Thesis, Department of Biological Sciences, Florida Institute of Technology; Melbourne, Florida.

Bowman, R. 1995. FWS Multi-Species Recovery Meeting. 5 December, 1995.

Bowman, R, G. E. Woolfenden, A.L. Fleischer, Jr., and L.M. Walton. 1996. Nest site selection by Florida scrub-jays in natural and modified habitats. Abstract, Archbold Biological Station 1996 Symposium. 12 September, 1996. Lake Placid, Florida.

Breininger, D.R. 1981. Habitat preferences of the Florida scrub jay *(Aphelocoma coerulescens coerulescens*) at Merritt Island National Wildlife Refuge, Florida. Unpublished M.S. thesis, Florida Institute of Technology; Melbourne, Florida.

Breininger, D.R. 1992. Habitat model for the Florida scrub jay on John F. Kennedy Space Center. NASA Technical Memorandum no. 107543. NASA Biomedical Operations and Research Office, John F. Kennedy Space Center, Florida.

Breininger, D.R., and P.A. Schmalzer. 1990. Effects of fire and disturbance on plants and animals in a Florida oak/palmetto scrub. American Midland Naturalist 123: 64-74.

Breininger, D.R., V.L. Larson, B.W. Duncan, R.B. Smith, D.M. Oddy, and M.F. Goodchild. 1995. Landscape patterns of Florida scrub jay habitat use and demographic success. Conservation Biology 9(6):1442-1453.

Breininger, D.R. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. January 26, 1998.

Burt, D.B. and A.T. Peterson. 1993. Biology of cooperative-breeding scrub jays (*Aphelocoma coerulescens*) of Oaxaca, Mexico. Auk 110:207-214.

Cox, J.A. 1987. Status and distribution of the Florida scrub jay. Florida Ornithological Society Special Publication number 3. Gainesville, Florida.

DeGange, A.R., J.W. Fitzpatrick, J.N. Layne, and G.E. Woolfenden. 1989. Acorn harvesting by Florida scrub jays. Ecology 70(2):348-356.

Fernald, R.T. 1989. Coastal xeric scrub communities of the Treasure Coast Region, Florida: A summary of their distribution and ecology, with guidelines for their preservation and management. Florida Game and Fresh Water Fish Commission, Nongame Wildlife Program technical report number 6. Tallahassee, Florida.

Fitzpatrick, J.W., and G.E. Woolfenden. 1988. Components of lifetime reproductive success in the Florida scrub jay. Pages 305-320 *in* T.H. Clutton-Brock, ed. Reproductive success. University of Chicago Press; Chicago, Illinois.

Fitzpatrick, J.W., G.E. Woolfenden, and M.T. Kopeny. 1991. Ecology and development-related habitat requirements of the Florida scrub jay (*Aphelocoma coerulescens coerulescens*). Florida Game and Freshwater Fish Comm. Nongame Wildlife Program technical report number 8. Tallahassee, Florida.

Fitzpatrick, J.W., R. Bowman, D.R. Breininger, M.A. O'Connell, B. Stith, J. Thaxton, B.R. Toland, and G.E. Woolfenden. 1994a. Habitat conservation plans for the Florida scrub jay: a biological framework. Unpublished draft report. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Fitzpatrick, J.W., B. Pranty, and B. Stith. 1994b. Florida scrub jay statewide map 1992-1993. Archbold Biological Station. Lake Placid, Florida.

Fleischer, A.L., Jr. 1996. Pre-breeding time budgets of female Florida scrub-jays in natural and suburban habitats. Abstract, Archbold Biological Station 1996 Symposium. 12 September 1996. Lake Placid, Florida.

Iverson, G. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 28, 1998.

Laessle, A.M. 1958. The origin and successional relationships of sandhill vegetation and sand pine scrub. Ecological Monographs 28:361-387.

Laessle, A.M. 1968. Relationships of sand pine scrub to former shore lines. Quarterly Journal of the Florida Academy of Science 30:269-286.

McGowan, K.J., and G.E. Woolfenden. 1989. A sentinel system in the Florida scrub jay. Animal Behavior 37:1000-1006.

McGowan, K.J., and G.E. Woolfenden. 1990. Contributions to fledgling feeding in the Florida scrub jay. Journal of Animal Ecology 59:691-707.

Mumme, R.L. 1992. Do helpers increase reproductive success? An experimental analysis in the Florida scrub jay. Behavioral Ecology and Sociobiology 31:319-328.

Mumme, R.L., and T.H. Below. 1995. Relocation as a management technique for the threatened Florida scrub jay. Annual project report, Florida Game and Fresh Water Fish Commission, December, 1995. On file at the U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Mumme, R.L., and T.H. Below. 1996. Viability of translocated scrub jays. Annual Project Report, Florida Game and Fresh Water Fish Commission, December, 1996. On file at the U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Myers, R.L. 1990. Scrub and high pine. Pages 150-193 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

Root, K.V. 1996. Population viability analysis for the Florida scrub-jay (*Aphelocoma coerulescens coerulescens*) in Brevard County, Florida. Unpublished Ph.D. dissertation, Florida Institute of Technology; Melbourne, Florida, May 1996.

Schaub, R., R.L. Mumme, and G.E. Woolfenden. 1992. Predation on the eggs and nestlings of Florida scrub jays. Auk 109:585-593.

Schmalzer, P.A., and C.R. Hinkle. 1992. Species composition and structure of oak-saw palmetto scrub vegetation. Castanea 57 (4):220-251.

Schmalzer, P.A., and C.R. Hinkle. 1987. Effects of fire on composition, biomass, and nutrients in oak scrub vegetation on John F. Kennedy Space Center, Florida. NASA Technical Memorandum no. 100305. NASA Biomedical Operations and Research Office, John F. Kennedy Space Center, Florida.

Stallcup, J.A., and G.E. Woolfenden. 1978. Family status and contribution to breeding by Florida scrub jays. Animal Behavior 26:1144-1156.

Stith, B.M., J.W. Fitzpatrick, G.E. Woolfenden, and B. Pranty. 1996. Classification and conservation of metapopulations: a case study of the Florida scrub jay. Pages 187-215 *in* D.R. McCullough, ed. Metapopulations and wildlife conservation. Island Press; Washington, D.C.

Thaxton, J.E. and T.M. Hingtgen. 1994. Responses of Florida scrub jays to management of previously abandoned habitat. District 4 annual research report, Florida Park Service; Tallahassee, Florida.

Thaxton, J.E. and T.M. Hingtgen. 1996. Effects of suburbanization and habitat fragmentation on Florida scrub-jay dispersal. Florida Field Naturalist 24 (2):25-60.

Thaxton, J.E. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. July 21, 1998.

Toland, B.R. 1991. Nest site characteristics of a Florida scrub jay population in Indian River County. Abstract. Florida scrub jay workshop. 23 May 1991. Ormond Beach, Florida.

Toland, B.R. 1996. Unpublished data summaries from research conducted 1988-1993 with Florida Game and Fresh Water Fish Commission. Received November 1996.

U.S. Fish and Wildlife Service [FWS]. 1990. Recovery plan for the Florida scrub-jay. U.S. Fish and Wildlife Service; Atlanta, Georgia.

U.S. Fish and Wildlife Service [FWS]. 1995. Endangered and threatened wildlife and plants, 50 CFR 17.11 and 17.12. October 31, 1995.

Woolfenden, G.E. 1974. Nesting and survival in a population of Florida scrub jays. Living Bird 12:25-49.

Woolfenden, G.E. 1975. Florida scrub jay helpers at the nest. Auk 92:1-15.

Woolfenden, G.E. 1978. Growth and survival of young Florida scrub jays. Wilson Bulletin 90:1-18.

Woolfenden, G.E., and J.W. Fitzpatrick. 1977. Dominance in the Florida scrub jay. Condor 79:1-12.

Woolfenden, G.E., and J.W. Fitzpatrick. 1978. The inheritance of territory in group-breeding birds. BioScience 28:104-108.

Woolfenden, G.E., and J.W. Fitzpatrick. 1984. The Florida scrub jay: demography of a cooperative-breeding bird. Princeton University Press; Princeton, New Jersey.

Woolfenden, G.E., and J.W. Fitzpatrick. 1986. Sexual asymmetries in the life histories of the Florida scrub jay. Pages 97-107 *in* D. Rubenstrin and R.W. Wrangham, eds. Ecological aspects of social evolution: birds and mammals. Princeton University Press, Princeton, New Jersey.

Woolfenden, G.E., and J.W. Fitzpatrick. 1990. Florida scrub jays: A synopsis after 18 years of study. Pages 241-266 *in* P.B. Stacey, and W.B. Koenig, eds. Cooperative breeding in birds. Cambridge University Press.

Woolfenden, G.E., and J.W. Fitzpatrick. 1991. Florida scrub jay ecology and conservation. Pages 542-565 *in* C.M. Perrins, J.D. Lebreton, and G.J.M. Hirons, eds. Bird population studies: relevance to conservation and management. Oxford University Press; Oxford, United Kingdom.

Woolfenden, G.E., and J.W. Fitzpatrick. 1996a. Florida scrub jay. Pages 267-280 *in* J. A. Rodgers, H. W. Kale, and H. T. Smith, eds. Rare and endangered biota of Florida, volume V. Birds. University Presses of Florida; Gainesville, Florida.

Woolfenden, G.E., and J.W. Fitzpatrick. 1996b. Florida scrub-jay. Pages 1-27 *in* A. Poole and F. Gill, eds. The birds of North America, No.228. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union; Washington, D.C.

Recovery for the Florida Scrub-jay

Aphelocoma coerulescens

Recovery Objective: To be determined by the recovery team during the ongoing revision of the range-wide recovery plan for the Florida scrub-jay.

South Florida Contribution: Stabilize and increase the South Florida population.

Recovery Criteria

Since its listing as a threatened species in 1987, the Florida scrub-jay population has declined by approximately 50 percent because of the destruction, fragmentation, and degradation of scrub communities throughout peninsular Florida, due to residential housing or commercial development. These areas are not restorable.

The South Florida recovery objective will be achieved when: a reserve design is developed that identifies contiguous patches of suitable-size scrub habitat, within and between all subregions, that is essential for preventing further declines in the population; any further loss, fragmentation, and degradation of habitat within the reserves has been prevented; occupied habitat within the reserves is protected through land acquisition or cooperative agreements with private landowners; scrub-jays and their scrub habitat are appropriately managed to assure population viability and habitat contiguity; unoccupied and overgrown scrub is restored and managed as suitable habitat within dispersal distance (up to 8 km) of occupied habitat to increase numbers of scrub-jays; and subpopulations within the reserves (throughout all subregions) exhibit an intrinsic rate of increase (r) equal to or greater than 0.0, sustained as a 3-year running average over at least 10 years.

Species-level Recovery Actions

S1. Determine the distribution of scrub-jays and status of scrub habitat in South Florida.

S1.1. Update the 1992-1993 statewide survey (Fitzpatrick *et al.* 1994) in 2002 by groundtruthing a sample of scrub sites that were considered "occupied" during those surveys to determine the current status of the habitat and to verify if scrub-jays are still present. Priority should be given to areas where habitat fragmentation has been the greatest over the past 5 years, *i.e*., Polk, Highlands, Sarasota, Charlotte, and Indian River counties. Identify key metapopulations that may require more frequent surveys.

S1.2. Maintain scrub-jay distribution data in a GIS database. Update the existing GIS database by including information obtained in **S1.1** on the distribution of known scrub-jay territories throughout South Florida and the current status of scrub habitat. Ensure terminology is consistent with the 1992-1993 survey: currently occupied, occupied in 1992-1993, formerly occupied (both pre-1980 and current changes from 1992-1993 survey), and unknown.

S2. Protect and enhance Florida scrub-jay populations.

S2.1. Develop a reserve design for scrub-jays in South Florida using landscape maps, GIS and spatially explicit population models. These reserves will consist of areas identified as critical to the survival and recovery of the scrub-jay in South Florida. Large, contiguous patches of scrub habitat with minimum interspersion of forested and urbanized areas are most ideal. Non-contiguous patches, outside of the maximum dispersal distance for scrub-jays, must be large enough to maintain viable populations, or must have corridors to link to additional patches of suitable habitat.

S2.1.1. Identify all public lands, other conservation lands, and private lands where scrub-jays currently exist. Determine the current status and distribution of scrub-jays on protected and private lands from **S1.2**.

S2.1.2. Identify all unoccupied, potentially restorable scrub on public and other conservation lands. Work with Federal, State, and county agencies and non-governmental organizations to identify areas where scrub management is needed, and where such management would benefit scrub-jays.

S2.1.3. Identify additional key privately owned lands that could enhance existing scrub-jay preserves on conservation lands to which suburban scrub-jays could emigrate, or that would provide corridors to facilitate dispersal between occupied conservation lands. Consider willingness of sellers and economic feasibility.

S2.1.4. Use spatially explicit models with the existing information on suitable and restorable scrub remaining in South Florida, and scrub-jay biology, to identify the most suitable and feasible alternative for development of a reserve design to conserve scrub-jays in South Florida.

S2.1.5. Develop criteria under which private lands would be considered for conservation.

S2.2. Protect, manage, and enhance Florida scrub-jay populations on public lands. In South Florida, scrub-jays occur on Avon Park AFR (Highlands and Polk counties), Hobe Sound NWR (Martin County) Lake Wales Ridge NWR (Highlands and Polk counties), and on the BLM and U.S. Coast Guard Jupiter Inlet tract (Palm Beach County). Scrub-jays also occur on many State and county-administered lands with a multitude of land-use designations. The survival of the Florida scrub-jay depends to a large extent on maintaining and improving scrub habitat on these public lands.

S2.2.1. Develop management plans for scrub-jays where they occur on public lands. With assistance from the FWS, each public property manager should develop a long-term management plan designed to protect and enhance scrub-jay populations on their property. The plans should include fire and/or mechanical management to maintain scrub in a suitable condition for scrub-jays.

S2.2.2. **Implement management plans for scrub-jays on public lands**. Public land managers should coordinate to ensure that implementation and timing of management actions on adjacent properties minimize conflict, and that equipment and personnel are used effectively and efficiently.

S2.2.3. **Facilitate communication among entities responsible for carrying out management activities on public lands**. Establish a multi-agency team to assist in coordination of management planning.

S2.3. **Protect, manage, and enhance Florida scrub-jay populations on privately owned lands**. Scattered and disjunct scrub-jay populations occur widely on privately owned lands throughout central and South Florida. The largest of these is on the Archbold Biological Station in Highlands County, where the bird has been extensively studied and is well protected.

S2.3.1. **Protect the "core" population on the Lake Wales Ridge**. Continue to protect scrub-jays at Archbold Biological Station and initiate protective measures on other private lands. Maintain this core population at or above 400 pairs of birds, and maintain habitat for this population such that dispersal distance between habitat gaps is 3.5 km or less (Stith *et al.* 1996).

S2.3.2. **Work with landowners to protect and maintain suitable habitat for scrub-jays**. Small, isolated populations of scrub-jays occur on numerous small patches of privately owned scrub in South Florida. Make efforts to contact landowners to encourage them to enhance and maintain scrub habitat to benefit scrub-jays. Where appropriate, use existing local, State or Federal programs to provide funding assistance.

S2.3.3. **Recognize or reward protection and management efforts**. Management efforts on private lands should be recognized and rewarded in any way possible in light of the limited legal responsibilities involved.

S2.3.4. **Explore and implement other conservation programs**. The opportunities for a tax incentive program at county, State, and Federal levels should be explored and implemented if feasible.

S2.3.5. **Provide information on management and legal requirements to private landowners and managers**. Develop articles and guidelines that contain information and visual aids to identifying habitat of the species, detailed information for managing the species by an array of options depending on the total land management objectives of the owner or manager, and specific information on the legal responsibilities of private landowners through section 9 of the ESA.

S2.4. **Enforce available protective measures**. Identify and implement local, State and Federal regulations and guidelines to protect scrub-jays and their habitat.

S2.4.1. **Initiate section 7 consultation when applicable**. All Federal agencies must consult with the FWS on any of their activities (authorized, funded, or carried out) that may affect scrub-jays. Such activities include (among others) pesticide use, road construction, military training exercises, clearing of land for new buildings and runways and implementing management plans. Implement on-site minimization through section 7 when needed.

S2.4.2. **Implement on-site minimization, habitat compensation, and mitigation on non-Federal lands through section 10 when needed**. Where adverse effects cannot be avoided, measures must be taken to minimize on-site disturbance, and compensate or mitigate for the impacts that remain. The FWS generally recommends that areas used as habitat compensation be located in the vicinity of the affected habitat, where appropriate, to enhance existing scrub-jay families, and avoid further fragmentation and isolation of existing habitat.

S2.4.3. **Use reserve design in combination with draft management guidelines when scrub-jays and their habitat may be affected by proposed projects.** The FWS, in conjunction with the GFC, developed management guidelines in 1991 (Fitzpatrick *et al.* 1991) that discuss ways to minimize adverse effects of proposed projects to scrub-jays. Although these guidelines are not official FWS policy, they are useful when reviewing projects and for making recommendations about scrub-jay conservation.

S3. **Identify research needs on the biology and population demography**. Although scrub-jays have been well studied at Archbold Biological Station in xeric oak scrub habitat, additional research is needed on the biology of scrub-jays in other xeric communities and in suburban areas.

S3.1. **Gather information on the biology of scrub-jays in southwest Florida**. Conduct research on habitat use, reproductive success, nesting, role of helpers, juvenile dispersal, adult and juvenile survival and mortality, predation, and food habits of birds in the scrubby flatwoods habitats of southwest Florida to compare with information known from populations at Archbold Biological Station.

S3.2. **Conduct risk assessment analysis** to determine the probability of persistence of the scrub-jay in South Florida, given the current amount of suitable scrub habitat as well as potentially restorable scrub habitat.

S3.2.1. **Identify which subpopulations of scrub-jays are considered "viable"** according to recovery criteria, and which subpopulations or groups of birds are most vulnerable to extinction.

S3.2.2. **Incorporate results of S3.2.1. into the reserve design** for scrub-jays to assist with project review and ESA consultation process.

S3.3. **Study the effects of habitat fragmentation due to urbanization**. On a landscape level, determine how residential development affects the metapopulation dynamics of scrub-jays. On a population level, identify the conditions that scrub-jays can tolerate and adapt to in a suburban setting, in addition to the conditions that significantly alter their vital rates, such as reproductive success, growth, and survival.

S3.4. **Determine the biological and ecological conditions necessary to ensure natural colonization following habitat restoration**. Describe the conditions that are conducive to natural immigration of scrub-jays after restoration of unoccupied scrub. Collect life history information on scrub-jays that naturally immigrate to restored habitat, including immigration, habitat use, territoriality, reproduction, adult and juvenile survival, dispersal, and recruitment.

S3.5. **Continue studies on translocation of scrub-jays**. To date, only one study of translocation of scrub-jays has been undertaken. Further research on this technique is needed to assess its utility in recovery. Translocation should only be considered when natural dispersal/immigration to a suitable-sized restored scrub parcel is unlikely, or to "rescue" demographically isolated birds from habitat that will be adversely modified. Translocation could also be used to re-establish birds to historically occupied habitat that is now being appropriately managed.

S3.5.1. **Establish protocols for successful translocation of scrub-jays into unoccupied areas**. Establish criteria for successful re-establishment following translocation, such as the number, age structure, social structure, and gender ratios of birds to be used, geographic boundaries for obtaining source birds, and appropriate techniques for capture and release.

S3.5.2. **Release birds into new sites**. It is recommended to use birds from source populations within the same subregion for translocation efforts.

S4. **Monitor scrub-jay subpopulations**.

S4.1. **Monitor representative groups within each subregion in South Florida** to collect data on habitat use, reproduction, survival, mortality, dispersal, and recruitment to determine the status and trends of the subpopulations and assess recovery efforts.

S4.2. **Monitor birds in urban areas for changes in their vital rates,** such as reproductive success, growth, and survival as urbanization affects territory size.

S4.3. **Monitor natural immigrants and translocated birds**. Collect data as in **S4.1** to determine the success of birds that inhabit newly restored scrub habitat as well as birds that have been translocated to new areas.

S5. **Inform and involve the public**. Inform the public through articles for the news media and popular publications. Particular emphasis should be placed on explaining the status, importance, and biological needs of scrub-jays and the legal responsibilities for the species' protection.

Habitat-level Recovery Actions

H1. **Prevent degradation of existing scrub habitat**. The long-term recovery of the Florida scrub-jay is dependent upon the immediate protection of as much of the remaining occupied and suitable and unoccupied suitable scrub communities as is economically feasible within South Florida.

H1.1. **Prioritize areas identified in reserve design for acquisition and management**. Large, contiguous habitat patches are the most ideal for conserving scrub-jays. High priority should be given to areas contiguous with, or within short dispersal distance of, existing conservation lands where scrub-jays occur. High priority should also be given to areas adjacent to suburban sites where scrub-jays occur, allowing natural dispersal of birds from suburban areas to protected habitat.

H1.2. **Protect scrub-jay habitat on private lands through easements, acquisitions, and donations**. Lands identified for acquisition should be located adjacent to, or be contiguous with, publicly owned conservation lands or other lands proposed for acquisition that contain scrub-jays. Lands containing scrub-jays should receive special consideration where these lands would consolidate Federal ownership or control and contribute to overall resource management objectives of the agencies. Private landowners should be encouraged to avail themselves of these options.

H1.2.1. **Continue Federal acquisition efforts**. Continue acquisition efforts within the Lake Wales Ridge NWR complex. Much of the habitat targeted for acquisition will be acquired by 1998. One or possibly two additional, but currently unidentified parcels may subsequently be targeted for acquisition.

H1.2.2. **Support State acquisition efforts**. The Florida (CARL) program has a number of ongoing projects and proposals for the acquisition of scrub habitat in Florida, totaling approximately 13,900 and 2,400 ha., respectively. About 90 percent of the ongoing projects are in South Florida, however the proposed projects are predominantly in North Florida. Florida's Save Our Rivers (SOR) acquisition program administered by the water management districts targets wetlands for protection but some sites also contain xeric uplands, and potentially scrub-jay habitat, that may also benefit.

H1.2.3. **Encourage acquisition by non-governmental organizations.** Occupied private sector and suitable, unoccupied scrub not targeted in Federal and State acquisition programs may become available for private purchase and management. Scrub habitats already protected such as those at Archbold Biological Station and The Nature Conservancy's Tiger Creek Preserve, Saddle Blanket Lakes, and Lake Apthorpe areas are important for the long-term persistence of scrub-jays.

H1.2.4. **Pursue acquisition of lands identified as necessary for developing scrub-jay reserves that are not covered under H1.2.1-H1.2.3 above**.

H1.3. **Maintain suitable habitat for scrub-jays**. Prescribed burning, where feasible, is the optimal management tool. The fire frequency will vary depending on the type and condition of habitat being managed and the natural fire return interval. Burns should be done in a rotation, with each covering small portions of a preserved tract of scrub. No more than 25 percent of an area occupied by scrub-jays should be burned at any one time (Fitzpatrick *et al.* 1991). In areas where burns are not feasible, mechanical treatments, such as rollerchopping, provide short-term alternatives.

H1.4. **Prevent loss or fragmentation of scrub habitat within scrub-jay reserves identified in S2.1**. Ensure that no habitat gaps > 8 km are created within and between scrub reserves that might preclude dispersal by scrub-jays. Also note any potential physical barriers to dispersal (Stith *et al.* 1996).

H2. **Restore overgrown or unsuitable scrub habitat**. After identification of unoccupied but potentially restorable scrub (see **S2.1.2.**), work with local, State and Federal agencies and non-governmental organizations to determine the most feasible and appropriate management protocols (*i.e.* controlled burns or mechanical techniques at specific rotations) to restore overgrown scrub to suitable habitat for scrub-jays. Implement mechanisms in the protocols or management plans for ensuring continued management of these sites.

H3. **Conduct research to determine the applicability and effectiveness of various mechanical treatments for scrub management**. Mechanical treatments, such as rollerchopping or thinning, are needed as an alternative to burning scrub habitat, particularly on lands in or adjacent to urbanized areas.

H4. **Monitor xeric communities that provide scrub-jay habitat.**

H4.1. **Monitor scrub habitat that is occupied by scrub-jays to ensure public lands are managed to maintain scrub in suitable condition for scrub-jays, and to assess when unmanaged areas become unsuitable for scrub-jays. Also monitor to ensure the site is not becoming a "sink" for the population**.

H4.2. **Monitor unoccupied scrub habitat following restoration to collect data on how habitat characteristics afect immigration and establishment of scrub-jays**.

H4.3. **Maintain scrub-jay habitat data in a GIS database**. Update the existing GIS database by including information obtained from surveys in **S1.1** on the current status of scrub habitat in South Florida. Denote the condition of the scrub, and the type and timing of all pertinent management actions.

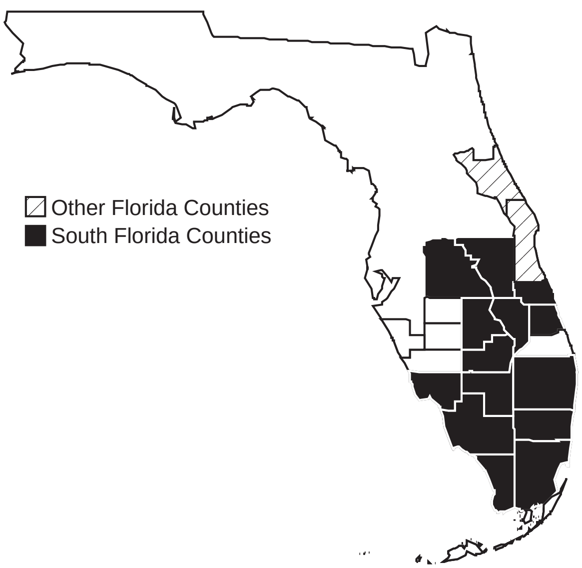
H5. Increase public awareness of the scrub ecosystem. Efforts should highlight habitat acquisition initiatives, importance of biodiversity, and biology of scrub-dependent species. Federal, State, and county governments, as well as private organizations, should support the development and dissemination of educational materials pertaining to the conservation of the scrub ecosystem and endemic scrub species. Materials such as brochures, posters, postcards, slide programs and videotapes can improve public understanding of and increase appreciation for protection of scrub habitat. Environmental education programs across central Florida should be encouraged to distribute materials or develop lesson plans on scrub ecosystems, particular scrub species, and the importance of maintaining biological diversity.

Everglade Snail Kite

Rostrhamus sociabilis plumbeus

Federal Status:	**Endangered (March 11, 1967)**
Critical Habitat:	**Designated (August 1977)**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. Florida distribution of the Everglade snail kite.



The Everglade snail kite (*Rostrhamus sociabilis*) is a wide-ranging New World raptor species found primarily in lowland freshwater marshes in tropical and subtropical America from Florida, Cuba, and Mexico south to Argentina and Peru. The subspecies from Florida and Cuba *(Rostrhamus sociabilis plumbeus)* was first listed as endangered pursuant to the Endangered Species Conservation Act in 1967. The common name used in the original listing was Everglade snail kite and this remains unchanged in the official FWS Code of Federal Regulations, even though the official name for the species is now simply snail kite (AOU 1983).

The Florida population of snail kites is considered to be a single population with considerable distributional shifts. The combination of a range restricted to the watersheds of the Everglades, lakes Okeechobee and Kissimmee, and the upper St. Johns River, with a highly specific diet composed almost entirely of apple snails (*Pomacea paludosa*), makes the snail kite's survival directly dependent on the hydrology and water quality of these watersheds. Each of these watersheds has experienced, and continues to experience, pervasive degradation due to urban development and agricultural activities.

This account represents a revision of the existing recovery plan for the Everglade snail kite (FWS 1986).

Description

The snail kite is a medium-sized raptor, with a total body length for adult birds of 36 to 39.5 cm and a wingspan of 109 to 116 cm (Sykes *et al.* 1995). In both sexes, the tail is square-tipped with a distinctive white base, and the wings are broad, and paddle-shaped. Adults of both sexes have red eyes, while juveniles have brown eyes (Brown and Amadon 1978, Clark and Wheeler 1987). The slender, decurved bill is an adaptation for extracting the kite's primary prey, the apple snail; the bill is a distinguishing character for field identification in both adults and juveniles.

Sexual dimorphism is exhibited in this species, with adult males uniformly slate gray and adult females brown with cream streaking in the face, throat, and breast. Most adult females have a cream superciliary line and cream chin and throat (Sykes *et al.* 1995). Females are slightly larger than males. Immature snail kites are similar to adult females but are more cinnamon-colored with tawny or buff-colored streaking rather than cream streaking. The legs and cere of females and juveniles are yellow to orange; those of adult males are orange, turning more reddish during breeding (Sykes *et al.* 1995).

In the field, the snail kite could be confused with the northern harrier (*Circus cyaneus*), a similarly sized hawk with a white rump. The northern harrier has a longer and narrower tail, with longer and narrower wings held in a dihedral. The snail kite's flight is slower and characterized by more wing flapping, with the head tilting down to look for snails; the northern harrier has a gliding, tilting flight. At a closer distance, the long, curved beak of the snail kite allows it to be easily distinguished from the northern harrier (Sykes *et al.* 1995).

Taxonomy

Three subspecies of the snail kite are currently recognized (Amadon 1975), but a larger sample size of body measurements is needed to confirm if the separation into three subspecies is valid (Sykes *et al.* 1995). These subspecies are: *Rostrhamus . s. plumbeus*, from peninsular Florida, Cuba, and northwestern Honduras; *R. s. major*, from Mexico, Guatemala, and the northern half of Belize; and *R .s. sociabilis*, from southern Nicaragua, through Panama and into South America as far south as northern Argentina. The *plumbeus* subspecies in Florida has a larger body size than that of *R. s. sociabilis*, with a beak of similar size. However, the validity of these subspecies remains a subject of debate; Beissinger (1988) is among those who question the validity of these designations.

The closest related species is the slender-billed kite (*R. hamatus*) from eastern Panama and South America (Ridgely and Gwynne 1989). The slender-billed kite, like the snail kite, feeds on snails of the genus *Pomacea*, but inhabits swamps or wet forests (Beissinger *et al.* 1988, Ridgely and Gwynne 1989).

Distribution

As noted above, the subspecies *R. s. plumbeus* occurs in Florida, Cuba (including Isla de la Juventud) and northwestern Honduras. There is no evidence of movement of birds between Cuba and Florida, but this possibility has not been ruled out (Sykes 1979, Beissinger *et al.* 1983).

In Florida, the original range of the snail kite was larger than at present. Historically, snail kites were known to nest in Crescent Lake and Lake Panasoffkee in north-central Florida and as far west as the Wakulla River (Howell 1932, Sykes 1984). Information on changes in distribution and abundance is in the Status and Trends section of this account.

Everglade snail kite.
Original photograph by Betty Wargo.

The current distribution of the Everglade snail kite in Florida (Figure 1) is limited to central and southern portions of the State. Six large freshwater systems are located within the current range of the snail kite: Upper St. Johns drainage, Kissimmee Valley, Lake Okeechobee, Loxahatchee Slough, the Everglades, and the Big Cypress basin (Beissinger and Takekawa 1983, Sykes 1984, Rodgers *et al.* 1988, Bennetts and Kitchens 1992, Rumbold and Mihalik 1994, Sykes *et al.* 1995). Habitats in the Upper St. Johns drainage include the East Orlando Wilderness Park, the Blue Cypress Water Management Area, the St. Johns Reservoir, and the Cloud Lake, Strazzulla, and Indrio impoundments. In the Kissimmee Chain of Lakes, snail kites are found at Lake Pierce, Lake Tohopekaliga, East Lake Tohopekaliga, Cypress Lake, Lake Hatchineha, Lake Marion, Lake Marian, Lake Kissimmee, Tiger Lake, Lake Arbuckle, and Lake Istokpoga. Lake Okeechobee and surrounding wetlands are major nesting and foraging habitats, particularly the large marsh in the southwestern portion of the lake and the area southwest of the inflow of the Kissimmee River. In the

Loxahatchee Slough region of Palm Beach County, snail kites are found at the West Palm Beach Water Catchment Area, the Pal-Mar Water Conservation District, and borrow lakes on property belonging to the Solid Waste Authority of Palm Beach County and the City of West Palm Beach. Wetlands in the Everglades region supporting the snail kite are the Arthur R. Marshall Loxahatchee NWR (including WCA 1, WCA 2, WCA 3), Shark River Slough and Taylor Slough in Everglades National Park, and the C-111 basin west of U.S. Highway 1. In the Big Cypress basin, snail kites use the Lostman's and Okaloacoochee sloughs, Hinson Marsh, and the East Loop and Corn Dance units of Big Cypress National Preserve. The Savannas State Preserve, in St. Lucie County, the Hancock impoundment in Hendry County, and Lehigh Acres in Lee County are among the smaller more isolated wetlands used by snail kites (Sykes *et al.* 1995). Although the above list generally describes the current range of the species, radio tracking of snail kites has revealed that the network of habitats used by the species includes many other smaller widely dispersed wetlands within this overall range (R. Bennetts, University of Florida, personal communication 1996, Bennetts and Kitchens 1997a).

Habitat

Snail kite habitat consists of freshwater marshes and the shallow vegetated edges of lakes (natural and man-made) where apple snails can be found. These habitats occur in humid, tropical ecoregions (Bailey 1978) of peninsular Florida and are characterized as palustrine-emergent, long-hydroperiod wetlands (Cowardin *et al.* 1979) often on an organic peat substrate overlying oolitic limestone or sand or directly on limestone or marl (Davis 1946).

Suitable foraging habitat for the snail kite is typically a combination of low profile (< 3 m) marsh with an interdigitated matrix of shallow (0.2-1.3 m deep) open water, which is relatively clear and calm. The marsh vegetation is dominated by spike rush (*Eleocharis cellulosa*), maidencane (*Panicum hemitomon*), sawgrass (*Cladium jamaicense*), and/or cattails (*Typha* spp.). The shallow open-water areas are with or without sparse vegetation, such as white water lily (*Nymphaea odorata*), arrowhead (*Sagittaria lancifolia*), pickerel weed (*Pontederia lanceolata*), and floating heart (*Nymphoides aquatica*). Giant bulrush (*Scirpus validus*) often grows at the deep-water edge of marshes in the lakes. Low trees and shrubs also are often interspersed with the marsh and open water. These often include willow (*Salix caroliniana*), dahoon holly (*Ilex cassine*), pond apple (*Annona glabra*), bald cypress *(Taxodium distichum*), pond cypress (*T. ascendens*), wax myrtle (*Myrica cerifera*), buttonbush (*Cephalanthus occidentalis*), and *Melaleuca quinquenervia*, an invasive exotic species.

Snail kites require foraging areas that are relatively clear and open in order to visually search for apple snails. Therefore, dense growth of herbaceous or woody vegetation is not conducive to efficient foraging. The interspersed emergent vegetation enables apple snails to climb near the surface to feed, breathe, and lay eggs. Nearly continuous flooding of wetlands for > 1 year is needed to support apple snail populations that in turn sustain foraging by the snail kite (Sykes 1979, Beissinger 1988). Cultural eutrophication of water bodies in Florida is occurring through disposal of domestic sewage and runoff of nutrient-laden water from agricultural lands. This degradation of water quality promotes dense growth of exotic and invasive native plants, particularly, cattail, water lettuce (*Pistia stratiotes*), water hyacinth (*Eichhornia crassipes*), and hydrilla (*Hydrilla verticillata*). Dense growth of these plants reduces the ability of snail kites to locate apple snails.

Nesting almost always occurs over water, which deters predation (Sykes 1987b). Nesting substrates include small trees (usually < 10 m in height), including willow, bald cypress, pond cypress, *Melaleuca*, sweetbay (*Magnolia virginiana*), swamp bay (*Persea borbonia*), pond apple and dahoon holly. Shrubs used for nesting include wax myrtle, cocoplum (*Chrysobalanus icaco*), buttonbush, *Sesbania,* elderberry (*Sambucus simpsonii*), and Brazilian pepper (*Schinus terebinthifolius*). Nesting also can occur in herbaceous vegetation, such as sawgrass, cattail, bulrush, and reed (*Phragmites australis*) (Sykes *et al.* 1995). Nests are more frequently placed in herbaceous vegetation around Lake Kissimmee and Lake Okeechobee during periods of low water when dry conditions beneath the willow stands (which tend to grow to the landward side of the cattails, bulrushes and reeds) prevent snail kites from nesting in woody vegetation. Nests constructed in herbaceous vegetation on the waterward side of the lakes' littoral zone are more vulnerable to collapse due to the weight of the nests, wind, waves, and boat wakes, and are more exposed to disturbance by humans (Chandler and Anderson 1974; Sykes and Chandler 1974; Sykes 1987b; Beissinger 1986, 1988; Snyder *et al.* 1989a). It is important to note that suitable nesting substrate must be close to suitable foraging habitat, so extensive areas of contiguous woody vegetation are generally unsuitable for nesting.

Roosting sites are also almost always located over water. In Florida, 91.6 percent are located in willows, 5.6 percent in *Melaleuca*, and 2.8 percent in pond cypress. Roost sites are in the taller vegetation among low-profile marshes. Snail kites tend to roost around small openings in willow stands at a height of 1.8 to 6.1 m, in stand sizes of 0.02 to 5 ha. Roosting in *Melaleuca* or pond cypress is in stands with tree heights of 4 to 12 m (Sykes 1985a).

Critical Habitat

Critical habitat was designated for the snail kite in 1977 and, since then, has not been revised. Critical habitat (Figure 2) includes the Arthur R. Marshall Loxahatchee NWR, WCA 2, portions of WCA 3, portions of Everglades NP, western portions of Lake Okeechobee, the Strazzulla and Cloud Lake reservoirs in St. Lucie County, and portions of the St. Johns Marsh in Indian River County. A complete description of the critical habitat is available in 50 CFR 17.95. Although snail kites have nested in several lakes (particularly East Lake Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee) in the headwaters of the Kissimmee River since the early 1980s, at the time of designation of critical habitat, potential habitat around these lakes was used only sporadically by snail kites, and was not included in the critical habitat.

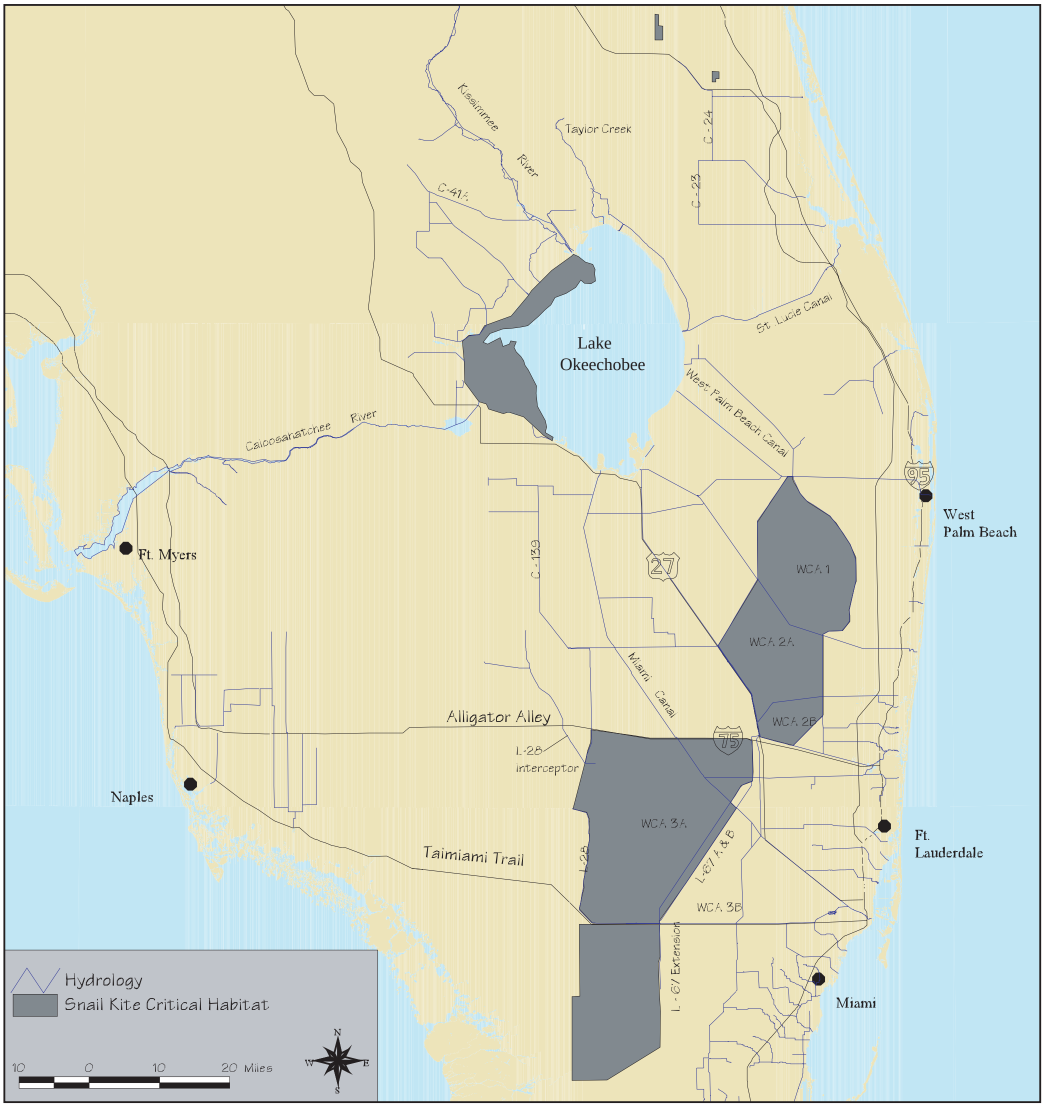


Figure 2. Snail kite critical habitat.

Behavior

Non-breeding snail kites use communal roosts throughout the year in association with other birds, particularly anhingas (*Anhinga anhinga*), herons, and vultures. The snail kite can nest solitarily, but more often in uneven clusters, and often hunts in close proximity without defending a foraging territory. However, defense of feeding territories, outside of the breeding season, occurs more often than previously thought; typically, however, these birds display no territorial behavior and feeding areas overlap (Stieglitz and Thompson 1967; Sykes 1979, 1985a, 1987a, b, c; Beissinger 1983, 1984, 1988).

Courtship

Pair bonds are formed by a series of behaviors with each nesting. Males often begin construction of the nest prior to attracting a mate. Materials are gathered with feet or bill and are carried in the bill one piece at a time to the nest site. The nest is a bulky loosely woven structure of dry sticks and other dry plant material. Thirty-two species of plants are known to be used in construction, with sticks from willow and wax myrtle the most common material (Sykes 1987b). Snail kites often use green nest material, especially the upper lining that forms a cup for holding the eggs; this functions to insulate the otherwise porous structure of dry sticks. Males display either in the air or at perch near the chosen nest site. Aerial displays often include carrying a stick in the bill and vocalizing; these displays may include skydance or undulating flight, deep wing beats, pendulum, mutual soaring, tumbling, and grappling. The male may feed the female a snail or bring her a stick. In Florida, most pair bonds form from late November to early June. Once a pair bond is established, the female may spend time at or near the nest site and may assist the male in completing the nest (Beissinger 1987a, 1988; Sykes 1987c).

Reproduction

Copulation can occur from early stages of nest construction, through egg-laying, and during early incubation if the clutch is not complete. Egg laying begins soon after completion of the nest or is delayed a week or more. An average 2-day interval between laying each egg results in the laying of a three-egg clutch in about 6 days. The clutch size is 1 to 5 eggs, with a mode of three (Sykes 1987c, Beissinger 1988, Snyder *et al.* 1989a). Incubation may begin after the first egg is laid, but generally after the second egg (Sykes 1987c). In Florida, the incubation period lasts 24 to 30 days (Sykes 1987c). Incubation is shared by both sexes, but the sharing of incubation time between sexes varies among nests (Beissinger 1987b).

Hatching success is variable from year to year and between areas. In nests where at least one egg hatched, hatching success averaged 2.3 chicks/nest. The most successful months for hatching are February (19 percent), March (31 percent), and April (23 percent) (Sykes 1987c).

The breeding season varies widely from year to year in relation to rainfall and water levels. Ninety-eight percent of the nesting attempts are initiated from December through July, while 89 percent are initiated from January through June (Sykes 1987c, Beissinger 1988, Snyder *et al.* 1989a). Snail kites often renest following failed attempts as well as after successful attempts (Beissinger 1986, Snyder *et al*. 1989a), but the actual number of clutches per breeding season is not well documented (Sykes *et al.* 1995).

Foraging

The snail kite feeds almost exclusively on apple snails (*Pomacea paludosa*) in Florida. The snail kite uses two visual foraging methods: course-hunting, while flying 1.5 to 10 m above the water surface, or still-hunting from a perch. While course-hunting, the flight is characterized by slow wing beats, alternating with gliding; the flight path is usually into the wind, with the head oriented downward to search for prey. Snails are captured with the feet at or below the surface, to a maximum reach of approximately 16 cm below the surface. Snail kites do not plunge into the water to capture snails and never use the bill to capture prey. Individuals may concentrate hunting in a particular foraging site, returning to the same area as long as foraging conditions are favorable (Cary 1985). Capture rates are higher in summer than in winter (Cary 1985), with no captures observed at a temperature less than 10°C. Snail kites frequently transfer snails from the feet to the bill while in flight to a perch. Feeding perches include living and dead woody-stemmed plants, blades of sawgrass and cattails, and fence posts.

The snail kite is known to feed on the introduced snail *Pomacea bridgesi* (Takekawa and Beissinger 1983). On rare occasions, snail kites in Florida prey on small turtles (Sykes and Kale 1974, Beissinger 1988, Bennetts *et al.* 1988). Snail kites have also been observed feeding upon crayfish (*Procambarus* spp.) and a speckled perch (*Pomoxis nigromaculatus*) (Bennetts *et al*. 1994).

Migration

Snail kites in Florida are not migratory. They are restricted to South and central Florida. Snail kites are nomadic in response to water depths, hydroperiod, food availability, and other habitat changes (Sykes 1978, 1983a; Beissinger and Takekawa 1983; Bennetts *et al.* 1994). Radio-tracking and sighting of marked individuals have revealed that nonbreeding individuals disperse widely on a frequent basis (Sykes 1979, 1983a; Beissinger 1988; Snyder *et al.* 1989b; Bennetts and Kitchens 1992; Bennetts *et al.* 1994). Shifts in distribution can be short-term, seasonal, or long-term, and can take place between areas from year to year (Rodgers *et al.* 1988), between areas within a given nesting season (Beissinger 1986), within areas in a given nesting season, and within or between areas for several days to a few weeks (Sykes (1983a) noted that during colder winters, snail kites will shift their distribution more to the southern part of their range. As noted above, there is no evidence of movement between Florida and Cuba, but the possibility has not been ruled out (Sykes 1979, Beissinger *et al.* 1983).

Rearing

The mating system of snail kites is characterized by sequential polygamy (ambisexual mate desertion). Desertion occurs in years with abundant food supply, but not during drought years. The deserted mate continues to tend the nest until independence of the chicks, which is for another 3 to 5 weeks (Beissinger 1984, 1986, 1987b; Beissinger and Snyder 1987). Young are fed through the nestling period and after fledging until they are 9 to 11 weeks old (Beissinger and Snyder 1987, Beissinger 1988). Chicks assume food begging postures and vocalizations when the tending adult approaches the nest with a snail. As the chicks mature, the food progresses from pieces of torn snail fed bill to bill, whole snails removed from the shell and with operculum removed, to completely intact snails (Beissinger 1988). When food is scarce, larger siblings may dominate the food supply brought to the nest. While rearing young, the adults forage no more than six km from the nest (Beissinger and Snyder 1987), and generally less than a few hundred meters

Relationship to Other Species

Snail kites and limpkins (*Aramus guarauna*) both feed on apple snails; habitat partitioning occurs between the two species where they feed in the same areas.

Limpkins feed tactually in dense emergent or floating vegetation as well as in open patches (Snyder and Snyder 1969), while snail kites feed visually in open water with a range of water depths.

When nesting, snail kites drive off turkey vultures (*Cathartes aura*) within 20 to 30 m of the nest. Aggressive behavior by snail kites near nests has been observed directed against other birds, including black-crowned night herons (*Nycticorax nycticorax*), ospreys (*Pandion haliaetus*), red-shouldered hawks (*Buteo lineatus*), limpkins, and boat-tailed grackles (*Quiscalus major*) (Sykes 1987b). Red-shouldered hawks, fish crows (*Corvus ossifagus*), and boat-tailed grackles are known to drive snail kites from a perch (Sykes *et al.* 1995).

Snail kite eggs are taken by fish crows, boat-tailed grackles, rat snakes (*Elaphe obsoleta*), and raccoons (*Procyon lotor*) (Chandler and Anderson 1974; Beissinger 1986, 1988; Sykes 1987c; Snyder *et al.* 1989a). Nestlings are lost to rat snakes and cottonmouths (Beissinger 1986, 1988; Sykes 1987c; Bennetts and Caton 1988), despite the fact that snail kites select nest sites in flooded wetlands, which tends to make the nests less vulnerable to predation.

The ranges of the endangered wood stork (*Mycteria americana*) and Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) overlap the range of the snail kite. While hydrological conditions most favorable to one species may not be most favorable for another, all of these animals survived the hydrologic variability characteristic of the natural system. The reduced heterogeneity and extent of the present system make these species more vulnerable to natural and man-caused threats. Management actions may be required on a temporary basis to protect a particular species from a high risk of extinction, but long-term management goals should not be driven by protection of a single species, because such actions may threaten the sustainability of the entire ecosystem.

Status and Trends

When the snail kite was listed as endangered in 1967 (32 FR 4001), the species was considered to be at an extremely low population level. In 1965, only 10 birds were found, eight in WCA2A and two at Lake Okeechobee. A survey in 1967 found 21 birds in WCA2A (Stieglitz and Thompson 1967). On this basis, the snail kite was included in the first group of species to be listed under the Endangered Species Conservation Act, the predecessor to the current Endangered Species Act. The publication Threatened Wildlife of the United States (Bureau of Sport Fisheries and Wildlife 1973) cited the following as the status of the snail kite:

> Jeopardized because of the very small population and increasingly limited amount of fresh marsh with sufficient water to ensure an adequate supply of snails on which it depends for food.

Historic records of snail kite nesting include areas as far north as Crescent Lake and Lake Panasoffke in north-central Florida and as far west as the Wakulla River (Howell 1932, Sykes 1984). Several authors (Nicholson 1926, Howell, 1932, Bent 1937) indicated that the snail kite was numerous in central and South Florida marshes during the early 1900s, with groups of up to 100 birds. Sprunt (1945) estimated the population to be 50 to 100 individuals. The snail kite apparently plummeted to its lowest population between 1950 and 1965. By 1954, Sprunt estimated the population at no more than 50 to 75 birds

(Sprunt 1954). Stieglitz and Thompson (1967) reported eight birds in 1963 at the Loxahatchee NWR, 17 on the refuge and two at Lake Okeechobee in 1964, eight in WCA2A and two at Lake Okeechobee in 1965, and 21 in WCA2A in 1966. Limited resources were available at that time for researchers to reach potential snail kite habitats, and the resulting low level of survey effort may have biased these low snail kite population estimates. However, there is no doubt that the snail kite was severely endangered at that time and that its range had been dramatically reduced.

Sykes (1983b) mentioned two reports, by other observers, of lone snail kites at Lake Kissimmee in 1973 and 1980. Sykes (1984) reported the range of the snail kite in Florida, as of 1980, included the following areas: southwestern Lake Okeechobee (Glades County), portions of WCAs 1, 2B, and 3A (Dade, Broward, and Palm Beach counties), the Lake Park Reservoir (Palm Beach County), the northern portion of Everglades National Park just south of Tamiami Trail (Miami-Dade County) the Savannas (St. Lucie County), and the headwaters of the St Johns River (Indian River and St. Lucie counties). Sykes (1984) did not mention the two isolated reports at Lake Kissimmee. Beissinger and Takekawa (1983) report that 3 to 25 snail kites were observed on Lake Kissimmee and 6 to 32 were sighted on Lake Tohopekaliga in 1981-1982, and classified these among a number of “drought related habitats.” The first reported nesting of snail kites occurred on these two lakes during that period. Rodgers (1994) has continued to find significant nesting and foraging by snail kites in the Kissimmee Chain of Lakes into the mid-1990s, which he characterized as a reoccupying of a portion of the species’ historic range.

Prior to 1969 the snail kite population was monitored only through sporadic and haphazard counts (reviewed by Sykes 1984). From 1969 to 1994, an annual quasi-systematic mid-winter snail kite count was conducted by a succession of principal investigators. Counts since 1969 have ranged from 65 in 1972 to 996 in 1994. Bennetts *et al.* (1993, 1994) caution that the 1993 and 1994 counts were performed with the advantage of having numerous birds radio-tracked. This certainly influenced the total count, because radio-instrumented birds could be easily located and often led researchers to roosts that had not been previously surveyed. Bennetts and Kitchens (1997a) and Bennetts *et al.* (1999a) have analyzed these counts and have analyzed the sources of variation in these counts, including observer effects, differences in level of effort, and sampling error. This analysis provides a convincing argument that these data could provide a crude indication of trends, provided that all influences of detection rates had been adequately taken into account. The sources of variation should be recognized prior to using these data in subsequent interpretations, especially in attempting to determine population viability and the risk of extinction. Table 1 presents the annual count data for the period 1985 to 1994.

While acknowledging the problems associated with making year-to-year comparisons in the count data, some general conclusions are apparent. Lake Okeechobee apparently retains some suitable snail kite habitat throughout both wet and dry years. In contrast, kite use of WCA3A fluctuates greatly, with low use during drought years, such as 1991, and high use in wet years, such as

Table 1. Mid-winter Everglade snail kite survey, 1985-1994.

Location	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	10-yr. Mean
St. Johns Marsh	8	6	7	30	38	68	81	81	10	27	36
L. Kissimmee	38	28	42	33	73	61	49	38	38	46	45
L. Tohopekaliga	17	13	1	1	19	118	2	19	2	7	20
East L. Tohopekaliga	0	0	0	0	18	30	5	9	24	21	11
L. Okeechobee	108	71	94	175	122	83	146	216	113	129	126
WCA2A	1	1	0	4	11	20	14	42	1	0	9
WCA2B	16	58	4	48	0	0	10	2	32	142	31
WCA3A	170	353	117	166	166	13	7	113	345	470	192
WCA3B	24	13	11	9	0	1	2	2	10	11	8
Big Cypress NP	0	0	0	0	0	0	0	32	28	43	10
Everglades NP	1	1	6	10	3	1	3	67	16	29	14
The Pocket	7	9	19	9	3	0	20	11	89	1	43
Other sites	10	10	24	13	11	27	17	113	139	70	43
Total for Year	400	563	325	498	464	422	356	745	847	996	562

1994. However, we caution against using these figures as absolute values for shifts in habitat use or measures of changes in total population. Although sharp declines have occurred in the counts since 1969 (for example, 1981, 1985, 1987), it is unknown to what extent this reflects actual changes in population. Rodgers *et al.* (1988) point out that it is unknown whether decreases in snail kite numbers in the annual count are due to mortality, dispersal (into areas not counted), decreased productivity, or a combination of these factors. Despite these problems in interpreting the annual counts, the data since 1969 have indicated a generally increasing trend (Sykes 1979, Rodgers *et al.* 1988, Bennetts *et al.* 1994). The degree of this apparent increase in the snail kite's population needs to be confirmed with alternative methods of estimating population size.

Bennetts and Kitchens (1997a) found that radio telemetry is an effective, but costly, method for estimating survival of snail kites. They suggest that mark-resighting is an effective and statistically reliable method for determining survival and population size. The FWS endorses the proposal to replace the annual snail kite counts with the mark-resighting methodology. This will require a continued commitment to support this work to ensure that a sufficient number of birds are marked. As the number of marked birds increases over several continuous years of marking, the number of resightings should increase, and this will allow a population estimate with a reasonable level of precision.

It is difficult to identify any long-term trend in reproductive success, because of the considerable variability in nest success among years, locations, and local nest environments (Sykes 1979, 1987c; Beissinger 1986; Bennetts *et al.* 1988; Snyder *et al.* 1989a), but several of these researchers have attributed the variability to water levels. As noted above, part of this effect, particularly in the lakes, is attributed to differences in nest site selection (more herbaceous substrates in low-water years versus a higher proportion of woody substrates in high-water years). The basis of comparison is between high-water years versus low-water years, rather than within-year differences between water depth at nest sites. Drought may affect nesting success by depressing apple snail populations (Kushlan 1975, Beissinger and Takekawa 1983) and through increased access by terrestrial predators (Beissinger, 1986).

Collapse of nests constructed in herbaceous vegetation is also cited as a cause of increased nest failure during low-water years. This is because the water table is usually below the ground surface at willow heads and other stands of woody vegetation during drought, causing snail kites to nest in herbaceous vegetation, where the nests are more vulnerable to collapse. This effect is more prevalent in the lakes than in the Everglades. Weather causes great variability in nesting success; wind storms cause toppling of nests, particularly on Lake Okeechobee and Lake Kissimmee due to the long wind fetch across these large lakes. Cold weather can cause nest failure, either through decreased availability of apple snails or mortality of young due to exposure. Abandonment of nests before egg-laying is common, particularly during drought or following passage of a cold front. The overall fledging success to a nestling age of 6 weeks in the 1980 to 1993 period was 0.83 fledgling/nest or 0.29 fledgling/egg (n = 776 nests) (Sykes *et al.* 1995). Although considerable variability (due to natural and man-caused variation in water levels) should be expected in future years of monitoring, this may serve as a baseline to compare the relative productivity of the snail kite population.

The snail kite has apparently experienced population fluctuations associated with hydrologic influences, both man-induced and natural (Sykes 1983a, Beissinger and Takekawa 1983, Beissinger 1986), but the amount of fluctuation is debated. The abundance of its prey, apple snails, is closely linked to water regime (Kushlan 1975; Sykes 1979, 1983a). Drainage of Florida's interior wetlands has reduced the extent and quality of habitat for both the snail and the kite (Sykes 1983b). The kite nests over water, and nests become accessible to predators in the event of unseasonal drying (Beissinger 1986, Sykes 1987c). In dry years, the kite depends on water bodies which normally are suboptimal for feeding, such as canals, impoundments, or small marsh areas, remote from regularly used sites (Beissinger and Takekawa 1983, Bennetts *et al.* 1988, Takekawa and Beissinger 1989). These secondary or refuge habitats are vital to the continued survival of this species in Florida.

The principal threat to the snail kite is the loss or degradation of wetlands in central and South Florida. Nearly half of the Everglades has been drained for agriculture and urban development (Davis and Ogden 1994). The Everglades Agricultural Area alone eliminated 8,029 km^2 of the original Everglades, and the urban areas in Miami-Dade, Broward and Palm Beach counties have also reduced the extent of habitat. North of Everglades National Park, which has preserved only about one-fifth of the original extent of the Everglades, the remaining marsh has been dissected into shallow impoundments. The Corps of Engineers' Central and Southern Florida Project encompasses 46,600 km^2 from Orlando to Florida Bay and includes about 1,600 km each of canals and levees, 150 water control structures, and 16 major pump stations. This system has disrupted the volume, timing, direction, and velocity of freshwater flow.

The natural sheet flow pattern under which the Everglades evolved since about 5,000 years ago has not existed for about 75 years (Parker *et al.* 1955, Leach *et al.* 1972, Klein *et al.*1974). The loss of fresh water to seepage, flood control releases to tidal waters, and extraction for irrigation and urban water supply has led to saltwater intrusion in some portions of the former Everglades. Although the major drainage works completed conversion of wetlands to agriculture in the Everglades Agricultural Area by about 1963, loss of wetlands continues to the present at a slower, but significant, rate. In the entire State of Florida between the mid-1970s to the mid-1980s, 105,222 ha of wetlands (including marine and estuarine offshore habitats) were lost (Hefner *et al.* 1994); we do not have an estimate for the loss of freshwater wetlands specifically in central and South Florida in those years.

Degradation of water quality, particularly runoff of phosphorous from agricultural and urban sources, is another threat to the snail kite. The Everglades was historically an oligotrophic system, but major portions have become eutrophic. The concentration of total phosphorus in Lake Okeechobee almost doubled from 49 µg/L in 1973 to 98 µg/L in 1984 (Janus *et al.* 1990). Most of this increase has been attributed to non-point source runoff from agricultural lands north of the lake, in the Kissimmee River, Taylor Slough and Nubbin Slough drainages (Federico *el al.* 1981). Eutrophication also is a concern in the Kissimmee chain of lakes. Nutrient enrichment leads to growth of dense stands of herbaceous emergent vegetation, floating vegetation (primarily water hyacinth and water lettuce) and woody vegetation, which inhibits the ability of snail kites to find food (See also Habitat section above).

Regulation of water stages in lakes and the WCAs is particularly important to maintain the balance of vegetative communities required to sustain snail kites. This is discussed in the Management section of this account.

Shooting of snail kites has been cited in the early literature as a threat (Sprunt 1945; Stieglitz and Thompson 1967; Sykes 1978, 1979). Although waterfowl hunting, particularly on Lake Okeechobee, may lead to shooting of snail kites, there are no recent documented cases (J. Rodgers, GFC, personal communication 1995).

Contaminant analyses have been conducted on snail kites and apple snails, and all contaminant residues (DDT, DDD, DDE, dieldrin, PCBs, mercury, lead, and arsenic) have been found at low levels (Stickel *et al.* 1969, 1970, 1984; Lamont and Reichel 1970; Wiemeyer *et al.* 1980; Patee *et al.* 1981; Sykes 1985b; Sykes *et al.* 1995; Eisemann *et al.* 1997).

Demographic concerns appear to outweigh immediate genetic threats for the snail kite in Florida. Rodgers and Stangel (1996) performed electrophoresis on samples from 150 snail kite nestlings at four wetland sites: Lake

Kissimmee, Lake Okeechobee, WCA2B, and WCA3A. They found short genetic distances among snail kites at the four wetlands, suggesting little differentiation within Florida. Despite the historic reduction in the snail kite population to low levels, heterozygosity in the snail kites at these locations varied from 4.1 percent to 5.2 percent, which is within typical values for birds. If the snail kite population were to decline in the future, this study provides a baseline to determine if heterozygosity has been reduced. However, there is no immediate concern about reaching a genetic bottleneck.

Management

Water management actions in the Everglades and in the lakes are the most important human-controlled factors in survival and recovery of the snail kite. A balanced approach to water level management is required to maintain favorable habitat conditions for the snail kite. Nearly continuous flooding of wetlands for > 1 year is needed to sustain apple snail populations (Sykes 1979, Beissinger 1988). Prolonged drying of wetlands, especially in an impounded area with little variation in water depth, can cause the local depletion of apple snails. Snyder *et al.* (1989a) attributed poor reproductive success of snail kites in WCA3A in years following drought to a lag time between re-flooding and recovery of apple snails to levels that allow higher nesting success.

When low-water stages occur during the nesting season on Lake Okeechobee and the Kissimmee Chain of Lakes, snail kites frequently nest in the waterward edge of herbaceous vegetation, where nests are more vulnerable to collapse due to the inability of the vegetation to support the nest and the greater exposure to wind, waves, and boat wakes. The location of the nests closer to open water during periods of low water also exposes snail kites to a potentially greater level of human disturbance. A water stage of 4.42-4.57 m on Lake Okeechobee is recommended near the beginning of the snail kite nesting season during most years (Sykes *et al.*1995, Rodgers 1996, J. Rodgers, GFC, personal communication 1996). The water stages can be allowed to recede gradually during the February through May period, to allow for successful foraging by wading birds, but should not be allowed to decline rapidly. However, prolonged periods (1 or 2 years) of water stages over 4.57 m are considered adverse to maintaining marshes in the littoral zone of Lake Okeechobee. Extended periods of high-water stages in Lake Okeechobee will drown out vegetation in the littoral zone. The lake is surrounded by a levee; above a water elevation of 4.57 m, water begins to rise against the levee, and there is no opportunity for marsh vegetation to expand to higher ground elevations. Rodgers (GFC, personal communication 1996) has initiated a similar analysis intended to correlate water stages in Lake Kissimmee with successful nesting. However, it should be noted that Lake Kissimmee is not surrounded by a levee, and although extended high-water stages might temporarily disrupt existing vegetation patterns, wetland vegetation could adjust in the longer term by shifting landward to higher ground elevations. In impounded areas, such as the WCAs and the St. Johns marshes, extended periods of high water can drown out willow or other woody vegetation. The availability of woody vegetation often results in higher fledging success through reduced nest collapse, which is more prevalent in non-woody substrates.

Lake Kissimmee and the surrounding lakes have been restricted to narrow water regulation schedules when compared to their natural degree of variability in years prior to regulation. Overly dense concentrations of vegetation begin to grow in the littoral zone, which restricts water flow and leads to the buildup of organic sediment in bands around the lakes' shorelines. This pattern is harmful to the overall productivity of the lakes. Ideally, lake management schedules throughout the Kissimmee Chain of Lakes should be modified to resemble the degree and timing of water level fluctuations in the pre-management period. However, water regulation schedules are now restricted by the proximity of floodable structures to shorelines and by water supply considerations.

Because these societal constraints make it impractical to fluctuate water levels according to historic cycles of flooding and drought, the SFWMD and the GFC have proposed periodic extreme drawdowns, with or without physical removal of organic sediment. Drawdowns were conducted on Lake Tohopekaliga in 1986 and East Lake Tohopekaliga in 1990. Snail kites did not resume nesting after the 1986 drawdown at Lake Tohopekaliga until 1990. The drawdown at East Lake Tohopekaliga caused the abandonment of 10 of 12 nests in 1990 (Rodgers 1994). The reason for the delay in resumption of nesting after the 1986 drawdown at Lake Tohopekaliga is not fully understood. However, snail kites have returned to nest in that lake in recent years, so the impact appears to be temporary. The loss of snail kite nests at East Lake Tohopekaliga in 1990 apparently was caused by the inability to remove the water quickly enough to below the level of the waterward edge of the littoral marsh before snail kites began to nest. Emergency dredging of an outlet canal was required to accelerate the drainage of water beyond the edge of the marsh. Lake Kissimmee was drawn down 1.5 m below its normal regulation schedule in 1977 and again in 1996. No recent snail kite nesting occurred on Lake Kissimmee prior to 1982. In 1996, dredging across a shoal occurred prior to commencement of the drawdown to speed up the drainage. Lake Kissimmee water stages were drained quickly enough before February 1996 such that snail kites did not attempt to nest there; presumably, snail kites dispersed to other suitable areas to nest. Snail kites returned to nest in Lake Kissimmee in 1997 and 1998, following the 1996 drawdown.

With adequate planning, extreme drawdowns can apparently be carried out without adversely affecting the snail kite and can enhance foraging conditions by opening up the dense vegetation. Any restrictions preventing rapid drainage of water need to be removed in advance. To date, the FWS has recommended that drainage should be initiated immediately after the threat of hurricanes has passed (around November 30) and that the water should be lowered beyond the extent of herbaceous vegetation prior to February 1 to discourage nesting of snail kites in areas where nests are likely to collapse. However, recent research by Darby *et al.*(1997) indicates that early drying may be far more detrimental to apple snail populations (and by extension, detrimental to snail kites) than the incidental take of snail kite nests that early drying is intended to avoid. Darby *et al.*(1997) suggest that the adverse impact on apple snails is lessened when drying occurs after the snails have completed their reproductive cycle and the young are of sufficient size to withstand a drying event. Not suprisingly, this point is "normally" reached during late May or June, the time that the natural system reached its minimum water levels. Further research on apple snail biology and the effects of the timing of drying events on snail kite nesting is needed to provide water managers guidance on the timing of intentional drawdowns that will maximize the long-term benefits on habitat structure while minimizing the short-term adverse impacts on snail kites and apple snails.

Anthropogenic drying of snail kite habitat in one watershed (*e.g.* St. Johns Marsh) should not coincide with natural drying in another watershed (*e.g.* Everglades). Although long-range prediction of drought and wet cycles is still not exact, consideration of the periodicity of these cycles should be factored into planning for periodic drying of managed areas. A strong correlation between the *El Niño*-Southern Oscillation (ENSO) cycle and precipitation in Florida was reported by Hanson and Maul (1991). Zhang and Trimble (1996) used three indicators of global climate cycles (sunspot number, geomagnetic activity, and the Southern Oscillation Index) in a neural network computing environment to predict inflows to Lake Okeechobee. Neidrauer *et al.* (1997) suggest that a combination of these indices can be used in water management decisions for Lake Okeechobee, based on a 6-month inflow forecast. These models should be refined and further tested, and as suggested by Zhang and Trimble (1996), the model's forecast horizon should be extended to determine how reliably it can predict longer-term shifts in rainfall patterns. The FWS recommends that this be based not only on inflows to Lake Okeechobee, but also be calibrated against other gages in the C&SF system. Because strong *La Niña (*conditions oposite to *El Niño*) conditions are generally associated with drought in Florida (Zhang and Trimble 1996), these indices may be useful in planning several years into the future to reduce the probability of human-caused drawdowns in one watershed coinciding with drought in another watershed. Human-caused drawdowns might be most adverse to the snail kite at the onset of multiple-year droughts, because it may be difficult to refill lakes or marsh impoundments during the following years, and the snail kite will have reduced opportunity to find suitable habitat.

Reduction of nutrient loading to marshes is needed to slow the growth of dense vegetation which hampers efficient foraging by snail kites. Efforts to reduce nutrient loading are being conducted to benefit the South Florida Ecosystem as a whole, and will have benefits to a number of fish and wildlife species in addition to the snail kite. Best Management Practices (BMPs) have been effective in reducing nutrient input to Lake Okeechobee from the Kissimmee River, Taylor Slough, and Nubbin Slough drainages. BMPs are included in implementation provisions of the Everglades Forever Act of 1994 (Chapter 373.4593 FS), as are the construction of Stormwater Treatment Areas. More effort needs to be directed at identifying and rectifying problems with nutrient inputs to the peripheral habitats so critical to the snail kite during drought.

Control of aquatic weeds has probably improved foraging conditions for the snail kite in a few localized areas by opening up dense growths of water hyacinth, water lettuce, and *Hydrilla.* However, spraying should not occur near snail kite nests located in non-woody species (*e.g.*, cattail, bulrush). The SFWMD, the GFC, and the DEP have cooperated in closing areas to herbicide spraying around snail kite nests, which reduces the risk of nest collapse in Lake

Okeechobee and Lake Kissimmee. However, more research is needed on the long-term effects of the herbicides being used on the aquatic food web in general, and particularly apple snails with respect to snail kites.

Nest baskets have been used effectively to reduce the collapse of nests in herbaceous substrates along the northwestern shoreline of Lake Okeechobee (Sykes and Chandler 1974). Similar nest supports have been used by GFC on Lake Tohopekaliga and East Lake Tohopekaliga. Although use of nest baskets may be a useful management technique in specific areas and instances (for example, to protect nests during a drawdown), their use on a routine basis is now considered to provide limited benefits relative to the intensive effort required (R. Bennetts, University of Florida, personal communication 1996; J. Rodgers, GFC, personal communication 1996).

Because snail kites use habitats with long hydroperiods, fire is not normally considered a management concern. However, fire is a natural component in the ecology of the Everglades and all of South Florida, and it is reasonable to expect that intense fires occurred historically during periods of drought in the snail kite's habitat. Intense fires that burn peat can transform habitats in the Everglades; dense sawgrass marshes having heavy fuel loads can be converted into a spikerush (*Eleocharis*) marsh, which will not carry fire for many years (Craighead 1971, Hoffman *et al.* 1994). Although such a fire would most likely eradicate apple snails from a particular location, its conversion to a spikerush marsh would, following recolonization by apple snails, make the area more suitable for foraging by snail kites. Prescribed burning could be implemented in conjunction with the intentional drawdowns mentioned above and in selected areas during drought.

The challenge for land managers is that intense fires are more difficult to control. Peat fires can smolder for weeks after initial passage of the fire (Craighead 1974, Robertson 1955); it may be difficult to prevent such fires from entering tree islands and hammocks, which may be of concern to managers if these areas are not the intended targets of the burn. Monitoring of vegetation, apple snails, and snail kite foraging in test plots before and after prescribed burns would provide useful information for refining fire management practices. Use of fire as a management tool in lakeshore environments may be more predictable and desirable than in the Everglades, where muck fires are considered to be damaging to tree island habitats and probably contributing to invasion of cattails.

Some authors have emphasized the importance of the availability of suitable habitat during periods of drought, which were thought to be a limiting factor in the population (Beissinger 1986, Sykes 1987b). Drainage of Florida's interior wetlands has reduced the extent and quality of habitat for both the snail and the kite (Sykes 1983b). Also, the kite nests over water, and nests become accessible to predators in the event of unseasonal drying (Beissinger 1986, Sykes 1987c). In dry years, the kite depends on water bodies which often are suboptimal for feeding during periods of normal rainfall, such as canals, impoundments, or small marsh areas, remote from regularly used sites (Beissinger and Takekawa 1983, Bennetts *et al.* 1988, Takekawa and Beissinger 1989). Beissinger and Takekawa (1983) and Takekawa and Beissinger (1989) divided snail kite habitat into “primary,” secondary” and “drought-related” areas. Bennetts (University of Florida, personal communication 1996) disagrees with characterizing any particular area into those categories; he believes that snail kites spread the risk of fluctuating habitat conditions by their ability to move long distances across the landscape within a “network” of habitats. Bennetts and Kitchens (1997b) hypothesize that the spatial extent and heterogeneity of habitat quality throughout the snail kite’s range buffers the risks that may be posed by droughts, because the spatial extent and duration of drought conditions will vary across the species’ range. Protection of both larger and smaller wetlands in several subregions (St. Johns Marsh, Kissimmee Chain of Lakes, Lake Okeechobee, Loxahatchee Slough, and Everglades/Big Cypress) is required to maintain this spatial heterogeneity and spatial extent. Because the 1992 to 1995 duration of Bennetts’ study did not include a period of drought, continued radio tracking of snail kites during a drought will be necessary to confirm this hypothesis.

Bennetts *et al.* (1988) found that snail kites nesting in WCA3A used wetlands having multi-year hydroperiods ranging from about 84 percent to 99 percent. However, Bennetts and Kitchens (1997a) have emphasized that foraging snail kites use a heterogeneous mosaic of wetlands. Snail kites will forage in shorter hydroperiod portions (wet prairies) within larger areas of longer hydroperiod (predominance of slough or lacustrine communities). Snail kites will also forage in smaller sloughs within areas that are primarily wet prairies. Therefore, in defining the desired future condition of the WCAs following hydropattern restoration, one must recognize the importance of a heterogeneous landscape within wetlands of relatively long (>85 percent) average hydroperiod. One must also acknowledge that these areas will dry out periodically. In evaluating the effects of these drying events on the demography of the snail kite, one must consider the average interval between drying events, their duration, and their spatial extent. Localized drying events are thought to have little adverse effect on the snail kite population, but droughts across the region extending from the St. Johns Marsh and the Kissimmee Chain of Lakes to the southern Everglades are likely to have adverse effects, particularly if the droughts occur in 2 or more consecutive years (Bennetts and Kitchens 1997a, 1997b).

Another factor to be considered in evaluating restoration of the WCAs is water depth. The compartmentalized system of WCAs differs from the natural system in at least two ways. First, increasing water flows in the natural system resulted in spreading of water across the landscape. In the managed system, water is confined within levees; increased water volumes result in water depths greater than those found in the natural system. Second, the levees surrounding the WCAs result in over-drained conditions at the upstream northern ends, and deeper water accumulation at the southern ends of the WCAs. The duration of these deep water conditions behind the levees is artificially prolonged relative to historic conditions (Gunderson and Loftus 1993). The appropriate restoration target for major portions of the WCAs is a heterogeneous wetland having a prolonged hydroperiod over most of the area, but without extended periods of deep water.

Another factor in restoration of the WCAs that will affect the habitat conditions for the snail kite and a variety of Everglades fauna is the effect of hydropattern restoration on growth of cattails. Rehydration of currently drained portions of the WCAs, such as northern WCA3A, will most likely result in growth of cattails, due to elevated phosphorus levels in the soil. The extent of the affected area and the time period that the cattail stands will persist is currently being debated. This effect must be considered in predicting habitat conditions in the WCAs following hydropattern restoration.

The Everglade snail kite population is now considered more resilient than previously thought to natural climatological fluctuations, but the resilience of kites to human-induced changes is less certain (Bennetts *et al.* 1994). The species is adapted to "boom and bust" cycles, and any consideration of recovery must be based on long-term (at least 5- to 10-year) averages in population levels and/or reproductive success. Radio telemetry indicates that snail kites use a broader network of wetland habitats than was previously recognized. Additional research is needed on survival following periods of drought. Previous opinions regarding the amount of mortality following drought may have been biased by lack of knowledge about the full range of dispersal of the species; mortality may have been overestimated because widely dispersed individuals were living in habitats not regularly searched (Bennetts *et al.* 1999a; Valentine-Darby *et al.* in prep.). Despite the previously mentioned problems in interpreting the annual counts, the general consensus is that the snail kite population has been at least stable since 1969, and has likely increased, on average, within a broad range of fluctuation (Bennetts *et al.* 1999a).

Anticipated restoration projects should benefit the Everglade snail kite. The FWS has predicted that the Kissimmee Headwater Lakes Revitalization Project and the Kissimmee River Restoration will benefit a variety of fish and wildlife, including the snail kite. Restoration of the Everglades should provide opportunities for recovery of the kite, but Bennetts *et al.* (1994) point out:

> Undoubtedly, compromise solutions will need to be identified in order to accommodate increasing demands for water, habitat for snail kites, and flow systems that will maintain the unique Everglades environment. Almost any proposed solution to the problems of the Everglades and the kite will meet with opposition from individuals or groups with differing objectives or viewpoints. Current restoration planning in the southern Everglades is no exception. Arguments can easily be made for restoring longer hydroperiods in the historic Shark River Slough. It is likely that the deeper areas of the slough and other pools within the Everglades basin were once used extensively by kites. It can also be argued, however, that the impoundments of the WCAs now serve this role and that substantial reductions in hydroperiod in these impoundments may, at least in the short term, have a negative impact on kites. It is not even clear that substantial reductions in hydroperiod would occur in the specific areas that are used most heavily by kites. What is certain is that whatever plans are adopted, they will not be unopposed.

It is appropriate to cite the fate of the WCAs as an example of likely controversy in Everglades restoration; the Central and Southern Florida Project Comprehensive Review Study (C&SF Restudy) must carefully consider the design of hydropattern restoration in the WCAs.

Another controversial issue not addressed in the above quotation is the management of water stages in Lake Okeechobee with respect to the downstream portions of the C&SF system. Opinions vary on the degree to which the ecological values of the littoral zone of Lake Okeechobee (which includes a portion of the Everglade snail kite's critical habitat) can be sacrificed to create increased water storage capacity to drive restoration of the Everglades. This and possibly many other pivotal issues must be evaluated through the C&SF Restudy.

A balanced restoration plan for the Everglades must be found that will mimic the hydrologic variation and other habitat characteristics of the natural system. We believe the restoration can be planned and carried out without conflicts among the recovery goals for listed species.

Because of the particular habitat requirements of the snail kite, the loss of spatial extent of the wetlands throughout the species' range, and the possibility of back-to-back catastrophic events, it may not be possible to remove the species entirely from protected status. {We believe the prognosis for recovery of the snail kite from endangered status to threatened by 2020 is good.}. The recovery goal should not be based solely on population estimates, but should also include measures of survivorship and fecundity. Reclassification to threatened could occur with a minimum population size of 650 individuals over a 10-year period, with a multi-year average finite rate of population change (λ, lambda) greater than or equal to 1. The breeding population should be distributed over enough individual "colony" sites and over a broad enough total area to ensure survival through catastrophic events, but until more precise stochastic modeling is available, we do not have a specific recovery criterion of this type. If the species meets these goals for reclassification as threatened, the FWS would then consider requirements for de-listing.

Recent biological studies of the Everglade snail kite indicate the species is highly mobile and adaptable, which might support a more optimistic view of the status and prognosis for the snail kite. However, recent information on the apple snail indicates that the species suffers high post-breeding mortality each year regardless of the hydrological condition, and may suffer poor recruitment of juvenile snails in the year following a drydown (P. Darby, University of Florida, personal communication 1997). Apple snails are stranded by receding water levels, even along a lake shore, where presumably snails could migrate to the remaining pool. Adult snails survived an average of 4 weeks under drydown conditions at the St. Johns Marsh (Darby *et al.* 1996a) and at Lake Kissimmee (Darby *et al.* 1996b, 1997). The vulnerability of apple snails to localized severe population declines must be considered in water management policy and in assessment of threats to the snail kite.

Continued monitoring of the snail kite population will be needed before, during, and after implementation of the many elements presently under consideration that together will result in restoration of the South Florida Ecosystem. Among the factors favoring the selection of the snail kite as a key indicator of success are the following:

a. The snail kite is an endangered species and is reasonably familiar to a large segment of the public.

b. In the United States, the snail kite is found only in the central and South Florida Ecosystem, making it a suitable biological symbol for the ecosystem as a whole.

c. The snail kite is a species adapted to the variable climatic conditions in central and South Florida, and the Everglades in particular. Water management in the restored ecosystem must be flexible enough to ensure survival and recovery of the snail kite through climatological extremes. Successful recovery of the snail kite should be included as one of several indicators of restoration of the dynamic variability of the long hydroperiod wetlands within South Florida.

Literature Cited

Amadon, D. 1975. Variation in the Everglades kite. Auk 92:380-382.

American Ornithologists' Union [AOU]. 1983. Check list of North-American birds. Sixth Edition. American Ornithologists' Union; Baltimore, Maryland.

Bailey, R. G. 1978. Ecoregions of the United States. U.S. Forest Service., Intermountain Region; Ogden, Utah.

Beissinger, S. R. 1983. Hunting behavior, prey selection, and energetics of snail kite in Guyana: consumer choice by a specialist. Auk 100:84-92.

Beissinger, S. R. 1984. Mate desertion and reproductive effort in the snail kite. Ph.D. dissertation, University of Michigan; Ann Arbor, Michigan.

Beissinger, S. R. 1986. Demography, environmental uncertainty, and the evolution of mate desertion in the snail kite. Ecology 67:1445-1459.

Beissinger, S. R. 1987a. Anisogamy overcome: female strategies in snail kites. American Naturalist 129:486-500.

Beissinger, S. R. 1987b. Mate desertion and reproductive effort in the snail kite. Animal Behavior 35:1504-1519.

Beissinger, S. R. 1988. Snail kite. Pages 148-165 *in* R. S. Palmer, eds. Handbook of North American birds, vol. 4, Yale University Press, New Haven, Connecticut.

Beissinger, S. R., and N. F. R. Snyder. 1987. Mate desertion in the snail kite. Animal Behavior 35:477-487.

Beissinger, S. R., A. Sprunt IV, and R. Chandler. 1983. Notes on the snail (Everglade) Kite in Cuba. American Birds 37:262-265.

Beissinger, S. R., and J. E. Takekawa. 1983. Habitat use and dispersal by snail kites in Florida during drought conditions. Florida Field Naturalist 11:89-106.

Beissinger, S. R., B. T. Thomas, and S. D. Strahl. 1988. Vocalizations, food habits, and nesting biology of the slender-billed kite with comparisons to the snail kite. Wilson Bulletin 100:604-616.

Bennetts, R.E. 1996. FWS Multi-species Recovery Team. April 22-24, 1996.

Bennetts, R.E. 1998. Comments on technical/agency draft muli-species recovery plan for South Florida. August 18, 1998.

Bennetts, R. E., and E. L. Caton. 1988. An observed incident of rat snake predation on snail kite (*Rostrhamus sociabilis*) chicks in Florida. Florida Field Naturalist 16:14-16.

Bennetts, R. E., M. W. Collopy, and S. R. Beissinger. 1988. Nesting ecology of snail kite in WCA 3A. Florida Cooperative Fisheries and Wildlife Research Unit Technical report number 31, University of Florida; Gainesville Florida.

Bennetts, R. E., M. W. Collopy, and J. A. Rodgers, Jr. 1994. The snail kite in the Florida Everglades: a food specialist in a changing environment. Pages 507-532 *in* J. Ogden and S. Davis, eds. Everglades: the ecosystem and its restoration, St. Lucie Press; Delray Beach, Florida.

Bennetts, R. E., P. Darby, and P. Darby. 1993. 1993 annual snail kite survey. Florida Cooperative Fisheries and Wildlife Research Unit, University of Florida; Gainesville, Florida.

Bennetts, R.E., V.J. Dreitz, W.M. Kitchens, J.E. Hines, and J.D. Nichols. 1999b. Annual survival of snail kites in Florida: Comparisons between radio telemetry and capture-resighting data. Auk (in press).

Bennetts, R. E., and W. M. Kitchens. 1992. Estimation and environmental correlates of survival and dispersal of snail kites in Florida. First annual report, prepared for the U.S. Fish and Wildlife Service and U.S. National Park Service, Florida Cooperative Fisheries and Wildlife Research Unit, University of Florida; Gainesville, Florida.

Bennetts, R.E., and W.M. Kitchens. 1997a. The demography and movements of snail kites in Florida. Final report. Florida Cooperative Fish and Wildlife Research Unit, National Biological Service, U.S. Department of the Interior; Gainesville, Florida.

Bennetts R.E., and W.M. Kitchens. 1997b. Population dynamics and conservation of snail kites in Florida: The importance of spatial and temporal scale. Colonial Waterbirds 20:324-329.

Bennetts, R.E, W.A. Link, J.R. Sauer, and P.W. Sykes, Jr. 1999a. Factors influencing counts in an annual survey of snail kites in Florida. Auk (in press).

Bent, A. C. 1937. Life histories of North American birds of prey. U.S. National Museum Bulletin 167.

Brown, L. H., and D. Amadon. 1976. Eagles, hawks, and falcons of the world. McGraw-Hill Book Company; New York.

Bureau of Sport Fisheries and Wildlife. 1973. Threatened wildlife of the United States. Resource publication 114, March 1973. Bureau of Sport Fisheries and Wildlife, U.S. Department of the Interior; Washington, D.C.

Cary, D. M. 1985. Climatological and environmental factors effecting the foraging behavior and ecology of Everglade Kites. Master's thesis, University of Miami; Coral Gables, Florida.

Chandler, R., and J. M. Anderson. 1974. Notes on Everglade kite reproduction. American Birds 28:856- 858.

Clark, W. S., and B. K. Wheeler. 1987. A field guide to hawks of North America. Houghton Mifflin Company; Boston.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. Biological Service Program, FWS / OBS-79/31. U.S. Fish and Wildlife Service; Washington, D.C.

Craighead, F.C. 1971. The trees of south Florida, vol. 1: The natural environments and their succession. University of Miami Press; Coral Gables, Florida.

Craighead, F.C. 1974. Hammocks of south Florida. Pages 53-60 *in* P.J. Glisson, ed. Environments of south Florida: Present and past, Miami Geological Society; Miami, Florida.

Darby, P.C. Telephone communication, May 1997.

Darby, P.C., P. Valentine-Darby, and H.F. Percival. 1996a. Assessing the impact of the Lake Kissimmee restoration on apple snails. 1996 annual report. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Darby, P.C., J.D. Croop, H.F. Percival, and W.M. Kitchens. 1996b. Ecological studies of apple snails (*Pomacea paludosa*). 1995 annual report. South Florida Water Management District; West Palm Beach, Florida; and St. Johns River Water Management District; Palatka, Florida.

Darby, P.C., P. Valentine-Darby, and H.F. Percival. 1997. Assessing the impact of the Lake Kissimmee restoration on apple snails. 1997 annual report. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Davis, J. H., Jr. 1946. The peat deposits of Florida. Geological Bulletin number 30, Florida Geological Service; Tallahassee, Florida.

Davis and Ogden. 1994. Pages 3-8 *in* Davis and Ogden, ed. Everglaades: the ecosystem and its restoration. St. Lucie Press; Delray Beach, Florida.

Eisemann, J.D., W.N. Beyer, R.E. Bennetts, and A. Morton. 1997. Mercury residues in South Florida apple snails (*Pomacea paludosa*). Bulletin of Environmental Contamination and Toxicology 58:739-743.

Federico, A.C., K.G. Dickson, C.R. Kratzer, and F.E. Davis. 1981. Lake Okeechobee water quality studies and eutrophication assessment. Technical publication 81-2, South Florida Water Management District; West Palm Beach, Florida.

Gunderson, L.H. and W.F. Loftus. 1993. The Everglades *in* W.H. Martin, S.C. Boyce, and A.C. Echternacht, eds. Biodiversity of the southeastern United States. John Wiley and Sons; New York.

Hanson, K., and G.A. Maul. 1991. Florida precipitation and the Pacific El Niño, 1859-1989. Florida Scientist 54:160-168.

Hefner, J.M., B.O. Wilen, T.E. Dahl, and W.E. Frayer. 1994. Southeast wetlands; status and trends, mid-1970s to mid-1980s. U.S. Department of the Interior, Fish and Wildlife Service; Atlanta, Georgia.

Hoffman, W.G., T. Bancroft, and R.J. Sawicki. 1994. Foraging habitat of wading birds in the WCAs of the southern Everglades. Pages 585-614 *in* S.M. Davis and J.C. Ogden, eds. Everglades: the ecosystem and its restoration. St. Lucie Press; Delray Beach, Florida.

Howell, A. H. 1932. Florida bird life. Coward-McCann; New York, New York.

Janus, L.L., D.M. Soballe, and B.L. Jones. 1990. Nutrient budget analyses and phosphorus loading goal for Lake Okeechobee, Florida. Internationale Vereinigung für Theoretische und Angewandte Limnologie Verhandlungen 24:538-546.

Klein, H., J. T. Armbruster, B. F. McPherson, and H. J. Freiberger. 1974. Water and the south Florida environment. South Florida Environmental Proceedings: Ecological Report Number DI-SFEP-74-75. U.S. Geological Survey; Atlanta, Georgia.

Kushlan, J. A. 1975. Population changes of the apple snail, *Pomacea paludosa*, in the southern Everglades. Nautilus 89:21-23.

Lamont, T., and W. Reichel. 1970. Organochlorine pesticide residues in whooping cranes and Everglade kites. Auk 87:158-159.

Leach, S. D., H. Klein, and E. R. Hampton. 1972. Hydrologic effects of water control and management of southern Florida. Bureau of Geology, Florida Department of Natural Resources; Tallahassee, Florida.

Neidrauer, C.J., P.J. Trimble, and E.R. Santee. 1997. Simulation of alternative operational schedules for Lake Okeechobee. South Florida Water Management District; West Palm Beach, Florida.

Nicholson, D. J. 1926. Nesting habitats of the Everglade kite in Florida. Auk 43:62 67.

Parker, G. G., G. E. Ferguson, S. L. Love, *et al*. 1955. Water resources of southern Florida. Water-supply paper 1255, U.S. Geological Survey; Washington, D.C.

Ridgely, R. S., and J. A. Gwynne, Jr. 1989. A guide to the birds of Panama. Princeton University Press; Princeton, New Jersey.

Robertson, W. B., Jr. 1955. An analysis of the breeding-bird populations of tropical Florida in relation to the vegetation. Ph.D. Dissertation, University of Illinois; Urbana, Illinois.

Rodgers, J.A., Jr. 1994. Effects of water fluctuations on snail kites nesting in the Kissimmee River basin. final report, study number II-H-1-2, 1 July 1991 - 30 June 1994. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Rogers, J.A., Jr., and H. T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. Conservation Biology 9:89-99.

Rodgers, J. A., Jr. 1996. Endangered Florida snail kite. Pages 42-51 *in* J. A. Rodgers, Jr., ed. Rare and endangered biota of Florida, Second Edition, University Presses of Florida; Gainesville, Florida.

Rodgers, J.A., Jr. Telephone communication. 1995.

Rodgers, J.A., Jr. Telephone communication. 1996.

Rodgers, J. A., Jr., S. T. Schwikert, and A. S. Wenner. 1988. Status of the snail kite in Florida: 1981-1985. American Birds 42:30-35.

Rodgers, J.A., Jr. and P.W. Stangel. 1996. Genetic variation and population structure of the endangered snail kite in south Florida. Journal of Raptor Research 30(3):111-117.

Rumbold, D. G., and M. B. Mihalik. 1994. Snail kite use of a drought-related habitat and communal roost in West Palm Beach, Florida: 1987-1991. Florida Field Naturalist 22:29-38.

Snyder, N. F. R., S. R. Beissinger, and R. Chandler. 1989a. Reproduction and demography of the Florida Everglade (Snail) Kite. Condor 91:300-316.

Snyder, N. F. R., S. R. Beissinger, and M. R. Fuller. 1989b. Solar radio-transmitters on snail kites in Florida. Journal Field Ornithology 60:171-177.

Snyder, N. F. R., and H. A. Snyder.1969. A comparative study of mollusc predation by limpkins, Everglade kites, and boat-tailed grackles. Living Bird 8:177-223.

Sprunt, A., Jr. 1945. The phantom of the marshes. Audubon Magazine 47:15-22.

Sprunt, A., Jr. 1954. Florida bird life. Coward-McCann, Incorporated and National Audubon Society; New York.

Stickel, W. H., L. F. Stickel, and F. B. Coon. 1970. DDE and DDD residues correlated with mortality of experimental birds. Pages 287-294 *in* W. P. Deichmann, ed. Inter-American conference on toxicology and occupational medicine, pesticide symposia, University of Miami, School of Medicine; Miami, Florida.

Stickel, W. H., L. F. Stickel, R. A. Dyrland, and D. L. Hughes. 1984. Aroclor 1254 residues in birds: lethal levels and loss rates. Archives Environmental Contamination and Toxicology 13:7-13.

Stickel, W. H., L. F. Stickel, and J. W. Spann. 1969. Tissue residues of dieldrin in relation to mortality in birds and mammals. Pages 74-204 *in* M. W. Miller and G. G. Berg, eds. Chemical fallout. Charles C. Thomas; Springfield, Illinois.

Stieglitz, W. O., and R. L. Thompson. 1967. Status and life history of the Everglade kite in the United States. Bureau of Sport Fisheries and Wildlife, Scientific report Wildlife, Number 109.

Sykes, P. W., Jr. 1978. Endangered Florida Everglade kite. Pages 4-7 *in* H. W. Kale II, ed. Rare and endangered biota of Florida, vol. 2. University Presses of Florida; Gainesville, Florida.

Sykes, P. W., Jr. 1979. Status of the Everglade Kite in Florida—1968-1978. Wilson Bulletin 91:495-511.

Sykes, P. W., Jr. 1983a. Recent population trends of the Everglade snail kite in Florida and its relationship to water levels. Journal of Field Ornithology 54:237-246.

Sykes, P. W., Jr. 1983b. Snail kite use of the freshwater marshes of south Florida. Florida Field Naturalist 11:73-88.

Sykes, P. W., Jr. 1984. The range of the snail kite and its history in Florida. Bulletin, Florida State Museum, Biological Sciences 29:211-264.

Sykes, P. W., Jr. 1985a. Evening roosts of the snail kite in Florida. Wilson Bulletin 97:57-70.

Sykes, P. W., Jr. 1985b. Pesticide concentrations in snail kite eggs and nestlings in Florida. Condor 87:438.

Sykes, P. W., Jr. 1987a. The feeding habits of the snail kite in Florida, USA. Colonial Waterbirds 10:84-92.

Sykes, P. W., Jr. 1987b. Snail kite nesting ecology in Florida. Florida Field Naturalist 15:57-84.

Sykes, P. W., Jr. 1987c. Some aspects of the breeding biology of the snail kite in Florida. Journal Field Ornithology 58:171-189.

Sykes, P. W., Jr., and R. Chandler. 1974. Use of artificial nest structures by Everglade kites. Wilson Bulletin 86:282-284.

Sykes, P. W., Jr., and H. W. Kale II. 1974. Everglade kites feed on non-snail prey. Auk 91:818-820.

Sykes, P. W., Jr., J. A. Rodgers, Jr., and R. E. Bennetts. 1995. Snail kite (*Rostrhamus sociabilis*) *in* A. Poole and F. Gill, eds. The birds of North America, Number 171, The Academy of Natural Sciences, Philadelphia, and the American Ornithologists Union; Washington, D.C.

Takekawa, J. E., and S. R. Beissinger. 1983. First evidence of snail kite feeding on the introduced snail, *Pomacea bridgesi*, in Florida. Florida Field Naturalist 11:107-108.

Takekawa, J. E., and S. R. Beissinger. 1989. Cyclic drought, dispersal, and the conservation of the snail kite in Florida: lessons in critical habitat. Conservation Biology 3:302-311.

U.S. Fish and Wildlife Service [FWS]. 1986. Everglades snail kite *(Rostrhamus sociabilis plumbeus*) revised recovery plan. On file at U.S. Fish and Wildlife Service; Atlanta, Georgia.

Valentine-Darby, P.L., R.E. Bennetts, and W.M. Kitchens. In preparation. Seasonal patterns of habitat use by snail kites in Florida.

Wiemeyer, S. N., T. G. Lamont, and L. N. Locke. 1980. Residues of environmental pollutants and necropsy data for eastern United States ospreys, 1964-1973. Estuaries 3:155-167.

Zhang, E., and P. Trimble. 1996. Predicting effects of climate fluctuations for water management by applying neural network. World Resource Review 8(3):334-348.

Recovery for the Everglade Snail Kite

Rostrhamus sociabilis plumbeus

Recovery Objective: RECLASSIFY to threatened once recovery criteria are met.

Recovery Criteria

The objective of this recovery plan is to restore the Everglade snail kite to a stable, secure and self-sustaining status allowing the reclassification of the species from endangered to threatened under the ESA. Due to the limited distribution of the species, its specialized ecological niche, and the irreversible loss of a significant portion of the Kissimmee/Okeechobee/Everglades watershed, the FWS believes it unlikely that the snail kite will ever be elevated above the threatened status. This objective will be achieved when: the 10-year average for the total population size is estimated as greater than or equal to 650, with a coefficient of variation less than 20 percent for the pooled data over the 10-year period; no annual population estimate is less than 500 in the 10-year period; the rate of increase of the population to be estimated annually or biannually, and over the 10-year period, will be greater than or equal to 1.0, sustained as a 3-year running average over 10 years; the feeding range of snail kites will not decrease from its current extent, including as a minimum, the St. Johns Marsh, the Kissimmee Chain of Lakes, Lake Okeechobee, Loxahatchee Slough, Loxahatchee NWR, all of the water conservation areas, Everglades National Park, Big Cypress National Preserve, Fakahatchee Strand, Okaloacoochee Slough, and marshes surrounding the Corkscrew Swamp; and snail kite nestings regularly occurs over the 10-year period in the St. Johns Marsh, Kissimmee Chain of Lakes, Lake Okeechobee, and at least one of the present compartments of the water conservation areas.

The FWS recognizes that the snail kite is a resilient species in a highly changeable environment and that to some degree a “boom and bust” population fluctuation is characteristic of the species. The above criteria for reclassification to threatened are flexible enough to allow substantial declines in population within a given year, while setting goals over a 10-year period. The global climate fluctuations that are correlated with cycles of flood and drought in South Florida occur on a periodicity of 9 to 14 years (Zhang and Trimble). 1996. The use of 650 individuals as a criterion for recovery needs to be supported by improved techniques of Population Viability Analysis (**H3.1**, below). Beissinger (1995) suggested that snail kite populations become viable above a minimum population size of 300 individuals, but this PVA needs to be re-evaluated based on the more precise population estimates anticipated from mark/resight techniques.

Species-level Recovery Actions

S1. Maintain information on the distribution and status of the Everglade snail kite. The present distribution of the snail kite and its recent history of distribution are well documented. Distribution must be monitored in the future. Radio-telemetry has provided information on movement of individuals within the species’ range, but would not be continued on a routine basis.

S1.1. Estimate population size, through mark/resighting of banded individuals. This method is considered technically superior to counts of snail kites at index locations because it allows estimation of the proportion of kites not observed and is less subject to certain errors, such as those caused by differences in experience among individuals conducting the counts and by year-to-year differences in the level of effort. Annual counts of snail kites at index locations do not provide a reliable estimate of population size, nor do they allow estimation of the coefficient of variation (Bennetts *et al.* 1999a), which is an integral part of the recovery criteria expressed above. An ongoing pilot study by Victoria Dreitz indicates that the mark/resighting techniques used by Bennetts *et al.* (1999b) to estimate survival is promising as a methodology to estimate population size (R. Bennetts, Station Biologique de la Tour du Valat, personal communication 1998). This method requires considerable commitment of resources to annually mark sufficient numbers of snail kites; this level of funding and personnel may be difficult to sustain in the long term.

S1.2. Continue surveys of nesting effort and success at the principal breeding areas. Monitoring of breeding should continue at principal breeding sites, such as the St. Johns marsh, Kissimmee Chain of Lakes, Lake Okeechobee, and Water Conservation Areas 2 and 3.

S1.3. Expand and refine existing information on movements and distribution of the snail kite, particularly changes attributable to drought. Radio telemetry has provided information on movements of snail kites within South Florida; it is expensive and labor-intensive. It may be logistically impractical to design and implement a radio telemetry study quickly enough to respond to a specific drought event. Additional radio telemetry studies should be initiated only to test specific hypotheses that cannot be tested through other methods.

S1.4. Organize and maintain a network of biologists to report Everglade snail kite sightings to a clearinghouse. In the past, information on snail kite sightings was requested from the general public, which led to unreliable reports. However, professional biologists can often provide reliable and useful sighting information, particularly when snail kites are dispersed during droughts.

S2. Protect and enhance the existing population. Because of the nomadic nature of snail kites, they integrate habitat conditions over a large geographic area and are dependent on natural and human-caused environmental conditions throughout the South Florida Ecosystem. The majority of management activities to protect and enhance the snail kite population must occur at an ecosystem level (see below). Actions at the level of the individual or groups of individuals included in the 1986 recovery plan are now considered extremely labor-intensive and would have limited benefit to the species. Such activities include installation of artificial perches and installation of artificial nest structures. Limited experimentation with captive propagation has shown it to be difficult, and the snail kite population is now considered more resilient and not currently in need of such emergency measures. Only two species-specific recovery tasks in this category are considered necessary at this time:

S2.1. Update the critical habitat designation for the Everglade snail kite. Critical habitat has not been modified since its original designation in 1977 and is in need of revision. Earlier publications correctly pointed out the importance of Lake Okeechobee and the Everglades as snail kite habitat. However, more recent information suggests that although restoration of Lake Okeechobee and the Everglades must be compatible with snail kite recovery, greater emphasis must be placed on larger wetland systems in the species, range and on smaller peripheral wetlands. Nesting of snail kites in Lake Kissimmee, Lake Tohopekaliga, and East Lake Tohopekaliga since the early 1980s is a significant change that should be considered in revising critical habitat. Although a portion of the St. Johns Marsh south of State Road 60 is included in the current critical habitat, the principal areas being used by snail kites north of that highway need to be included. Other areas outside of the Okeechobee/Everglades basin that should be considered for designation are the Big Cypress National Preserve and marshes surrounding the Corkscrew Swamp.

S2.2. **Use provisions of section 7 of the ESA to protect the Everglade snail kite**. Water management of the COE's C&SF project is critical to the survival and recovery of the snail kite. The SJRWMD and SFWMD are involved with the COE in water management decisions subject to section 7 consultation. The FWS needs to provide conservation recommendations to enhance habitat conditions for the snail kite throughout the C&SF project. Specific guidance should include water regulation of the St. Johns Marsh impoundments, Kissimmee Chain of Lakes, Lake Okeechobee, Loxahatchee NWR, Water Conservation Areas 2 and 3, Everglades National Park and Big Cypress National Preserve.

S3. Continue or initiate research on the life history of the Everglade snail kite.

S3.1. **Expand information on survival of juvenile and adult snail kites.** Although snail kites have been banded for decades, intensive banding for estimation of survival has occurred only since 1992. Intensive banding must be continued through long-term meteorological cycles to estimate the effects of drought on snail kite survival. This is a key unknown element in the life history of the species that has significance in assessing opportunities for recovery and probability of extinction relative to natural cycles and water management policy.

S3.2. **Develop and validate a snail kite model that can evaluate both stochastic natural events and human-caused modifications of habitat throughout the species' range.** An individual-based spatially explicit snail kite model is being developed as part of the Across Trophic Level System Simulation (ATLSS). The geographic scope of ATLSS does not include the Kissimmee Chain of Lakes or the St. Johns Marsh. While complete modeling across all trophic levels will not include these northern areas, they should be appended to the boundaries of the model at levels dealing with snail kite dispersal, reproduction, and survival, to model the snail kite population as a whole.

S3.3. **Investigate the genetic variability of the Everglade snail kite.** Analysis by electrophoresis has not indicated the potential for a genetic bottleneck in the snail kite population. Although additional genetic research does not appear to be a high recovery priority, analysis of heterozygosity using DNA analysis would be desirable.

S4. Monitor trends in Everglade snail kite population and levels of contaminants.

S4.1. **A mark-resighting effort will provide estimates of both total population size and survival.** Because marking of birds is most often conducted at nesting aggregations, routine monitoring has included counting the total nests and determining nesting success. However, there is general agreement among researchers that changes in the kite population is more sensitive to survival than reproduction. Although researchers should continue to monitor reproduction at the major nesting areas, the emphasis of long-term monitoring should be estimation of total population size and survival.

S4.2. Conduct periodic monitoring of contaminant levels in apple snails and Everglade snail kites. The limited sampling of apple snails and Everglade snail kites to date has emphasized the potential risks of methylmercury contamination. Although this limited sampling has not suggested an immediate threat to snail kites from mercury contamination, additional studies should be conducted on a regular basis in the long term (approximately 5 to 10 year intervals). Apple snails can be collected specifically for analysis, whereas analysis of snail kites is generally limited to occasional discovery of dead specimens or analysis of shed feathers. More emphasis must be placed on detection of herbicides in both apple snails and snail kites. Snail kites can ingest apple snails containing herbicides (such as bypiridyls), applied in agricultural fields and transported by runoff into the aquatic food web, or herbicides (such as fluoridone), applied to control aquatic vegetation.

S5. Increase public awareness about Everglade snail kites. A snail kite brochure has been distributed via donations from the St. Johns River Water Management District, Palm Beach County Solid Waste Authority, and Florida Power and Light Co. This material should be reviewed, updated, and published as a second edition. The GFC is developing signs to inform ORV users at launching sites along I-75 about responsible ORV use, including protection of the snail kite. Funding is needed to produce and install similar signs informing the public about protection of snail kites at boat launching sites in the Kissimmee Chain of Lakes, St. Johns marsh, and Lake Okeechobee. Information on the biology of the snail kite and the threats it faces should be included in middle school and high school curricula.

Habitat-level Recovery Actions

H1. Prevent degradation of existing Everglade snail kite habitat.

H1.1. Plan and carry out periodic extreme drawdowns of individual lakes on a rotational basis in the Kissimmee Chain of Lakes. These projects involve extensive cooperation and cost sharing among a number of agencies, often including simultaneous lake management activities, such as muck removal, discing, burning, and aquatic weed control. Water levels must be lowered early enough to avoid initiation of nesting by snail kites and thus prevent incidental take of nests. Cooperation is needed between the water management districts to ensure that no more than one human-caused drawdown occurs simultaneously among the principal habitats for the snail kite.

H1.2. Control or remove exotic vegetation in wetlands. The long-term direct and secondary effects on snail kites or apple snails of spraying aquatic weeds are poorly known. Research on these long-term impacts should be initiated. Current control programs are mainly directed at *Melaleuca quinquenervia*, *Schinus terebinthifolius*, and *Hydrilla verticillata.*

H1.3. Use controlled burns to open up areas of overly dense herbaceous and/or shrubby vegetation in lake littoral zones and marshes. Burning can be accomplished under natural low water conditions or in conjunction with the extreme drawdowns mentioned above. Although controlled burns with the presence of surface water or saturated soils may be beneficial, it would probably not be practical or advisable to attempt to change plant communities through uncontrollable muck fires in the Everglades.

H1.4. Ensure that information on wetlands of importance to Everglade snail kite nesting and feeding is considered in review of regulatory permits. The COE and DEP are preparing GIS data layers that will be routinely available to regulators. Information on snail kite nesting areas and other important habitats needs to be included.

H1.5. Prevent cultural eutrophication of lakes and marshes. Addition of nitrogen and phosphorus from agricultural and residential areas is accelerating eutrophication of Florida's lakes and marshes. Long-term degradation of habitat caused by eutrophication leads to buildup of organic muck, overly dense herbaceous and shrubby vegetation, and oxygen depletion. Moderate eutrophication may not harm the snail kite, but in the long term, both the abundance of apple snails and the ability of snail kites to locate snails in dense vegetation is reduced. Reduction of nutrient inputs at the source needs to be addressed by best management practices, including rates of application and stormwater retention on site. Construction and maintenance of wastewater treatment plants must be improved to control discharge of nutrients in lakes and streams.

H1.6. Evaluate effects of Lake Okeechobee's regulation schedule on Everglade snail kite habitat. Observations since 1992 suggest a general degradation of nesting habitat in the littoral zone of Lake Okeechobee from the loss of willows in nesting areas (R. Bennetts. Station Biologique de la Tour du Valat, personal communication 1998). Modification of the regulation schedule to increase water storage could cause additional loss of vegetation in the littoral zone, which would be adverse to the ecology of the lake as a whole, including the snail kite. Conversely, extending periods of low water in the lake through a combination of agricultural, urban, and environmental restoration demands would also be detrimental to the snail kite. Evaluation of proposed changes to water regulation in Lake Okeechobee must consider the effect on the snail kite in the context of protection of all the fish and wildlife resources in the lake and elsewhere in the C&SF system. Long-term monitoring of changes in wetland vegetation in relation to water management practices needs to be conducted throughout the C&SF system as indicators of habitat suitability for snail kites, rather than relying on short-term changes in snail kite population, distribution, or reproduction.

H2. Restore areas to suitable habitat.

H2.1. Reverse the expansion of cattails as a dominant plant in portions of the Everglades through reduction in nutrient loading from agricultural and urban sources. Portions of the Water Conservation Areas and the Holey Land WMA are now relatively unsuitable habitat for the snail kite due to growth of dense monocultures of cattails. The Everglades Construction Project and additional treatment areas (such as portions of the Water Preserve Areas in the C&SF Restudy) need to be implemented. The influence of nutrient levels bound in the soil on the persistence of cattails after water quality improvement needs to be predicted and then determined empirically.

H2.2. Construct and operate the Modified Water Deliveries to Everglades National Park and C-111 projects. These projects will restore flow patterns to northeast Shark River Slough and other portions of the southern Everglades, enhancing Everglade snail kite habitat.

H2.3. **Through the C&SF Restudy, investigate, plan, and carry out restoration projects in the Kissimmee/Okeechobee/Everglades watershed.** As a whole, restoration projects proposed through the C&SF project should restore water quantity, water quality, timing, and sheetflow, as opposed to flow through canals Wherever practical, impoundment of water behind levees should be reduced, provided that this action does not overdrain areas upstream of the presently impounded areas. The establishment of Water Preserve Areas and additional compartments for storage and treatment of water should be reviewed for management opportunites that may support recovery of the Everglade snail kite.

H3. **Conduct research on the biology and life history of the Everglade snail kite.**

H3.1. **Complete and use ATLSS modeling of the snail kite to predict the response of snail kites to changes in hydropattern anticipated for specific water management proposals.** In addition to the need to correctly describe the life history of the snail kite itself, the ATLSS modeling must include linkage to apple snail distribution and abundance, vegetation characteristics in the landscape influencing the snail kite's successful foraging, and linkage of all these factors to hydrology. ATLSS simulations (and/or other Population Viability Analysis models) can also provide estimates of the vulnerability of the snail kite population as a whole to extinction. Such information should be used to refine, if necessary, our use of 650 birds as a recovery criterion.

H3.2. **Continue and expand research on the effects of natural and human-caused hydrologic events on the ecology of the apple snail.** This research will provide needed information for the ATLSS modeling described above, and even before completion of ATLSS, this research can be used in decisions on water management.

H3.3. **Evaluate the effectiveness of long-term climate predictions to reduce the likelihood of coincidence of human-caused drawdowns and drought.** Prediction of long-term climate patterns is still inexact, but climatological monitoring can increasingly predict the probability of *El Niño* events perhaps 1 or two years in advance. Florida's subtropical climate is significantly affected by these global shifts, and this may be useful in adjusting water regulation schedules according to anticipated "wet" or "dry" years. Human-caused drawdowns should be avoided prior to entering a drought, because snail kites will have fewer options for refuge from drought and because refilling of drained lakes or marshes will be prolonged during drought.

H3.4. **Perform a detailed statistical analysis of rainfall records throughout central and South Florida to identify the intensity and spatial and temporal extent of droughts.** This information will provide an estimate of the threat to the snail kite from region-wide drought. It will be used to estimate the probability of extinction over long time scales in response to severe drought under a range of future land use scenarios.

H3.5. **Evaluate the need for secondary treatment in addition to the nutrient removal afforded by macrophytic stormwater treatment areas.** Determine effective methods of treatment to reduce nutrients below levels affecting the ecology of the Everglades.

H4. Monitor habitat/ecological processes. Expansion of existing monitoring programs throughout the C&SF system is expected as restoration projects are generated through the C&SF Restudy, with an increased emphasis on adaptive management. The snail kite should be included in monitoring of ecological indicators along with analysis of vegetation patterns and hydrology throughout the system.

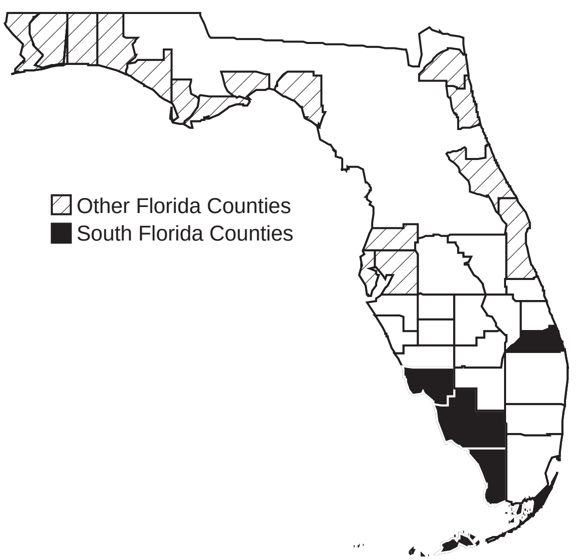
H5. Increase public awareness of ecological relationships, environmental stressors, and restoration activities in the South Florida Ecosystem. Because the range of the snail kite coincides closely with the C&SF system and because it is endangered, it can serve as a symbolic species for restoration efforts in South Florida. Information on the kite's status, threats, and its ecological relationship with other species should be integrated in public education on restoration activities. Public outreach can include newsletters, newspapers, magazines, the worldwide web, and classroom materials.

Piping Plover

Charadrius melodus

Federal Status:	**Threatened (Dec. 11, 1985)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. Florida distribution of the piping plover



The piping plover (*Charadrius melodus*) is a small, migratory shorebird that breeds only in three geographic regions of North America: on sandy beaches along the Atlantic Ocean, on sandy shorelines throughout the Great Lakes, and on riverine systems and prairie wetlands of the Northern Great Plains. The Great Lakes population is listed as endangered, whereas the Atlantic Coast and Great Plains populations are listed as threatened.

Though this species does not breed in Florida, individuals from the three breeding populations winter in Florida. The Atlantic Coast birds use Florida's Atlantic and Gulf of Mexico coastlines in the winter. Until recently, the Great Lakes and Great Plains populations were observed along the Gulf Coast shoreline. In 1997, piping plovers from the Great Lakes population were sighted in Georgia. Birds from all three breeding populations have been observed in the Florida Keys.

Early 20th century accounts indicate shorebird harvesting for the millinery trade was the cause of the first known major decline of the species. Since then, many factors contributed to the continued decline of the species. Habitat destruction, human disturbance of nesting and wintering birds, and predation were the main factors affecting the species when it was listed in 1985. At the time of listing, there were less than 2,500 breeding pairs estimated in the U.S. and Canada.

Piping plovers are inconspicuous due to their coloring (sand-colored above and bright white underneath) and behavior. In favored roosting, feeding, and breeding areas, piping plovers tend to spend more time walking or running than flying. Territoriality within breeding sites is well documented and has also been observed at wintering sites.

This account represents South Florida's contribution to the rangewide recovery plan for the piping plover (FWS 1988, 1996).

Description

Piping plovers are one of five commonly occurring North American species of belted plovers. They have an overall body length of 17 to 18 cm (National Geographic Society

1983, Haig 1992) and weigh between 46 g and 64 g (average 55 g) (Wilcox 1959, Haig 1986). Wing lengths range from 11.0 to 12.7 cm, the tarsi range from 2.1 to 2.4 cm, and culmen lengths vary from 1.0 cm to 1.4 cm (Wilcox 1959, Haig 1986). Throughout the year, adults have sand-colored upper body parts, white undersides, and orange legs. During the breeding season, adults acquire a black forehead, a single black breast band, and orange bills with black tips (Bent 1929, Graul 1973, Johnsgard 1981). In general, males have brighter bands than females, and inland birds have more complete bands than East Coast birds (Moser 1942, Wilcox 1959, Haig and Oring 1987). Postbreeding birds lose the black markings and orange on their bill, but are easily distinguished from snowy plovers (*Charadrius alexandrinus*) and collared plovers (*C. collaris*) by their slightly larger size and orange legs (Haig 1987a). Fledglings have flesh-colored legs and black bills (Wilcox 1959) and immature plumage is similar to adult non-breeding plumage. Juveniles acquire adult plumage in spring following the hatching year (Haig 1987b).

The piping plover is similar to other ringed plovers in size and body shape; however, the very pale color of its upper parts, its orange legs, and the complete white band across the upper tail coverts are diagnostic characteristics (Haig 1992).

Taxonomy

Described as a race of *Charadrius hiaticula* (Wilson and Bonaparte [n.d.]), the taxonomy of piping plovers has undergone a number of revisions (Wilson and Bonaparte [n.d.], AOU 1945, 1957). Ord was the first to consider piping plovers a separate species, but it was not until the fourth edition of the AOU Checklist that the binomial, *Aegialitis meloda*, was changed to *Charadrius melodus* (Ridgway 1919, AOU 1931, Moser 1942, Wilcox 1959). In addition to changes in the binomial, ornithologists have argued for over 100 years about acceptance of two subspecies: *C. m. melodus* (Atlantic birds) and *C. m. circumcinctus* (inland birds). The first two editions of the AOU Checklist listed the two forms, the third and fourth listed one form (AOU 1886, 1895, 1910, 1931). Moser’s argument that breast bands differed between inland and coastal birds facilitated changing back to two forms in the 1945 supplement of the checklist. Wilcox (1959) reported a variety of breast band forms from birds on Long Island. Subsequent morphological measurements of Atlantic Coast and inland birds did not indicate there was a significant difference between birds from different regions (Moser 1942, Griscom and Snyder 1955, Wilcox 1959). Additionally, electrophoretic samples collected by Haig and Oring (1988a) from piping plovers in Saskatchewan, Manitoba, North Dakota, Minnesota, and New Brunswick, did not indicate genetic differences among local or regional populations. The subspecies designation was only included in the AOU (1957) Checklist (AOU 1983). Recent studies indicated the separation of the species into subspecies is not supported (Haig and Oring 1988a, Haig 1992).

Piping plover.
Original photograph courtesy of Theodore H. Below.

Distribution

The piping plover has a broad distribution within North America (Bell 1978, Johnsgard 1981, AOU 1983, Dinsmore 1983, Haig 1985, Haig and Oring 1985, FWS 1996). Historically, breeding occurred in three geographic regions: (1) the Northern Great Plains of the U.S. and Canada, from Alberta to Manitoba south to Kansas; (2) beaches along the Great Lakes; and (3) Atlantic coastal beaches from Newfoundland to North Carolina.

Currently, the species' range remains similar to historic range accounts except that breeding sites in the Great Lakes have almost disappeared (Cairns and McLaren 1980, Russell 1983, Haig and Oring 1985). Piping plovers are no longer known to breed in Illinois, Indiana, Ohio, Pennsylvania, and Lake Ontario (Haig 1992).

Historical winter sites were not well described, although piping plovers were generally seen along Gulf of Mexico beaches, southern U.S. Atlantic beaches from North Carolina to Florida, in eastern Mexico, and numerous islands scattered throughout the Caribbean (Ridgway 1919, Bent 1929, Nicholls and Baldassarre 1990a). The complete winter distribution of the piping plover remains to be determined, although specific Gulf and Atlantic coastal sites are becoming better recognized for their importance to wintering birds (Haig and Oring 1985, 1987; Haig 1986; Nicholls and Baldassarre 1990a; Sprandel *et al.* 1997).

Some birds, however, may winter beyond North America. Nicholls (1989) documented small numbers of birds in the Bahamas, Bermuda, Puerto Rico, Virgin Islands, and Yucatan between 1985 and 1988. Haig and Oring (1985) also reported that winter birds have been recorded in the Bahamas, Barbados, Bermuda, Cuba, Dominican Republic, Ecuador, Haiti, Jamaica, Mexico, Netherlands-Antilles, Puerto Rico, U.S. Virgin Islands, and the West Indies by various observers between 1929 and 1984. The broad range of the sightings and the limited number observed indicates that a substantial number of piping plovers may use winter sites outside the U.S.

In 1991, 10 nations participated in an international census of wintering and breeding habitat of the piping plover (Haig and Plissner 1992). The number of birds identified during the winter census (3,451 individuals) comprised 63 percent of those noted during the breeding census (5,482 individuals). In general, birds from the Great Lakes/Northern Great Plains populations tended to winter in the Gulf of Mexico, while those from the Atlantic Coast population wintered along the coastline further to the south. Though some crossover of these populations did occur, the moratorium on banding Atlantic Coast birds affected identifying the actual amount of intermixing (Haig andPlissner 1993). However, piping plovers from the Great Lakes population were sighted in Georgia in 1997.

A second international census was conducted in 1996; the winter census (2,515 birds) comprised 43 percent of the breeding census (5,913 birds). As in 1991, the greatest numbers of wintering birds are concentrated primarily along the western Gulf of Mexico, particularly the south Texas coast. Typically, wintering birds located in Texas have been observed with 400+ in 1984 (Haig and Oring 1985), 834 from 22 sites in 1987 (Nicholls and Baldassarre 1990a), 1,904 birds located at 64 sites in 1991 (Haig and Plissner 1992, 1993), and 1,333 birds censused at 32 sites in 1996 (Plissner and Haig 1997).

In Florida, Nicholls and Baldassarre (1990a) found 375 birds at 39 sites in a winter survey conducted between December 1986 and March 1987. During the 1991 international winter census of piping plovers, 551 birds were seen on both the Atlantic and Gulf coasts (70 and 481 birds, respectively) (Haig and Plissner 1992). Sprandel *et al.* (1997) found 229 birds at 25 sites during a winter survey conducted between November 1993 and March 1994. For the 1996 international winter census, a total of 333 to 375 birds were counted on both coasts of Florida (18 to 24 on the Atlantic and 315 to 351 on the Gulf). The lower numbers of piping plovers between the two census intervals could be associated with fewer birds and/or a reduced censusing effort.

Florida counties where wintering piping plovers are usually seen include Bay, Brevard, Collier, Miami-Dade, Duval, Escambia, Franklin, Gulf, Hillsborough, Lee, Martin, Monroe, Okaloosa, (possibly) Palm Beach, Pasco, Pinellas, Santa Rosa, (possibly) Sarasota, St. Lucie, St. Johns, Taylor, Volusia, Wakulla, and Walton (Stevenson and Anderson 1994, Nicholls 1996) (Figure 1).

Habitat

At sites on the Gulf of Mexico and Atlantic coasts, piping plover wintering habitat includes beaches, mudflats, and sandflats, as well as barrier island beaches and spoil islands (Haig 1992). These birds may also be seen on ocean beaches and sand or algal flats in protected bays (Wilkinson and Spinks 1994). Nicholls and Baldassarre (1990b) surmise that environmental heterogeneity may be an important factor in winter piping plover distribution. On the Atlantic Coast, they found that piping plovers were most often found foraging in areas adjacent to large inlets and passes. On the Gulf Coast, preferred foraging areas were associated with wider beaches, mudflats, and small inlets.

More roosting sites for wintering birds need to be identified and described before conclusions can be made regarding their habitat associations (Nicholls

1996). Climo's (1998) landscape-level analysis of suitable wintering habitat indicates piping plovers selected landscapes or sites on the Gulf Coast that provided the greatest extent of open water, such as sand spits and barrier islands. Piping plovers seem to prefer landforms that provide tidal flats for foraging and open beaches for roosting within close proximity of each other. Johnson and Baldassarre (1988) observed that wintering piping plovers use sandflats and mudflats for feeding, whereas, sandy beaches are used for resting and probably roosting.

Behavior

Reproduction and Demography

Although piping plovers are only winter residents in Florida, an overview of their reproductive behavior is provided herein. Courtship rituals in piping plovers involve aerial displays by the male over his territory. These flights decrease after a mate has been secured and egg-laying is initiated. The male also exhibits a tilt display during courtship. He stands with head down and body at a 30 degree angle, and the female then stands beneath his tail (Haig 1992). Male piping plovers also perform nest-scraping displays, which involve excavation of prospective scrapes while vocalizing. Copulation follows a complex display involving tilting and posturing as the male approaches his mate. After copulation, both birds may "stone toss" small shells or stones into the prospective nest scrape, thus lining the nest with shells or stones (Wilcox 1959, Haig 1992). The male may also engage in this behavior early in the season, at which time it is usually associated with the tilt display (Haig 1992).

The pair bond established during courtship is maintained throughout the nesting season. Some birds change mates following nest losses. However, those that change mates produce fewer fledglings than those that retain their original mates. There is no evidence that pair bonds extend beyond the nesting season (Haig 1992).

Piping plover pairs generally raise one brood per year, with both sexes incubating the eggs. Females may renest several times, if their nests are destroyed. Nests are usually no closer than 30 m from the nearest neighbor and are usually more than 61 m (Wilcox 1959). The most common size of a clutch is four eggs. Eggs are laid every other day until the clutch is complete. Incubation most likely begins with the laying of the third egg or when the clutch is complete; most shorebirds with precocial young have synchronous hatching (Wilcox 1959). Incubation lasts between 27 and 31 days (Wilcox 1959).

Both parents brood the chicks, although the female may desert the brood within five to 10 days after hatching. Brooding is infrequent after 21 days posthatching and the young generally remain within the territory of the male parent (Wilcox 1959, Haig 1992). As in most shorebirds, the young are cryptically colored; they drop to the ground and become motionless when threatened.

Piping plovers may maintain family groups (made up of at least the male and chicks) and chicks are cared for and fed through fledging and sometimes until fall migration (Haig 1992). Fledglings leave the breeding grounds slightly later than adults (Patterson *et al.* 1990). Chicks fledge at different rates in different locations with a range of 21 to 35 days post hatching.

There is little information on immature postbreeding season movements or behavior. Site fidelity in adults varies, but is generally high (Wilcox 1959; Haig and Oring 1988a, 1988b; Haig 1992).

The piping plover is reported to be long-lived. During his 20-year banding study of piping plovers in the northeast, Wilcox (1959) found several birds that were at least 11 years of age at the end of his study. Clapp *et al.* (1982) noted that a 14-year-old bird was caught and released in the vicinity of its banding site in 1963. The average lifespan of the piping plover is less than 5 years (Wilcox 1959). Based on the resightings of 103 adults and 61 chicks color-banded between 1985 and 1988, the mean annual survival rate is estimated to be 0.74 for birds greater than 1 year old and 0.48 for chicks from the Atlantic Coast population (FWS 1996).

Foraging

The piping plover feeds primarily on marine, freshwater, and terrestrial invertebrates. A variety of invertebrates from the Mollusca, Annelida, Arthropoda, Crustacea, and Nematoda phyla have been found in fecal samples from Gulf of Mexico winter birds (Nicholls 1989). Foraging behavior consists of short pecks and runs, as well as “foot trembling” (vibrating one foot against wet sand, possibly in order to bring invertebrates to the surface or startle insects on the surface). Birds may also forage near nests in drier sand (Haig 1992, Nicholls 1996).

Piping plovers do not forage cooperatively, but may forage in small groups. Foraging also occurs at any time of day and may be influenced by tidal stage and other environmental factors (Haig 1992). Nocturnal foraging behavior of adults and chicks has been documented (Burger 1991, Staine and Burger 1994).

Piping plovers on their wintering grounds spend a greater portion of their time foraging in fall and winter than in the spring (Johnson and Baldassarre 1988). Greater energy requirements in winter weather may affect the duration or rate of foraging, although tidal stage, prey availability, breeding cycle stage, weather, and levels of human disturbance also influence the amount of foraging (Johnson and Baldassarre 1988, Haig 1992). In fact, tidal stage may influence piping plover behavior in all stages of its life cycle (Staine and Burger 1994).

Migration

Piping plover migration patterns are not well documented. Fall migration southward extends from late July through September, whereas migration north to the breeding grounds occurs from late February to early April (Haig 1992). Birds from the Great Lakes/Great Plains regions tend to stage on Texas beaches prior to moving north; a staging area has not been identified for the Atlantic Coast birds.

Specific routes of the Great Lakes/Great Plains birds are poorly understood, but it appears that the birds may fly nonstop to the Gulf Coast (Haig and Plissner 1993). Color-banded plovers have been observed at several sites in North Carolina and Florida, indicating their use by migrating and wintering birds (McConnaughey *et al.* 1990, FWS 1996). Generally, males arrive at the breeding grounds first in the spring, whereas females are the first to leave the breeding sites in the fall (Haig 1992).

Relationship to Other Species

Piping plovers may nest in tern colonies (*Sterna* spp.) or in close proximity to other shorebirds, such as the American avocet (*Recurvirostra americana*). Predators that take piping plover eggs include gulls, crows, raccoon (*Procyon lotor*), red fox (*Vulpes fulva*), opossum (*Didelphis marsupialis*), and skunks (MacIvor *et al.* 1990, Flemming 1991). In addition, rats (*Rattus* spp.) and house mice (*Mus musculus*) may be egg predators (Wilcox 1959, Dyer 1993). Adults may be taken by falcons and great horned owls (*Bubo virginianus*). Arctic terns (*S. paradisaea*) are aggressive toward piping plovers; the death of one individual from such an encounter has been reported (Flemming 1991).

Dunlins (*Calidris alpina*), western sandpipers (*C. mauri*), sanderlings (*C. alba*), least sandpipers (*C. minutilla*), semipalmated plovers (*C. semipalmatus*), snowy plovers, and black-bellied plovers (*Pluvialis squatarola*) as well as some colonial waterbirds, occupy the same winter habitats as piping plovers (Haig 1992, Sprandel *et al.* 1997). Wintering piping plovers are rarely found alone and are most often found within 1 km of four of the first five species listed above (Nicholls and Baldassarre 1990b).

Status and Trends

Historical piping plover population data are mainly qualitative. There is no estimate of total population size available prior to 1980. Historic data for the Atlantic Coast population indicates a decline since at least 1955 (Haig and Oring 1985, Wilkinson and Spinks 1994). Uncontrolled hunting and egg collecting were the primary cause of piping plover decline along this region prior to the passage of the Migratory Bird Treaty Act in 1918 (Dyer 1993, FWS 1996). The population rebounded somewhat from this decline until after World War II, when human development and dune stabilization in breeding areas increased in the Northeast (Raithel 1984, Haig and Oring 1985). Other regions (*e.g.*, the Great Lakes) have suffered significant declines (Haig and Oring 1985). The Northern Great Plains population was declining as a result of severe drought and incompatible water management practices (Haig 1992).

In 1985, breeding pair counts for the U.S. population of piping plovers ranged between 930 and 1,650. Total breeding pair counts varied from 1,649 to 1,939 (Haig and Oring 1985). A 1987 to 1991 census indicated the total number of pairs ranged from 2,065 to 2,334 with 1,266 to 1,589 pairs occurring in the U.S. (Haig 1992). The Atlantic Coast population ranged from 790 to 987 pairs for this period; whereas, from 1992 to 1997, the population ranged from 1,026 to 1,391 pairs (FWS 1998) (Table 1).

Table 1. Piping plover breeding pair estimates[1]

Year	Great Lakes	Great Plains	Atlantic Coast	Total
1986	16		790	
1987	16	1,258-1,326	790	2,064-2,132
1988	14	1,271	886	2,171
1989	15	1,007-1,064	957	1,979-2,036
1990	12	862	980	1,854
1991	17	1,372	987	2,376
1992	16		1,026	
1993	18		1,113	
1994	19		1,150	
1995	21		1,349	
1996	23	1,297	1,348	2,668
1997	23		1,391	
1998	24		1,372	1,396

[1] Breeding pair population estimates taken from Haig 1992; FWS 1996, 1998.

In Florida, wintering piping plovers have been extirpated from entire counties over the past 50 years. Museum records and Christmas Bird Count data indicate piping plovers regularly wintered in Bay, Brevard, Broward, Collier, Miami-Dade, Duval, Franklin, Gulf, Hillsborough, Indian River, Lee, Monroe, Nassau, Orange, Pinellas, St. Johns, St. Lucie, Sarasota, Taylor, Volusia, and Wakulla counties. During the 1991 and 1996 winter census, there were no records of piping plovers for Brevard, Broward, Miami-Dade, Hillsborough, Indian River, Nassau, Palm Beach, St. Lucie, Sarasota, and Wakulla counties; piping plovers were recorded in Martin and Monroe counties during the 1996 census (Howell 1932; FWS 1988, 1996; Nicholls 1989; Plissner and Haig 1997).

The significant alteration of sandy beaches and other littoral habitats due to recreational or commercial developments and dune stabilization in the Great Lakes region, Atlantic Coast beaches, and Gulf of Mexico winter sites is partly responsible for the decline of the species (Bent 1929, Russell 1983, Master and French 1984, Haig 1985, Haig and Oring 1985, FWS 1988, Burger 1991, Dyer 1993). As of the 1991 census, numbers of piping plovers declined to such levels that destruction of any part of their breeding or wintering habitat would significantly affect the species. Population viability anaylsis (PVA) modeling of the piping plover shows that extinction probabilities are sensitive to changes in survival rates (FWS 1996). PVA modeling results show a 4 percent extinction probability over 100 years for a 2,000-pair population based on survival rates of 0.74 for birds greater than 1 year old and 0.48 for chicks. When declines in adult (5 percent) and chick (10 percent) survival rates were modeled, the extinction probability increased to 32 percent (FWS 1996). Such declines in survival rates could occur due to the continued degradation and alteration of wintering habitat.

The Final Rule designating piping plover populations as endangered or threatened identified habitat disturbance and destruction, and human disturbance of nesting individuals as the greatest threats to the species (50 FR 50733). Human disturbance continues to be a major impediment to recovery at both breeding and wintering sites. Many of the remaining breeding and wintering locations available to plovers are plagued by various forms of human disturbance, which may include pedestrian recreationists, their pets, and off-road vehicle enthusiasts (FWS 1988, 1996; Haig 1992; Melvin *et al.* 1994; Staine and Burger 1994).

Human disturbance reduces the amount of time breeding plovers spend foraging (Burger 1991, Staine and Burger 1994), which could affect reproductive success as well as the ability of an individual to survive migration and winter (Burger 1991). Vehicle mortalities are an issue in the northeastern breeding areas. Melvin *et al.* (1994) described 14 vehicle mortality incidents in their study area; they believe that this is a larger problem than has previously been acknowledged. Human disturbance may also be a problem for wintering plovers. Recreational activity levels, including pedestrians and off-road vehicles, were higher on beaches without wintering piping plovers than on those that had wintering plovers (Nicholls 1989). It is important to note the type of human activity as well as the amount and duration of the activity when studying the effects of disturbance on wintering and breeding birds. Each of these types of activities has a different detrimental effect on piping plovers. In addition to human disturbance, predation continues to be a problem in some areas. Predator exclosure cages placed over the nests appear to be ameliorating this threat in the Atlantic Coast and Great Lakes areas (Haig and Plissner 1993).

Shoreline stabilization and erosion control efforts concurrent with urban development have dramatically reduced historic piping plover nesting habitat in Maine, Rhode Island, and the Great Lakes. A quantitative analysis of the effects of these types of activities in Canada has not been performed. Dune maintenance to protect roadways may also impact nesting plovers in New Jersey and Massachusetts. Water management practices (*e.g.*, reservoir construction, channelization, and modification of river flows) have eliminated many nesting sites along the Missouri and Platte Rivers in North and South Dakota, Iowa, and Nebraska (FWS 1988, 1996; Nicholls and Baldassarre 1990b; Loegering and Fraser 1991; Haig 1992).

Environmental contaminants do not appear to be adversely affecting piping plover populations, although high levels of selenium have been documented on the Missouri River and the Platte River (FWS 1991, 1993; Ruelle 1993). Oil spills pose a threat to piping plovers throughout their life cycle (FWS 1996). Dinsmore (1983) reviewed the impact of surface mining on piping plovers and concluded that there was potential for habitat destruction as well as enhancement in mining areas.

Management

Prior recovery plans prepared for piping plovers breeding on the Great Lakes and Northern Great Plains and the Atlantic Coast have outlined those tasks necessary to promote recovery of this species. The Great Lakes and Northern Great Plains Recovery Plan identified six major tasks that needed to be accomplished in order to facilitate recovery of the interior piping plover population. These tasks focused on determining the distribution and population trends of the piping plover; determining the habitat requirements and habitat status of the birds; protecting, enhancing, and increasing piping plover populations in this region; and preserving and enhancing habitat for the species. The Atlantic Coast Population Revised Recovery Plan recommended managing breeding piping plovers and habitat to maximize survival and recovery of the species; monitoring and managing wintering and migratory areas to maximize survival and recruitment to the breeding population; protecting essential wintering habitat by preventing degradation and disturbance of these sites; scientific investigations of factors that will facilitate recovery; developing and implementing a public information and education program; and reviewing the recovery progress annually and revising recovery efforts as appropriate (FWS 1988, 1996).

Both recovery plans concentrate on habitat protection and enhancement as a major factor in piping plover recovery nationwide. Habitat protection and enhancement could include maintenance of natural coastal formation processes, actual physical manipulation of the sites, predator control, minimization of human disturbance, and control of off-road vehicle access (FWS 1988, 1995; Patterson *et al.* 1990; Dyer 1993; Haig and Plissner 1993; Sidle and Kirsch 1993; Cox *et al.* 1994).

Piping plovers spend 7 to 8 months associated with their wintering areas (Haig and Oring 1985). The factors listed above can substantially affect their survival and recovery. Aside from piping plovers, wintering areas are also used by many other shorebirds.

In Florida, the focus of piping plover management has been the protection of specific wintering sites. The GFC can provide short-term protection by designating such sites as "critical wildlife areas," a designation that affords some protection from disturbance and destruction with limited enforcement opportunities. At least one important wintering site in Collier County, Florida, has been designated as a critical wildlife area.

Another method for conserving piping plover populations is through land acquisition. A small key on the western end of the Seven-mile bridge in the lower Florida Keys, known as Ohio Key, is one such site that has been acquired by the FWS.

Additional surveys to locate other important wintering areas and analyze the essential components of those areas are needed. Once located, mechanisms to protect and enhance those areas must be implemented, such as the regulatory process under section 7 of the Endangered Species Act (Sidle *et al.* 1991).

The Atlantic Coast Revised Recovery Plan projects recovery by 2010 with the implementation of all the identified recovery actions. The Great Lakes and Northern Great Plains Recovery Plan does not identify a projected date for reclassification of the Great Lakes population to threatened status or recovery of the Great Plains population.

Literature Cited

American Ornithologists' Union [AOU]. 1886. Checklist of North American birds. First Edition.

American Ornithologists' Union. 1895. Checklist of North American birds Second Edition.

American Ornithologists' Union. 1910. Checklist of North American birds. Third Edition.

American Ornithologists' Union. 1931. Checklist of North American birds. Fourth Edition.

American Ornithologists' Union. 1945. Twentieth supplement to the checklist of North American birds. Auk 62:436-449.

American Ornithologists' Union. 1957. Checklist of North American birds. Fifth Edition. Lord Baltimore Press, Baltimore, Maryland.

American Ornithologists' Union. 1983. Checklist of North American Birds. Sixth Edition. Allen Press, Lawrence, Kansas.

Bell, F.H. 1978. The piping plover (*Charadrius melodus*) in Canada. Unpublished status report to the Committee on the Status of Endangered Species in Canada (COSEWIC); National Museum of Canada, Ottawa.

Bent, A.C. 1929. Life histories of North American shorebirds. U.S. National Museum Bulletin 146:236-246.

Burger, J. 1991. Foraging behavior and the effect of human disturbance on the piping plover (*Charadrius melodus*). Journal of Coastal Research 7(1):39-51.

Cairns, W.E., and I.A. McLaren. 1980. Status of the piping plover on the east coast of North America. American Birds 34(2):206-208.

Clapp, R.B., M.K. Klimkiewicz, and J.H. Kennard. 1982. Longevity records of North American birds: Gaviidae through Alcidae. Journal of Field Ornithology 53(2):81-124.

Climo, L. 1998. A landscape-level analysis of piping plover (*Charadrius melodus*) winter habitat. M.S. thesis, University of Minnesota, St. Paul, Minnesota.

Cox, J.H., H.F. Percival, and S.V. Colwell. 1994. Impact of vehicular traffic on beach habitat and wildlife at Cape San Blas, Florida. U.S. Biological Survey Technical Report 50. Florida Cooperative Fish and Wildlife Research Unit, Gainesville, Florida.

Dinsmore, J.J. 1983. Piping plover (*Charadrius melodus*). *In* Armbruster, J.S., ed. Impacts of coal surface mining on 25 migratory bird species of high federal interest. U.S. Fish and Wildlife Service FWS/OBS-83/35.

Dyer, R.W. 1993. The piping plover: conservation needs in the eastern United States. Underwater Naturalist 21(3&4):19-23.

Flemming, S.P. 1991. Arctic tern, *Sterna paradisaea*, kills piping plover, *Charadrius melodus*. Canadian Field-Naturalist 105(3):389-390.

Graul, W.D. 1973. Possible functions of head and breast markings in Charadriinae. Wilson Bulletin 85:60-70.

Griscom, L., and D. Snyder. 1955. Birds of Massachusetts. Peabody Museum, Salem, Massachusetts.

Goossen, J.P. 1989. Piping plover. Canadian Wildlife Service. Catalogue No. CW69-4/78E.

Haig, S.M. 1985. The status of the piping plover in Canada. Report to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC); National Museum of Canada, Ottawa.

Haig, S.M. 1986. Winter distribution and population status of the piping plover on the Gulf of Mexico. *In* Endangered Canadian Prairie Species. Canadian Wildlife Service; Edmonton, Alberta.

Haig, S.M. 1987a. Winter distribution and population status of the piping plover on the Gulf of Mexico. *In* Endangered Canadian Prairie Species. Symposium proceedings published by Canadian Wildlife Service; Edmonton, Alberta.

Haig, S.M. 1987b. The population biology and life history patterns of the piping plover. Ph.D dissertation, University of North Dakota. Grand Forks, North Dakota.

Haig, S.M. 1986. Unpublished data based on 6 years of field studies and over 800 hours of focal pair time budget data collection. University of North Dakota, Grand Forks, North Dakota.

Haig, S.M. 1992. Piping Plover. No. 2 *In* A. Pools, P. Stettenheim, and F. Gill, eds. The Birds of North America. Philadelphia: The Academy of Natural Sciences; Washington, D. C. The American Ornithologists' Union.

Haig, S.M., and L.W. Oring. 1985. The distribution and status of the piping plover throughout the annual cycle. Journal of Field Ornithology 56:334-345.

Haig, S.M., and L.W. Oring. 1987. The piping plover. *In* The Audubon Society, 1987 Audubon Wildlife Report. Washington., D.C.

Haig, S.M., and L.W. Oring. 1988a. Genetic differentiation of piping plovers across North America. Auk 105(2):260-267.

Haig, S.M., and L.W. Oring. 1988b. Distribution and dispersal in the piping plover. Auk 105(4):630-638.

Haig, S.M., and J.H. Plissner. 1992. 1991 International Piping Plover Census. Report to U.S. Fish and Wildlife Service, Region 3, Division of Endangered Species, Fort Snelling, Minnesota.

Haig, S.M., and J.H. Plissner. 1993. Distribution and abundance of piping plovers: results and implications of the 1991 international census. Condor (95):145-156.

Howell, A.H. 1932. Florida bird life. Coward-McCann, Inc.; New York, New York.

Johnsgard, P.A. 1981. The plovers, sandpipers and snipes of the world. University of Nebraska Press; Lincoln, Nebraska.

Johnson, C.M., and G.A. Baldassarre. 1988. Aspects of the wintering ecology of piping plovers in coastal Alabama. Wilson Bulletin 100:214-233.

Loegering, J.P., and J.D. Fraser. 1991. Human impacts on barrier island piping plovers. Virginia Journal of Science 42(2):172. Abstract only.

MacIvor, L.H., S.M. Melvin and C.R. Griffin. 1990. Effects of research activity on piping plover nest predation. Journal of Wildlife Management 54(3):443-447.

Master, L., and T. French. 1984. Notes from the piping plover and least tern inventory/protection/management workshop for northeastern states. The Nature Conservancy; Boston, Massachusetts.

McConnaughey, J.L., J.D. Fraser, S.D. Coutu, and J.P. Loegering. 1990. Piping plover distribution and reproductive success on Cape Lookout National Seashore. Unpublished report to the National Park Service.

Melvin, S.M., A. Hecht, and C.R. Griffin. 1994. Piping plover mortalities caused by off-road vehicles on Atlantic Coast beaches. Wildlife Society Bulletin 22(3):409-414.

Moser, R.A. 1942. Should the belted piping plover be recognized as a valid race. Nebraska Bird Review 10:31-37.

National Geographic Society. 1983. Field guide to the birds of North America. Washington, D.C.

Nicholls, J.L. 1989. Distribution and other ecological aspects of piping plovers wintering along the Atlantic and Gulf Coasts. M.S. thesis, Auburn University; Auburn, Alabama.

Nicholls, J.L. 1996. The piping plover. Pages 61-72 *in* J.A. Rodgers, H.W. Kale, and H.T. Smith, eds., Rare and endangered biota of Florida. Volume 5: Birds. University Press of Florida, Gainesville, Florida.

Nicholls, J.L. 1996. Telephone conversation April, 1996.

Nicholls, J.L., and G.A. Baldassarre. 1990a. Winter distribution of piping plovers along the Atlantic and Gulf Coasts of the United States. Wilson Bulletin 102(3):400-412.

Nicholls, J.L., and G.A. Baldassarre. 1990b. Habitat associations of piping plovers wintering in the United States. Wilson Bulletin 102(4):581-590.

Patterson, M.E., J.D. Fraser, and J.W. Roggenbuck. 1990. Piping plover ecology, management, and research needs. Virginia Journal of Science 41(4A):419-426.

Plissner, J.H., and S.M. Haig. 1997. 1996 International Piping Plover Census. Report to U.S. Geological Survey, Biological Resources Division, Forest and Rangeland Ecosystem Science Center, Corvallis, Oregon.

Raithel, C. 1984. The piping plover in Rhode Island. Unpublished manuscript.

Ridgway, R. 1919. *Charadrius melodus* Ord. *In* The Birds of North and Middle America. U.S. National Museum Bulletin 8, Washington, D.C.

Ruelle, R. 1993. Contaminant evaluation of interior least tern and piping plover eggs from the Missouri River in South Dakota. Proceedings from the Missouri River and its tributaries piping plover and least tern symposium/workshop. South Dakota State University, Brookings, South Dakota.

Russell, R. 1983. The piping plover in the Great Lakes region. American Birds 37(6):951-955.

Sidle, J.G,. and E.M. Kirsch. 1993. Least tern and piping plover nesting at sand pits in Nebraska. Colonial Waterbirds 16(2):139-148.

Sidle, J.G., K. Mayne, and E.N. McPhillips. 1991. Protecting the piping plover under section 7 of the Endangered Species Act. Environmental Management 15(3):349-356.

Sprandel, G.L., J.A. Gore, and D.T. Cobb. 1997. Winter shorebird survey. Final performance report. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Staine, K.J., and J. Burger. 1994. Nocturnal foraging behavior of breeding piping plovers (*Charadrius melodus*) in New Jersey. Auk 111(3):579-587.

Stevenson, H.M,. and B.H. Anderson. 1994. Birdlife of Florida. University Presses of Florida; Gainesville, Florida.

U.S. Fish and Wildlife Service [FWS]. 1988. Great Lakes and Northern Great Plains

Piping Plover Recovery Plan. U.S. Fish and Wildlife Service; Twin Cities, Minnesota.

U.S. Fish and Wildlife Service [FWS]. 1991. A contaminant evaluation of interior least tern and piping plover eggs and chicks on the Missouri River, South Dakota. U.S. Fish and Wildlife Service; Pierre, South Dakota.

U.S. Fish and Wildlife Service [FWS]. 1993. Environmental contaminants survey of the South Platte River in northeastern Colorado. U.S. Fish and Wildlife Service; Golden, Colorado.

U.S. Fish and Wildlife Service [FWS]. 1996. Piping plover *(Charadrius melodus*), Atlantic Coast Population, Revised Recovery Plan. U.S. Fish and Wildlife Service; Hadley, Massachusetts.

U.S. Fish and Wildlife Service [FWS]. 1998. 1997 status update: U.S. Atlantic Coast piping plover population. Sudbury, Massachusetts.

Wilcox, L. 1959. A twenty year banding study of the piping plover. Auk 76:129-152.

Wilkinson, P.M., and M. Spinks. 1994. Winter distribution and habitat utilization of piping plovers in South Carolina. Chat 58(2):33-37.

Wilson, A., and C.L. Bonaparte. [n.d.] Piping plover (*Charadrius melodus*). *In* American Ornithology. Volume III. Cassell, Petter and Galpin, NY.

Recovery for the Piping Plover

Charadrius melodus

Recovery Objective: DELIST.

South Florida Contribution: ASSIST in the long-term maintenance of wintering habitat, sufficient in quantity, quality, and distribution to maintain survival rates for a 2,000-pair population.

Recovery Criteria

The objective of this recovery plan is to support and contribute to the recovery of all populations of the piping plover through fulfillment of Criterion 5 in the Atlantic Coast Piping Plover Revised Recovery Plan (FWS 1996). This criterion identifies the need to maintain wintering habitat sufficient in quantity and quality to maintain survival of the Atlantic Coast population of piping plovers. Florida provides only wintering habitat, so no objectives related to reproductive success may be identified. Once wintering ecological needs are identified, measurable criteria may be defined for wintering populations of the piping plover in Florida.

Species-level Recovery Actions

S1. **Determine the distribution and abundance of wintering piping plovers in Florida by surveying beaches and other suitable habitat to determine additional wintering sites.** Only 63 percent of the known adult population has ever been accounted for during the winter period. Suitable habitat should be surveyed in a manner consistent with the Atlantic Coast Piping Plover Revised Recovery Plan (FWS 1996).

S2. **Protect and enhance the wintering population in Florida by managing human use of beaches important to piping plovers.** Human disturbance disrupts foraging and loafing patterns of wintering plovers. In addition, other human uses may limit suitable habitat for plovers by rendering some areas unusable. The effects of human activities on piping plovers have been investigated, but are not entirely understood.

S3. **Conduct research on the wintering ecology of piping plovers in Florida.**

S3.1. **Investigate the wintering ecology of piping plovers.** Research on the Texas coast will provide valuable information on piping plover wintering ecology. However, the Texas coastal system is complex, and habitat selection and use may be somewhat different from other areas along the Atlantic and Gulf Coasts. Possible research sites include: Ohio Key/Woman's Key/Boca Grande Key in the Florida Keys; Marco Island/Sand Dollar Island in Collier County; and Estero Island, Cayo Costa State Park, North Captiva Island, Bunches Beach in Lee County.

S3.2. **Determine the spatial and temporal use of wintering habitat.** Analysis of data from aerial photographs using computerized GIS may provide insight about the relative importance of the juxtaposition of roosting and foraging habitat (*i.e.*, how far will plovers travel between foraging and roosting sites). Time budget analyses and observations of marked birds may also yield more information on the spatial and temporal (tidal, year-to-year, wind-influenced) use of habitat, whether or not there are prime and alternate feeding and roosting sites, and importance of sites during weather and tidal extremes.

S3.3. **Investigate the effects of human disturbance on wintering plovers.** The degree to which human disturbance and off-road vehicles affect the distribution, habitat use, energetics, and survival of wintering piping plovers needs further study; investigation of the mechanisms by which human activities affect the birds is also needed.

S4. **Monitor known and potential wintering sites.** Recent wintering surveys have identified many new wintering sites, but there is a need for better information about spatial and temporal use patterns, habitat trends, and threats. This can be advanced through a continuing monitoring program.

S4.1. **Monitor abundance and distribution of known wintering plovers through periodic wintering surveys.** A comprehensive rangewide survey (*i.e.*, International Census) of wintering sites patterned after Haig and Plissner (1993) should be conducted at intervals of not more than 5 years to assess population trends, discover additional wintering sites, and determine relative site importance. Major wintering sites along both the Atlantic and Gulf coasts should be surveyed annually to provide additional information on site importance and to assess population fluctuations on a site-by-site basis.

S4.2. **Monitor human use of piping plover wintering sites.** Develop a program to monitor human use of important wintering piping plover sites. This information will assist agencies in determining the appropriate management of these sites.

S5. **Implement public information and education programs.** The Atlantic Coast Piping Plover Revised Recovery Plan (FWS 1996) and the Great Lakes and Northern Great Plains Recovery Plan (FWS 1988) identify the need for an education program and describes strategies for disseminating this information. This education program should be implemented in South Florida focusing on wintering habitat. Expanded efforts to increase public awareness of protection needs of piping plovers, other rare beach species, and the beach ecosystem are needed.

S5.1. **Develop piping plover information and education materials specific to Florida and wintering populations.** These materials should be designed to reach new target audiences, take advantage of advancing media, and stimulate continuing public interest and awareness. In addition, all materials must be kept reasonably current regarding the status of the species and protection efforts. At present, there is a need to integrate more information about the role of piping plover conservation efforts in protection of the beach ecosystem and the plight of other rare beach-dwelling species into plover informational and educational materials.

S5.2. **Establish a network for distribution of information and education materials.** While development of information and educational materials is a major task, distribution of these materials to target audiences requires an even larger commitment of time and other resources.

Habitat-level Recovery Actions

H1. Protect essential wintering habitat by preventing habitat degradation and disturbance. All known wintering areas are currently considered essential to piping plover conservation. Recovery of the three breeding populations is contingent on availability of wintering habitat for more than double the current number of piping plovers (FWS 1996). As information needed to accurately estimate carrying capacity of wintering habitat becomes available in the future, it may be possible to identify habitat that is not considered essential to plover conservation, but, for now, all known wintering sites are considered essential habitat and should be protected.

H1.1. Protect habitat from direct and indirect impacts of shoreline stabilization, navigation projects, and development. Coastal development projects should be carefully assessed with regard to this species. Recommendations from the FWS (under the Endangered Species Act and the Fish and Wildlife Coordination Act) and/or State agencies should focus on avoiding or minimizing adverse effects to wintering habitat. Where adverse effects cannot be avoided, agencies should document potential impacts so that cumulative effects on this species' habitat can be assessed.

H1.2. Utilize the section 7 consultation process to minimize the effects of Federal actions (beach renourishment, coastal armoring) on piping plover wintering habitat. Apprise resource and regulatory agencies of population status and threats to wintering piping plovers and their habitats. Periodic workshops should be held to inform resource management and regulatory agencies about threats, research and management needs, *etc.* A coordinated approach to conservation of plover wintering areas should be encouraged.

H1.3. Protect wintering habitat from disturbance by recreationists and their pets. More information about the mechanisms and effects of disturbance on wintering plovers and their habitat is needed. As information becomes available, it should be incorporated into conservation efforts since wintering sites in Florida currently face their greatest threats from human disturbance.

H1.4. Protect piping plovers and their wintering habitat from contamination and degradation due to oil or chemical spills. Contamination from oil or chemical spills or leaks poses a significant threat to wintering piping plovers. Efforts must be made to minimize the likelihood of such events in the vicinity of plover wintering areas. Oil/chemical spill emergency response plans should provide for protection of known plover wintering areas, as should State plover, shorebird, or coastal ecosystem protection plans. In the event of a spill in the vicinity of a known piping plover wintering area, surveys should be conducted and efforts should be made to prevent oil/chemicals from reaching plover use areas, and restoration efforts should begin expeditiously. If piping plovers or their habitats are damaged by an oil/chemical spill or leak, appropriate claims should be filed under the Natural Resource Damage Assessment regulations to recover damages and undertake relevant restoration work.

H1.5. Provide for long-term protection of wintering habitat, including agreements with landowners and habitat acquisition. Wintering areas deemed important (essential) should be protected through management plans and/or written agreements. Conservation easements and acquisition of wintering sites should be considered. Priority should be afforded to important sites facing the most imminent threats of permanent habitat loss or degradation.

H1.6. **Compile management guidelines for wintering piping plovers.** Use the information and data obtained under **S3** and **H2** to develop management guidelines that can be used by Federal, State, and local governments as well as private entities to implement conservation actions for wintering piping plovers.

H2. **Conduct research on wintering habitat.**

H2.1. **Characterize wintering habitat.** Research is needed to identify winter foraging and roosting habitat characteristics in Florida. Features should be identified on both the local (*e.g.*, substrate type) and landscape level (*e.g.*, the availability or diversity of microhabitats in coastal complexes). Information on habitat characteristics and use will help in locating new and protecting existing wintering sites.

H2.2. **Identify factors limiting the quantity and quality of habitat or its use by piping plovers at specific wintering sites.** Potential direct and indirect threats to wintering plovers and their habitat have been identified, but a better understanding of the exact mechanisms and degree of impacts on the birds is needed. Some of this information will be obtained through formal scientific investigations (discussed in **S3** of species-level recovery actions), but much information can and should be acquired through monitoring the response of habitat and birds to various factors, including natural coastal formation processes, dredging and other channel maintenance, beach renourishment, and recreational activities. Careful documentation of all observations is a key component of such monitoring. Opportunities to incorporate monitoring into plans for Federal activities subject to section 7 of the Endangered Species Act, such as dredging and discharges regulated by the COE, should be sought. For example, a 1994 biological opinion regarding the reopening of Packery Channel, between Mustang and North Padre Islands, Texas, recommended that the COE conduct pre- and post-project monitoring of the area's tidal amplitude, size of intertidal flats, salinity, vegetation, and invertebrate populations.

H2.3. **Evaluate impacts of artificial inlet closure and other beach stabilization projects on piping plover wintering habitat suitability.** Piping plovers nest and forage in storm-maintained habitats, including sandspits, overwashes, and blowouts, and the species' survival and recovery as well as the well-being of other early succession beach-dwelling species is dependent on the maintenance and perpetuation of these habitat characteristics. Beach stabilization projects, such as renourishment and coastal armoring are sometimes implemented despite their deleterious effects on plovers and sea turtles. Additional information is needed to more fully determine the type, extent, and duration of impacts from these types of coastal modifications and to facilitate more complete analysis of impacts on wintering piping plovers. Such studies should also seek to define possible project modifications that will minimize adverse impacts on piping plovers, other Federally threatened species, and the beach ecosystem. Studies may also facilitate creation and enhancement of wintering habitat to mitigate unavoidable adverse effects of artificial beach stabilization.

H3. **Monitor and manage wintering and migration areas to maximize survival and recruitment into the breeding population.** The probability of persistence of Atlantic Coast and Great Plains piping plover populations are highly sensitive to changes in survival rates. Since piping plovers spend 55 to 80 percent of their annual cycle associated with wintering areas, factors that affect their well-being on the wintering grounds can substantially affect their survival and recovery. Piping plover wintering areas are also used by many other shorebirds; their protection will contribute to the conservation of a richly diverse and important ecosystem.

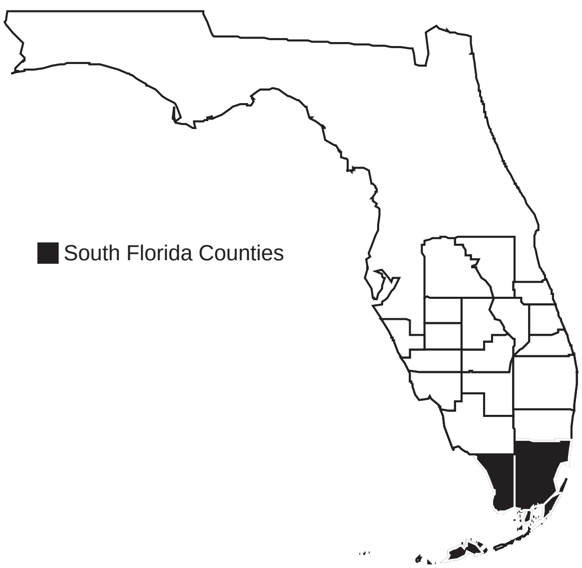
H4. **The Recovery Team recommends integrating the monitoring and protection tasks specified below into a State action plan for the piping plover.** A State action plan that includes all shorebirds or entire coastal systems may be an effective vehicle for piping plover protection. The State action plan should identify several specific needs: (1) monitoring--a program to monitor the size of the wintering population of piping plovers should be developed. This monitoring program could be derived from several index beaches or areas to provide a qualitative measure of population fluctuations; (2) identification of protection and management needs--management plans should be developed and implemented for wintering beaches that have special management needs or special management conflicts; (3) education needs--the need for meetings or workshops to train personnel from regulatory agencies on the needs of piping plovers on their wintering grounds should be conducted in Florida. For example, a 1991 workshop was held in North Carolina specifically for representatives of the regulatory agencies to inform them of the plover's habitat needs and ecology, and requirements to protect and consult on this species; (4) recognition of important sites--a mechanism for providing special recognition or designation of sites that are critical for the survival and recovery of piping plovers should be developed and implemented.

Cape Sable Seaside Sparrow

Ammodramus maritimus mirabilis

Federal Status:	**Endangered (March 11, 1967)**
Critical Habitat:	**Designated (August 11, 1977)**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of the Cape Sable seaside sparrrow.



Cape Sable seaside sparrows (*Ammodramus maritimus mirabilis)* are medium-sized sparrows restricted to the Florida peninsula. They are non-migratory residents of freshwater to brackish marshes. The Cape Sable seaside sparrow has the distinction of being the last new bird species described in the continental United States prior to its reclassification to subspecies status. The restricted range of the Cape Sable seaside sparrow led to its initial listing in 1969. Changes in habitat that have occurred as a result of changes in the distribution, timing, and quantity of water flows in South Florida, continue to threaten the subspecies with extinction.

This account represents a revision of the existing recovery plan for the Cape Sable seaside sparrow (FWS 1983).

Description

The Cape Sable seaside sparrow is a medium-sized sparrow, 13 to 14 cm in length (Werner 1975). Of all the seaside sparrows, it is the lightest in color (Curnutt 1996). The dorsal surface is dark olive-grey and the tail and wings are olive-brown (Werner 1975). Adult birds are light grey to white ventrally, with dark olive grey streaks on the breast and sides. The throat is white with a dark olive-grey or black whisker on each side. Above the whisker is a white line along the lower jaw. A grey ear patch outlined by a dark line sits behind each eye. The lores of the head are yellow. The leading edge of each wing has a small yellow patch near the alula. The legs and bill are grey (Curnutt 1996). There are no noticeable differences in markings between the sexes. However, there are significant differences in the sizes of specific body parts between the sexes (Werner 1975). Young birds differ from adults in that they do not have whisker marks, lack the yellow lores, and have brown streaking on the back.

Taxonomy

Seaside sparrows are members of the family Fringillidae. There are nine recognized subspecies. Two of the subspecies, the Cape Sable seaside sparrow and the recently extinct dusky seaside sparrow (*Ammodramus maritimus nigrescens*), occurred in isolated and restricted ranges (Curnutt 1996), and were once considered separate species (AOU 1983). Howell (1919) originally described the Cape Sable seaside sparrow and named it *Thryospiza mirabilis*, based on its distinct plumage and size. Due to its light coloration, Griscom (1944) and Beecher (1955) considered it to be a form of seaside sparrow (*Ammospiza maritima*). Stimson (1956, 1968) noted similar behavioral characteristics to the dusky seaside sparrow, and, in 1973, the Cape Sable seaside sparrow was designated as a subspecies of the seaside sparrow (Eisenmann 1973). The scientific name of the Cape Sable seaside sparrow was officially changed from *Ammospiza maritima* to *Ammodramus maritima* in 1982 (AOU 1983). Because Cape Sable seaside sparrows utilize habitats markedly different from those utilized by other seaside sparrows, Curnutt (1996) proposes full species status for the Cape Sable seaside sparrow.

Distribution

The eight surviving subspecies of seaside sparrow are distributed along the east coast of the United States, from Massachusetts to southern Florida, and along the Gulf coast, from southeast Texas to the west coast of Florida. Cape Sable seaside sparrows have a very restricted range and occur only in the Everglades region of Miami-Dade and Monroe counties in South Florida (Figure 1). They are non-migratory and isolated from other breeding populations of seaside sparrows. The Scott's seaside sparrow, which is the closest in locality to the Cape Sable seaside sparrow, occurs 300 km to the north. When Howell first discovered Cape Sable seaside sparrows on Cape Sable in Monroe County, the sparrows were utilizing freshwater and brackish water marshes there. The original range most likely included all suitable habitat in south and southwestern Florida (Werner 1978), and extended from Cape Sable (south) to Ochopee (northwest), and east to Taylor Slough and the east Everglades. Presently, the known distribution of the sparrow is restricted to two areas of marl prairies east and west of Shark River Slough, and flanking Taylor Slough.

Habitat

In the 1930s, Cape Sable was the only known breeding range for the sparrow (Nicholson 1928); areas on Cape Sable that were occupied by Cape Sable seaside sparrows in the 1930s have experienced a shift in vegetative communities from freshwater vegetation to mangroves, bare mud flats, and salt-tolerant plants such as *Batis maritima* and *Borrichia frutescens* (Kushlan and Bass 1983). The hurricane of 1935 is believed to have initiated the succession of the plant community on Cape Sable from one dominated by freshwater plants to one dominated by salt tolerant plants. Sea level rise, reduced freshwater flows to the area resulting from upstream water management practices, and another hurricane in 1960 were also likely factors in this habitat change. As a result, Cape Sable seaside sparrows no longer use this area.

Cape Sable seaside sparrow.
Original photograph courtesy of Everglades National Park.

The currently preferred nesting habitat of Cape Sable seaside sparrows appears to be a mixed marl prairie community that often includes muhly grass (*Muhlenbergia filipes*) (Stevenson and Anderson 1994). These short-hydroperiod prairies contain moderately dense, clumped grasses, with open space permitting ground movements by the sparrows. Sparrows tend to avoid tall, dense, saw-grass-dominated communities, spike-rush (*Eleocharis*) marshes, extensive cattail (*Typha*) monocultures, long-hydroperiod wetlands with tall, dense vegetative cover, and sites supporting woody vegetation (Werner 1975, Bass and Kushlan 1982). Cape Sable seaside sparrows avoid sites with permanent water cover (Curnutt and Pimm 1993). Several studies (Armentano *et al.*1995, Curnutt *et al.* 1998, Nott *et al.* 1998) have documented a tight correlation between increased hydroperiods resulting from current water management practices, and shifts in sparrow habitat areas from mixed marl prairie vegetation suitable for breeding to sawgrass-dominated vegetation that sparrows do not use for nesting. Qualitative observations (S. Pimm, University of Tennessee, personal communication 1998) suggest that some sparrow habitat areas west of Shark River Slough that were converted to unsuitable sawgrass-dominated vegetation types have now begun to recover under the somewhat dryer conditions observed in 1997 to 1998.

The suitability of short-hydroperiod, mixed marl prairie communities for the sparrow is driven by a combination of hydroperiod and periodic fires (Kushlan and Bass 1983). Fires prevent hardwood species from invading these communities and prevent the accretion of dead plant material, both of which decrease the suitability of these habitats for Cape Sable seaside sparrows. In the Taylor Slough area, Werner (1975) found that sparrow numbers increased annually in areas that had been burned up to 3 years previously. Four years after a fire, he expected the suitability of these habitats to decline sharply. Taylor (1983) suggested that the response of the sparrow population following fire is dependent on the rate of vegetation recovery, the soil depth, and the amount of exposed pinnacle rock. Taylor (1983) found that on sites where soil depth was 40 cm or greater, or on soils without pinnacle rock, vegetation recovery is rapid and the birds recovered more quickly following fire. At sites where soil depths are less than 20 cm and where considerable pinnacle rock occurs, the birds begin to reoccupy sites 4 years post fire (Taylor 1983). However, recent analysis suggests that a 4 year fire return frequency reduces habitat suitability and causes decline in resident sparrow populations (Curnutt *et al.* 1998). This most recent study observed increased sparrow numbers up to at least 10 years post fire (Curnutt *et al.* 1998). Results of a recent wintering ecology study (Dean and Morrison 1998) reveal that Cape Sable seaside sparrows remain in short hydroperiod mixed prairie habitats throughout the non-breeding season.

Critical Habitat

Critical habitat for the Cape Sable seaside sparrow was designated on August 11, 1977 (50 CFR 17.95), before the full distribution of the subspecies was known (Figure 2). The critical habitat, as designated, does not adequately account for the distribution of the present-day core subpopulations, or the areas necessary for continued survival and recovery. An important area west of Shark River Slough, which until 1993 supported one of two core subpopulations (nearly half of the entire population), is not included within the designation, and has been undergoing detrimental changes in habitat structure as a result of water management practices. Additionally, other parts of the designated critical habitat have been converted to agriculture, and are no longer occupied by sparrows. Thus, Cape Sable seaside sparrow critical habitat requires significant review and redesignation. When redesignating critical habitat for the Cape Sable seaside sparrow, it will be important to include all potential habitat necessary for recovery, including areas not recently utilized by the birds. This will help to protect habitat for future expansion of existing subpopulations and provide for the natural variability associated with the Everglades ecosystem. Definition of constituent elements will be another important task when re-designating critical habitat. A key constituent element for the Cape Sable seaside sparrow should be a hydroperiod pattern that maintains the preferred vegetative communities for successful breeding. During the breeding season, surface water levels should be at or below the surface within the short-hydroperiod prairies, and should be achieved through adherence to a rainfall-driven operational schedule. Adherence to such a regulation schedule will provide for restoration of hydropatterns that best support Cape Sable seaside sparrows, in addition to other native Everglades species. Other constituent elements should include vegetative structure necessary to support successful breeding.

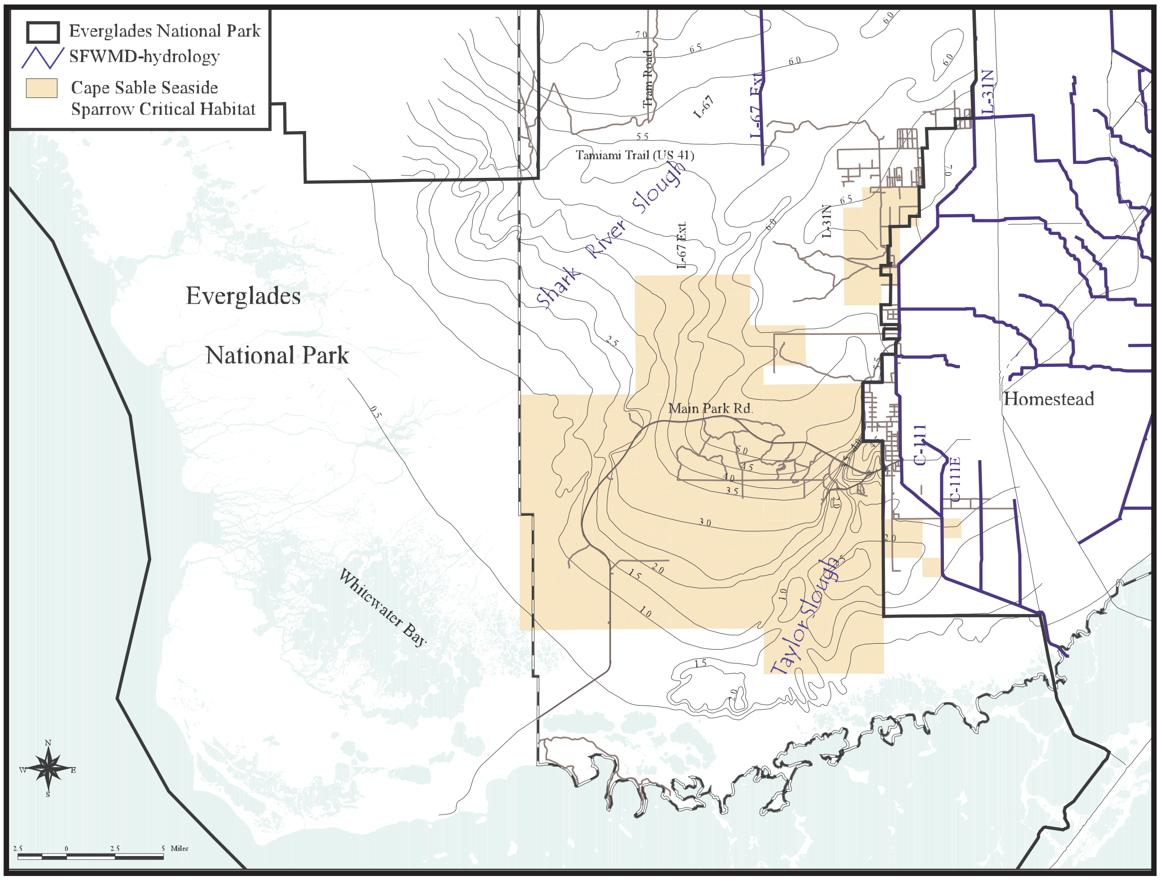


Figure 2. Cape Sable seaside sparrow critical habitat.

Behavior

Territoriality

The Cape Sable seaside sparrow is a non-migratory subspecies. As with many other seaside or savannah sparrows, males occupy and defend their territories during the breeding season. Cape Sable seaside sparrows defend territories centered around their nest sites that are smaller than their home ranges (Kushlan *et al.* 1982), but may include foraging habitat. Breeding activity by males, particularly singing behavior, appears to decrease with increased surface-water conditions (Nott *et al.* 1998, Curnutt and Pimm 1993).

Vocalizations

The primary song of Cape Sable seaside sparrows is sung by males, and is composed of clicks and trills. The head bobs up and down during the introductory clicks and then tilts slightly up and back as the song is completed with a buzzy trill (Werner 1975). The primary song is normally sung from a conspicuous perch and functions to both mark territories and attract mates. The song lasts approximately 1.5 seconds and may be repeated 10 to 13 times per minute. Singing by males occurs most often during early morning and late afternoon and evening, with unmated males singing the most persistently. As the temperature rises over the course of the day, the time spent singing decreases. Singing ceases if water levels rise above approximately 10 cm (Lockwood *et al.* 1997).

Reproduction and Demographics

Nesting has been observed from late February through early August (FWS 1983). The majority of nesting occurs in the spring when large areas of the marl prairies are dry. Cape Sable seaside sparrows usually raise one or two broods in a season, although they may raise a third brood if weather conditions allow (Kushlan *et al.* 1982, FWS 1983). Sparrows build new nests for each successive brood. Nest cups are placed approximately 14 cm above the ground and are constructed with grasses (Werner 1975, Lockwood *et al.* 1997). Sparrows construct their nests with materials that are locally common and sometimes place taller grasses over the nest cup to conceal the nest. Nests are placed in clumps of grasses composed primarily of *Muhlenbergia* and *Spartina* (Pimm *et al.* 1996). A typical nest is constructed using sawgrass as the base and finer grasses for the lining. Most nests are constructed with dead material although one nest observed during the 1997 breeding season was constructed with some live material. Pimm (University of Tennessee, personal communication 1996) suggests that nesting will not be initiated if water levels are at a depth greater than 10 cm during the breeding season. The end of the breeding season appears to be triggered by the onset of the summer rains. When water levels rise above the mean height of the nests off the ground, sparrows cease breeding (Lockwood *et al.* 1997). Werner (1975) found that Cape Sable seaside sparrows often retained the same mate for successive nest cycles but that some individuals changed mates after one nest cycle. Additionally, some males failed to pair during the entire breeding season. Interactions between male and female Cape Sable seaside sparrows include chasing behavior, food begging by the female, males carrying food to the female, and males carrying nest material while softly singing (Lockwood *et al.* 1997). Males chase females as often as they chase males. Often, females have difficulty flying any distance without being chased by a male into the grass (Werner 1975). Cape Sable seaside sparrows lay three to four eggs in each clutch (Werner1978). Incubation has been estimated to take 12 to 13 days (Sprunt 1968, Trost 1968). The young spend 9 to 11 days at the nest. Both parents rear and feed the young birds and may do so for an additional 10 to 20 days after the young fledge (Woolfenden 1956, 1968, Trost 1968). Fledglings often occur in groups of two to seven and are occasionally alone. They are incapable of flight until they are approximately 17 days of age; when approached, flightless fledglings will freeze on a perch until the threat is less than a meter away, and then run along the ground (Werner 1975, Lockwood *et al.* 1997). There are conflicting data on the reproductive potential of the Cape Sable seaside sparrow. Werner (1975) documented a 62 percent nest success rate in the Taylor Slough area, demonstrating a high reproductive potential for this subspecies. However, Pimm *et al.* (1996), report a significantly lower success rate (42 percent) during the 1995 and 1996 breeding seasons, which were years with extremely high rainfall. Lockwood *et al.* (1997) report an 88 percent hatching rate, but only 40 percent of the eggs laid contribute to the total population each year. Kushlan *et al.* (1982) contend that the population has the ability to maintain or expand due to the 90 percent survival rate of males they observed, and the potential to produce two clutches of four eggs each breeding season. Other researchers estimate a 50 percent adult survival rate (Nott *et al.* 1998) and suggest that the population has a fairly low potential for expansion.

Foraging

Cape Sable seaside sparrows typically forage by gleaning items from low vegetation or from the substrate (Ehrlich *et al.* 1992). The Cape Sable seaside sparrow is a dietary generalist (Pimm *et al.* 1996). They commonly feed on soft-bodied insects such as grasshoppers, spiders, moths, caterpillars, beetles, dragonflies, wasps, marine worms, shrimp, grass and sedge seeds (Stevenson and Anderson 1994). Significant differences were detected in nestling diet between years and sites (Lockwood *et al.* 1997), which reflects the patchy distribution of insects and opportunistic nature of the sparrow (Post and Greenlaw 1994). The sparrow appears to shift the importance of prey items in its diet in response to their availability (Pimm *et al.* 1996).

Movements

The Cape Sable seaside sparrow is nonmigratory. The fidelity of breeding male sparrows to their territories is high; many male seaside sparrows will defend the same area for 2 to 3 years (Werner 1975). Short-range movements have been observed during the nonbreeding season. Preliminary results of a wintering ecology study (J. Lockwood, University of Tennessee, personal communication 1997) report that resighted banded adults during the 1996 to 1997 wet season moved short distances (less that 1 km) from the sites they were banded in during 1995 and 1996. Sparrows have been observed to congregate and fly short distances within their range (Dean and Morrison 1998,

S. Pimm, University of Tennessee, personal communication 1995). Dean and Morrison (1998) also observed several longer-range flights (5 to 7 km) during the nonbreeding season. However, each of these longer-range movements ended when the individual sparrow reached the edge of short hydroperiod marl prairie habitat. Dean and Morrison (1998) further suggest that large expanses of deep water or wooded habitats are barriers to long-range sparrow movements.

Relationship to Other Species

The Cape Sable seaside sparrow evolved in a variable environment. This variability allowed an abundance of organisms with different habitat needs to coexist. For example, the endangered snail kite (*Rhostrhamus sociabilis plumbeus*) requires areas of deep water that support apple snails for optimal foraging habitat; the endangered wood stork (*Mycteria americana*), requires water levels to drop to concentrate fish during the breeding season. These conditions differ from those breeding conditions required by the Cape Sable seaside sparrow which, as stated above, requires less than 10 cm of surface water to nest successfully; yet these species evolved to co-exist in the Everglades system and could do so because of the large spatial extent and diverse environmental conditions available in the South Florida landscape (Davis and Ogden 1994). If we manage the system to restore more natural timing, volume and pattern of water flows, the needs of the Cape Sable seaside sparrow should not conflict with other native Everglades species.

Status and Trends

The Cape Sable seaside sparrow (*A.m. mirabilis*) was listed as an endangered species on March 11, 1967, pursuant to the Endangered Species Preservation Act of 1966 (32 FR 4001). That protection was continued under the Endangered Species Conservation Act of 1969 and the Endangered Species Act of 1973, as amended. The Cape Sable seaside sparrow was listed because of its limited distribution and threats to its habitat posed by large-scale conversion of land in South Florida to agricultural uses. Critical habitat for the Cape Sable seaside sparrow was designated on August 11, 1977 (42 FR 40685). Historically, the Cape Sable seaside sparrow was found in freshwater and brackish water marshes from Carnestown to the marl prairies adjacent to Shark River and Taylor sloughs, including the Cape Sable area. This area periodically experiences extensive flooding, fires, and hurricanes which may result in shifts in habitat suitability for the Cape Sable seaside sparrow created by changing vegetative composition and structure. Cape Sable seaside sparrows may have adapted to this natural disturbance by varying their distribution within their range as habitat suitability changed.

Howell (1919) found the Cape Sable seaside sparrow to be “moderately numerous” on Cape Sable when he first discovered them in 1918. The Great Labor Day Hurricane of 1935 is thought to have initiated vegetative changes in the Cape Sable area that were later responsible for extirpating the Cape Sable population of the sparrow. Reduced freshwater flow to the area due to upstream water management practices, along with sea level rise, may also be contributing factors. In 1970, Werner rediscovered Cape Sable seaside sparrows in three cordgrass marshes on Cape Sable. By 1979, the Cape Sable subpopulation appeared to have been extirpated again; no sparrows were noted in surveys conducted on Cape Sable in 1979, 1980, or 1981 (FWS 1983). By 1983, the stands of *Spartina*-dominated vegetation that once covered extensive areas of Cape Sable had been reduced to small patches invaded by mangroves (Werner and Woolfenden 1983), and Cape Sable seaside sparrows have not been seen in this area since.

Cape Sable seaside sparrows were first documented in the Big Cypress basin in 1928 by Nicholson. They appeared to flourish there in the 1950s (Stimson 1956), but had been extirpated as a result of widespread frequent fires by the time surveys were conducted in the early 1960s (Stimson 1968). In the early 1970s, they were rediscovered in the Big Cypress area (Kushlan and Bass 1983, Werner and Woolfenden 1983), but were considered rare.

Cape Sable seaside sparrows were initially located in the Ochopee marshes of the Big Cypress basin by Anderson (1942), but few birds have been found since the mid-1980s. The decline of this subpopulation has been attributed to fires and salinity changes associated with altered hydrology (FWS 1983). Werner (1978) stated that predation by feral cats and dogs, anthropogenic fires, and human land exploitation could have caused the population declines of the sparrow in the Ochopee region.

The results of several studies suggest that Cape Sable seaside sparrows exist as several subpopulations whose distribution, size, and importance to the persistence of the species changes with time (Figure 3). Bass and Kushlan (1982) described two core subpopulations of the sparrow, one northwest of Shark River Slough in the southeast portion of the Big Cypress National Preserve, and a second one in the Taylor Slough area southeast of Shark River Slough. Curnutt and Pimm (1993) recognized six subpopulations (subpopulations A-F) of the Cape Sable seaside sparrow that roughly correspond to the groupings recognized by Bass and Kushlan in 1982 (Figure 3). Pimm (1998) suggested that three breeding subpopulations are critical to the long-term survival of the Cape Sable seaside sparrow.

In 1981, Bass and Kushlan (1982) estimated a total of 6,656 birds in the six subpopulations (Table 1); two core subpopulations that held most of the sparrows, and four peripheral subpopulations. Core subpopulation A inhabited the marl prairies west of Shark River Slough extending into Big Cypress National Preserve and held an estimated 2,688 individuals. Core subpopulation B held approximately 2,352 birds inhabiting the marl prairies southeast of Shark River Slough near the center of Everglades NP. Peripheral subpopulation E, north of subpopulation B, held about 672 sparrows, while subpopulation C, located along the eastern boundary of Everglades NP, and subpopulation D, just to the southeast of subpopulation C, held about 400 birds each. Peripheral subpopulation F, the northernmost peripheral subpopulation located on the western edge of the Atlantic coastal ridge, was the smallest subpopulation with an estimated 112 birds. Bass repeated the survey in 1992, with population estimates similar to those in 1981.

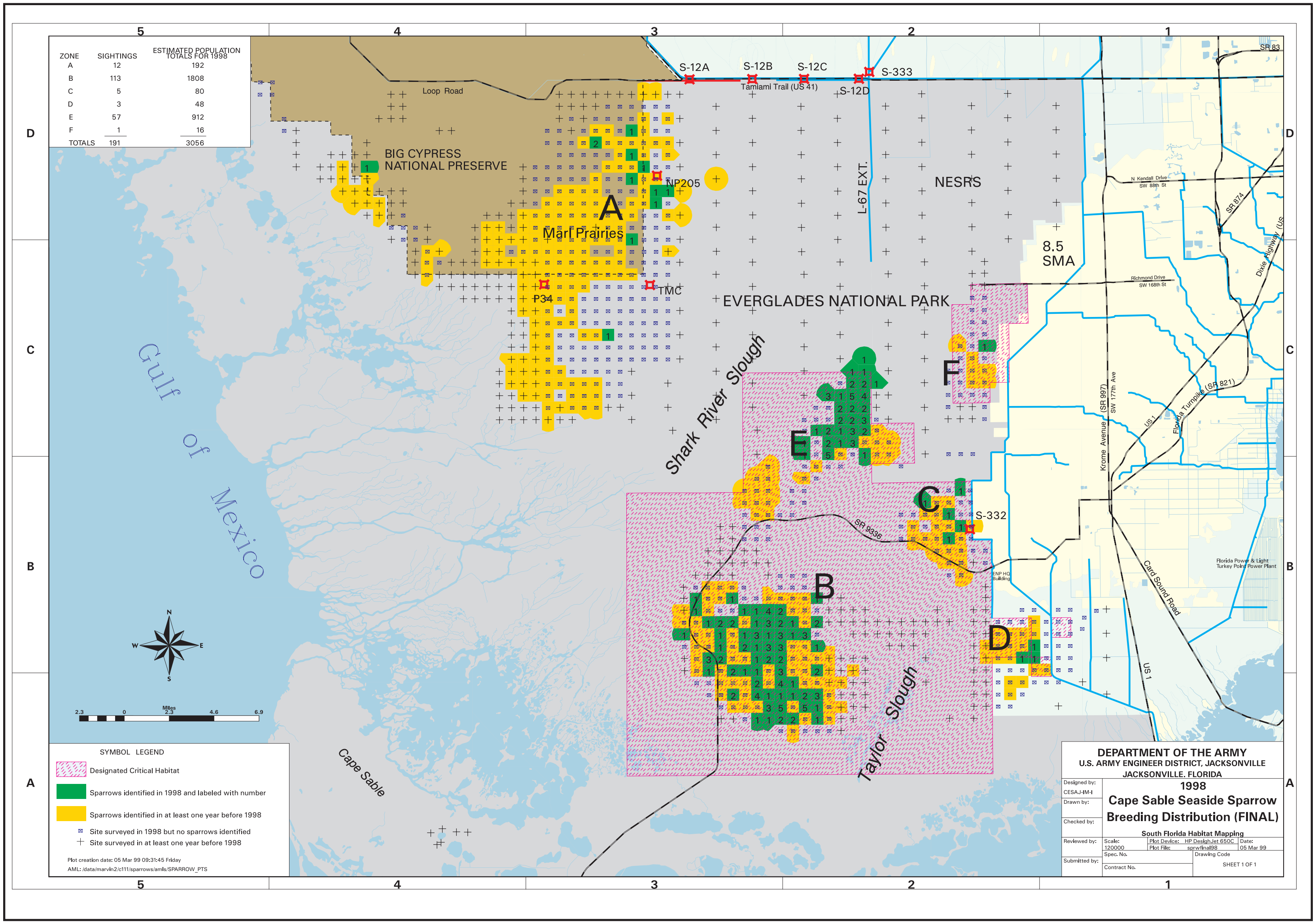


Figure 3. Breeding distribution and designated critical habitat of the Cape Sable seaside sparrow.

Table 1. Cape Sable seaside sparrows population estimates from Everglades NP.

Subpopulation	1981	1992	1993	1994	1995	1996*	1997	1998
A	2688	2608	432	80*	240	272	272	192
B	2352	3184	2464	2224	2128	1888	2832	1808
C	432	48	0	-	0	48	48	80
D	400	112	96	-	0	80	48	48
E	672	592	320	112	352	208	832	912
F	112	32	0	-	0	16	16	16
TOTAL	6656	6576	3312	2416*	2720	2512	4048	3056

Population estimate = Number of singing males counted X 16 (based on final proofed data sets from Everglades National Park as of 16 November 1998; except 1996 should be considered provisional, pending final proofing).

** Estimate based on incomplete survey.*

- No survey conducted.

Table 1 presents the results of the last eight censuses of the Cape Sable seaside sparrow (Bass 1998). The actual number of birds observed is corrected to give an estimate for the total population using the methods developed by Bass and Kushlan (1982). Logistical problems resulted in incomplete surveys in 1994.

In 1981 and 1992, the area west of Shark River Slough (subpopulation A) supported nearly half of the total Cape Sable seaside sparrow population. Starting in 1993, the number of individuals declined precipitously in this area. By 1994 and 1995, the birds were absent from this area except for a few locations (Pimm *et al.* 1994, Pimm *et al.* 1995), and the number of individuals had dropped to less than 10 percent of 1992 numbers. Population estimates improved slightly during the 1996 breeding season as the numbers of sparrows found west of Shark River Slough increased from approximately 240 in 1995 to 272 birds in 1996 and 1997 (Pimm *et al.* 1996). However, in 1998, the total number of birds west of Shark River Slough declined again to about 192 birds (Bass 1998).

Core subpopulation B increased by more than 800 birds from 1981 to 1992, declined slightly from 1992 to 1995, remained stable from 1995 to 1997, and decreased by approximately 1,000 individuals in 1998 (O. Bass, Everglades NP, personal communication 1998). It is not clear whether these changes in subpopulation B numbers represent natural variation or a response to some type of stressor, but loss of individuals from this subpopulation increases the susceptibility of the subspecies to extinction.

Curnutt *et al.* (1998) noted the following regarding the peripheral subpopulations: subpopulation C declined to 11 percent of its 1981 value by 1992. After 3 years of no birds, 48 birds were estimated in this area in 1996 and 1997 and 80 birds were estimated in 1998. Subpopulation D declined from 1981 to 1993, and was not counted in 1994. No birds were found in 1995, but 80 birds were estimated in this area in 1996, and 48 in 1997 and 1998. Subpopulation E decreased little between 1981 and 1992, fluctuated in the mid

1990's and increased to 912 in 1998. No sparrows were observed in subpopulation F in 1993, and only 16 birds were estimated in 1996 to 1998.

The most recent data indicate that Cape Sable seaside sparrows have declined by as much as 60 percent range-wide since 1992 (Curnutt *et al.* 1998, Nott *et al.* 1998). Biologists studying the sparrow have documented that high water levels, due in large part to managed water releases, in western Shark River Slough have caused the decline of the western subpopulation and continue to contribute to the absence of a population rebound (Nott *et al.* 1998). These declines cannot be attributed to the effects of Hurricane Andrew, which traversed this area in 1992 (Curnutt *et al.* 1998, Nott *et al.* 1998). Declines in sparrow population numbers were detected following Hurricane Andrew; however, a leveling off of declines, or rebound in population numbers, would be expected if populations were recovering from a single adverse event, such as Hurricane Andrew. Instead, declines continued as would be expected under continuing adverse hydrological conditions. Between 1992 and 1998, the size of the western breeding subpopulation of the Cape Sable seaside sparrow, which had represented 50 percent of the total population in 1992, had declined to about 10 percent of its previous size.

This combination of an approximately 90 percent decline in the western core subpopulation, a 60 percent decline in the overall sparrow population, and the significant risk of catastrophic fire in the sparrow's remaining core subpopulation B, has led the FWS to conclude that this subspecies is at significant risk of imminent extinction. The best scientific and commercial information available to the FWS also leads to the conclusion that current water management practices in the remaining Everglades are primarily responsible for declines in the sparrow population since 1992 and, therefore, jeopardize the continued existence of this endangered species. At this writing, negotiations are underway to develop a reasonable and prudent alternative to current water management practices that will avoid jeopardy conditions.

Competition and predation also threaten the Cape Sable seaside sparrow. Raccoons (*Procyon lotor*), snakes, rice rats (*Oryzomys palustris*), and hawks may be the chief predators (Lockwood *et al.* 1997, Dean and Morrison 1998). Predation by cottonmouth (*Agkistrodon piscivorus*) has been documented (T. Dean, Eagle Environmental, Inc., personal communication 1998). Lockwood *et al.* (1997) also suggest that increasing water levels are associated with significant increases in predation rates. Additional research on predation rates and their relation to water levels is needed.

Management

South Florida's ecosystems have been severely degraded by the Central and Southern Florida Project which encompasses 4,660,000 ha from Orlando to Florida Bay, and includes about 1,600 km each of canals and levees, 150 water control structures, and 16 major pump stations. This system has disrupted the natural volume, timing, quality and flow of surface and ground water throughout the Everglades. The Cape Sable seaside sparrow's short hydroperiod prairie habitat is contained entirely within the C&SF Project and has been extensively altered by this project (Nott *et al.* 1998). Because the sparrow's habitat is primarily dependent upon proper hydrological conditions for its restoration and maintenance, improving the sparrow's habitat through changes in the current C&SF Project operations will be the highest priority recovery action for this subspecies.

In recognition of the detrimental effects that this water supply and flood control system has had on the ecosystems in South Florida, several hydrological projects which attempt to aid in the restoration of South Florida's ecosystems, while maintaining flood control, are in various stages of planning and implementation. Recent FWS analyses of these projects through section 7 consultation reveals mixed results in expected effects to the Cape Sable seaside sparrow. Details of these analyses are available in the August 7, 1998 biological opinions for the C&SF Project Comprehensive Review Study (Restudy) and the February 19, 1999, biological opinion for the Program of Modified Water Deliveries to Everglades NP Project (Modified Waters), C-111 Project and Experimental Program of Water Deliveries to Everglades National Park (Experimental Program). In summary, the Restudy, Modified Waters and C-111 projects are expected to provide improved habitat suitability and availability for the Cape Sable seaside sparrow as compared to current conditions. The FWS has concluded that Tests 1 to 7 of the Experimental Program are the primary cause of declines in sparrow populations since 1992 and have jeopardized, and will continue to jeopardize the continued existence of this endangered species. At this writing, negotiations are underway seeking to develop an acceptable reasonable and prudent alternative to the current Test 7 of the Experimental Program that would avoid further jeopardy conditions.

It will be critical to carefully monitor hydrology, vegetation and sparrow populations as new hydrological schedules are implemented in order to ensure that unexpected adverse effects to the Cape Sable seaside sparrow do not occur. With careful monitoring and continued close coordination with the FWS and other natural resource professionals, the Modified Waters and Restudy projects have the potential to provide significant progress towards recovery for this subspecies.

Fire management and control of exotic woody vegetation will also be essential to restoration and maintenance of Cape Sable seaside sparrow habitats. Early research in this area (Werner 1975) suggested that sparrow use of habitat areas declined dramatically 4 years after fire in the Taylor Slough area. Taylor (1983) suggested that the relationship may depend on soil depths, with sparrows reoccupying sites with shallow soils about 4 years after a burn and remaining at low densities (2 to 5 males per 40.5 ha) for up to 10 years. On deeper soils or on soils without pinnacle rock, sparrows were present in the second breeding season after a burn and increased in numbers through the fourth year. More recent research (Curnutt *et al.* 1998) documents increasing sparrow numbers up to at least 10 years following fire. Several recent authors (Curnutt *et al.* 1998, Nott *et al.* 1998, Pimm *et al.* 1996) agree that observed annual or biannual fire return frequencies over large areas of the sparrow's eastern habitats are directly linked to reduced hydroperiods in these areas produced by current water management practices, and are the most likely cause of declines, and failure to recover, in subpopulations F and C. This effect is exacerbated by invasion of exotic and other woody vegetation over much of the eastern marl prairies, rendering the habitat unsuitable for sparrow breeding even when fire frequencies are reduced. In addition, subpopulation B habitat has not experienced a large-scale fire since 1989, and Everglades NP fire experts warn that occurrence of a large, possibly catastrophic fire in this area is only a matter of time. Additional research is necessary to determine optimum fire frequencies for each habitat area and to develop effective fire management techniques for restoring and maintaining suitable sparrow habitat.

Literature Cited

American Ornithologists' Union [AOU]. 1983. Checklist of North American birds. Sixth Edition. American Ornithologists' Union; Baltimore, Maryland.

Anderson, W. 1942. Rediscovery of the Cape Sable seaside sparrow in Collier County. Florida Naturalist 16:12.

Armentano, T.V., R.F. Doren, W.J. Platt, and T. Mullins. 1995. Effects of Hurricane Andrew on coastal and interior forests of southern Florida: overview and synthesis. Journal Coastal Res. Spec. Issue No. 21:111-144.

Bass, O.L., Jr., and J.A. Kushlan. 1982. Status of the Cape Sable sparrow. U.S. Department of the Interior, National Park Service, South Florida Research Center Report T-672; Homestead, Florida.

Bass, O. L., Jr. 1998. Information from annual report to U.S. Army Corps of Engineers, Jacksonville Florida, December, 1998.

Beecher, W.J. 1955. Late pleistocene isolation of salt marsh sparrows. Ecology 36:23-28.

Curnutt, J.L. 1996. Cape Sable seaside sparrow. Pages 137-143 *in* J.A. Rogers, Jr., H.W. Kale II, and H.T. Smith, eds. Rare and endangered biota of Florida: volume five, birds. University Press of Florida; Gainesville, Florida.

Curnutt, J.L., and S.L. Pimm. 1993. Status and ecology of the Cape Sable seaside sparrow. Unpublished report prepared for the U.S. Fish and Wildlife Service and the National Park Service; Vero Beach, Florida.

Curnutt, J.L., A.L. Mayer, T.M. Brooks, L. Manne, O.L. Bass, D.M. Fleming, M.P. Nott, and S.L. Pimm. 1998. Population dynamics of the endangered Cape Sable seaside sparrow. Animal Conservation 1:11-21.

Davis, S.L., and J.C. Ogden. 1994. Toward ecosystem restoration. Pages 769-796 *in* S.M. Davis and J.C. Ogden, eds. Everglades: the ecosystem and its restoration. St. Lucie Press; Delray Beach, Florida.

Dean, T.F., and J.L. Morrison. 1998. Non-breeding season ecology of the Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*): 1997-1998 field season final report. Unpublished report submitted to the U.S. Fish and Wildlife Service.

Eisenmann, E. 1973. Thirty-second supplement to the American Ornithologist's Union checklist of North American birds. Auk 90:411-419.

Ehrlich, P.R. D.S. Dobkin, and D. Wheye. 1992. Birds in jeopardy. Stanford University Press; Stanford, California.

Griscom, L. 1944. A second revision of the seaside sparrows. Louisiana State University Museum; Baton Rouge, Louisiana.

Howell, A.H. 1919. Description of a new seaside sparrow from Florida. Auk 36:86-87.

Kushlan, J.A., O.L. Bass, Jr., L.L. Loope, W.B. Robertson Jr., P.C. Rosendahl, and D.L. Taylor. 1982. Cape Sable seaside sparrow management plan. South Florida Research Center Report M-660. U.S. Department of the Interior, Everglades National Park; Homestead, Florida.

Kushlan, J.A., and O.L. Bass, Jr. 1983. Habitat use and the distribution of the Cape Sable seaside sparrow. Pages 139-146 *in* T.L. Quay, J.B. Funderberg, Jr., D.S. Lee, E.F. Potter, and C.S. Robbins, eds. Occasional Papers of the North Carolina Biological Survey, 1983-1985; Raleigh, North Carolina.

Lockwood, J.L., K.H. Fenn, J.L. Curnutt, D. Rosenthal, K.L. Balent, and A.L. Mayer. 1997. Life history of the endangered Cape Sable seaside sparrow. Wilson Bulletin 109(4), pp. 720-731.

Nicholson, D.J. 1928. Nesting habits of seaside sparrows in Florida. Wilson Bulletin 40:234-237.

Nott, M.P., O.L. Bass, Jr., D.M. Fleming, S.E. Killeffer, N. Fraley, L. Manne, J.L. Curnutt, J.M. Brooks, R. Powell, and S.L. Pimm. 1998. Water levels, rapid vegetational changes, and the endangered Cape Sable seaside sparrow. Animal Conservation 1:23-32.

Pimm, S.L. 1998. An assessment of the risk of extinction for the Cape Sable seaside sparrow. Chapter 10, annual report 1998. Unpublished report prepared for the U.S. Army Corps of Engineers, U.S. National Park Service and the U.S. Fish and Wildlife Service; Vero Beach, Florida.

Pimm, S.L., J.L. Curnutt, and M.P. Nott. 1994. Population ecology of the Cape Sable seaside sparrow (*Ammodramus maritima mirabilis*), Annual Report 1994. Unpublished report prepared for the U.S. National Park Service and the U.S. Fish and Wildlife Service. U.S. Fish and Wildlife Service; Vero Beach, Florida.

Pimm, S.L., K. Balent, T. Brooks, J. Curnutt, T. Fenn, N. Fraley, S. Killeffer, J. Lockwood, L. Manne, A. Mayer, M.P. Nott, G. Russell, and E. Stanton. 1996. Population ecology of the Cape Sable seaside sparrow, draft report. Unpublished report prepared for the U.S. National Park Service and the U.S. Fish and Wildlife Service; Vero Beach, Florida.

Post, W. and J.S. Greenlaw. 1994. Seaside Sparrow (*Ammodramus maritimus*). *In* The Birds of North America, No. 127 (A. Poole and F. Gill, Eds.). Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornthologists' Union.

Sprunt, A., Jr. 1968. MacGillivray's seaside sparrow. Pages 831-835 *in* A.C. Bent, O.L. Austin, Jr., eds. Life histories of North American cardinals, grosbeaks, buntings, towhees, finches, sparrows, and allies. U.S. National Museum Bulletin; Washington, D.C.

Stevenson, H.M. and B.H. Anderson. 1994. The birdlife of Florida. University Press of Florida; Gainesville, Florida.

Stimson, L.A. 1956. The Cape Sable seaside sparrow: its former and present distribution. Auk 73:489-502.

Stimson, L.A. 1968. Cape Sable sparrow. Pages 859-868 *in* A.C. Bent , O.L. Austin, Jr., eds. Life histories of North American cardinals, grosbeaks, buntings, towhees, finches, sparrows, and allies. U.S. National Museum Bulletin; Washington, D.C.

Taylor, D.L. 1983. The seaside sparrow, its biology and management. Pages 147-152 *in* T.L. Quay *et al.,* eds., Occasional papers of the North Carolina Biological Survey. North Carolina State Museum; Raleigh, North Carolina.

Trost, C.H. 1968. Dusky seaside sparrow. Pages 859-868 *in* A.C. Bent, O.L. Austin, Jr., eds. Life histories of North American cardinals, grosbeaks, buntings, towhees, finches, sparrows, and allies. U.S. National Museum Bulletin; Washington, D.C.

U.S. Fish and Wildlife Service [FWS]. 1983. Cape Sable seaside sparrow recovery plan. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Walters, 1992. A shadow and a song. Chelsea Green Publishing Company; Post Mills, Vermont.

Werner, H.W. 1975. The biology of the Cape Sable sparrow. Unpublished report prepared for the U.S. Fish and Wildlife Service. U.S. Department of the Interior, Everglades National Park; Homestead, Florida.

Werner, H.W. 1978. Cape Sable seaside sparrow. Pages 19-20 *in* H.W. Kale, II, eds. Rare and Endangered Biota of Florida. Volume 2: Birds. University Presses of Florida; Gainesville, Florida.

Werner, H.W. and G.E. Woolfenden. 1983. The Cape Sable sparrow: its habitat, habits, and history. Pages 55-75 *in* T.L. Quay, J.B. Funderburg Jr., D.S. Lee, E.F. Potter, and C.S. Robbins, eds. The seaside sparrow, its biology and management. North Carolina Biological Survey and North Carolina State Museum; Raleigh, North Carolina.

Woolfenden, G.E. 1956. Comparative breeding behavior of *Ammospiza candacuta* and *A. maritima.* University of Kansas Publishing, Museum of Natural History; Lawrence, Kansas.

Woolfenden, G.E. 1968. Northern seaside sparrow. Pages 153-162 *in* A.C. Bent, O.L. Austin, Jr., eds. Life histories of North American cardinals, grosbeaks, buntings, towhees, finches, sparrows, and allies. U.S. National Museum Bulletin; Washington, D.C.

Recovery for the Cape Sable Seaside Sparrow

Ammodramus maritimus mirabilis

Recovery Objective: **RECLASSIFY** to threatened once recovery criteria are met.

Recovery Criteria

Before the sparrow's listing as an endangered species, the distribution and abundance of the short-hydroperiod prairies that provide habitat for the Cape Sable seaside sparrow had declined by more than 50 percent due to destruction, fragmentation, and degradation of habitat for residential housing construction or agriculture. These areas are probably not restorable. Many of the remaining short-hydroperiod prairies that supported the Cape Sable seaside sparrow have been converted into long-hydroperiod wetlands, or have been degraded due to increased fire frequencies and/or woody species invasion as a result of reduced hydroperiods by water management practices in South Florida. The feasibility of fully restoring these areas is still uncertain. Consequently, this recovery plan outlines criteria for reclassifying the Cape Sable seaside sparrow from endangered to threatened.

This objective will be achieved: if the loss of functional Cape Sable seaside sparrow habitat, as a result of current and past water management practices, and the invasion of woody and exotic plant species, is eliminated; if Cape Sable seaside sparrow habitat west of Shark River Slough and in Taylor Slough, which has been degraded by current and past water management practices, is restored; when demographic information on the Cape Sable seaside sparrow supports, for a minimum of 5 years, a probability of persistence [$T_{(N)}$] that is equal to or greater than 80 percent (±0.05), for a minimum of 100 years; when the rate of increase (*r*) for the total population is equal to or greater than 0.0 as a 3-year running average for at least 10 years; when a minimum of three stable, self-sustaining core breeding areas are secured; when a stable age structure is achieved in the core populations; and, when a minimum population of 6,600 birds is sustained for an average of 5 years, with all fluctuations occurring above this level.

Species-level Recovery Actions

S1. Determine the distribution and status of Cape Sable seaside sparrows.

S1.1. Continue and expand distribution surveys. Conduct annual distribution surveys in all areas known to have historically supported Cape Sable seaside sparrows. Expand distribution surveys as appropriate, based on results of previous nesting and telemetry surveys and peer review. Survey information will be used to approximate total population numbers.

S1.2. Incorporate information from wintering ecology studies on Cape Sable seaside sparrow habitat use into a GIS database. Information on the distribution of Cape Sable seaside sparrows during the nonbreeding season should be incorporated into a GIS database.

S1.3. **Review and revise the current critical habitat designation based on distribution surveys.** Presently designated critical habitat does not adequately encompass the areas occupied by core populations and must be re-evaluated. Critical habitat should, at minimum, include habitat west of Shark River Slough that supports one of the two core subpopulations, and should include an analysis of wintering habitat requirements. Additionally, some of the currently designated critical habitat has been lost to agricultural development and may not be appropriate for inclusion in a revised designation.

S1.4. **Survey habitat components of both occupied and unoccupied habitat to determine why Cape Sable seaside sparrows are absent.** An improved understanding of Cape Sable seaside sparrow habitat selection within short-hydroperiod marl prairies will improve our ability to optimally manage sparrow habitats.

S2. **Protect existing populations of Cape Sable seaside sparrows.** Existing short-hydroperiod marl prairie must be protected and enhanced for Cape Sable seaside sparrows if the population is to survive. Current water management practices must be changed to restore more natural timing, volume, and placement of water flows.

S2.1. **Develop the appropriate water management regimes to protect Cape Sable seaside sparrows in Everglades NP, Big Cypress National Preserve, and the Southern Glades Wildlife and Environmental Area.** The Cape Sable seaside sparrow is restricted to the marl prairies of South Florida that are in public ownership. Many of these prairies have been altered by water management practices. Protecting the existing core breeding populations of the Cape Sable seaside sparrow is critical to the species' survival and recovery and will depend on changing current water management regimes to improve this species' breeding habitat.

S2.2. **Conduct section 7 consultations on Federal activities that may affect Cape Sable seaside sparrows.** Numerous Federal activities to restore the Everglades ecosystem are in planning stages or are currently in operation. Cape Sable seaside sparrows are presently utilizing habitats that will be affected by these activities. Any Federal activities resulting in changes in hydropatterns within areas presently utilized by sparrows must receive thorough analyses with regard to effects on sparrows, and management decisions must be made that allow sparrow numbers to remain stable or increase.

S2.3. **Develop and implement Reasonable and Prudent Alternatives (RPAs) to avoid the likelihood of jeopardy.** Current water management practices are jeopardizing the continued existence of the Cape Sable seaside sparrow. RPAs that will avoid further jeopardy conditions must be developed and implemented.

S3. **Increase the distribution and abundance of the Cape Sable seaside sparrow.** Where possible, potential habitat should be managed to encourage (re)occupation by Cape Sable seaside sparrows. In general, maintenance and/or restoration of Cape Sable seaside sparrows in all areas will involve water management, fire management, control of exotics, and control of human-related habitat impacts (airboats, *etc.*).

S3.1. **Recover the core subpopulation west of Shark River Slough.** Between 1981 and 1993, an important core area west of Shark River Slough supported nearly half of the total sparrow population. By 1996, the number of sparrows utilizing the habitat west of Shark River Slough had decreased by approximately 90 percent (Pimm *et al.*

1996). The main factor affecting sparrow habitat in this area is disruption of natural hydrological patterns. The key to restoring this subpopulation will be the restoration of more natural flows to northeast Shark River Slough and a reduction of damaging regulatory releases through the S-12 structures.

S3.2. **Recover East Everglades-Taylor Slough subpopulations to levels consistent with restored hydropatterns.** The major factors affecting birds within these regions are fire and related hydrological conditions. To maintain populations in Taylor Slough and adjacent areas of eastern Everglades NP and the Southern Glades Wildlife and Environmental Area, the effects of water management and fire management programs should be considered. The effects of the operation of pump stations and adjacent canals should be evaluated. The effects of the fire program should also be evaluated, specifically, the effects of large area burns, including boundary burning.

S3.3. **Restore disturbed habitats identified as potential Cape Sable seaside sparrow habitat, creating opportunities for this species to recolonize former habitat, including Lostman's Slough, the historic Ochopee population, and any additional sites that may be suitable within Everglades National Park, Big Cypress National Preserve, and the Southern Glades Wildlife and Environmental Area.** Restore habitats for recolonization by Cape Sable seaside sparrows. Management techniques to restore disturbed Cape Sable seaside sparrow habitat may include controlled burning, hydrological manipulation, and exotic removal.

S3.4. **Re-establish subpopulations of Cape Sable seaside sparrows through translocation.** Every effort should be made to restore and maintain the short hydroperiod marl prairies. However, if efforts to manage water deliveries and habitat result in improved habitat conditions, but do not result in a stable or increasing Cape Sable seaside sparrow population, then translocation should be initiated as a last resort.

S3.4.1. **Develop a protocol for translocating Cape Sable seaside sparrows.** The necessary protocol to translocate Cape Sable seaside sparrows needs to be developed. DOI guidelines should be followed.

S3.4.1.1. **Determine the subpopulation levels that will trigger translocation.** Determine the number of sparrows within each subpopulation that will trigger implementation of translocation. Determine the length of time that each subpopulation should remain at these numbers before initiating translocation.

S3.4.1.2. **Determine the subpopulation levels at which the removal of individuals from the donor site has minimal risk.** Determine the minimum number of individuals necessary within a subpopulation before individuals can be removed without causing risk to the donor subpopulation.

S3.4.1.3. **Determine whether translocated individuals must have a specific age structure. A particular age structure may be necessary to improve chances for successful translocation.**

S3.4.2. **Identify recipient sites for Cape Sable seaside sparrows.** There is a need to determine where translocated birds should be placed. Should they be placed in proximity to occupied areas in order to establish a genetic link or do we place them as far from occupied habitat as possible?

S3.5. **Initiate controlled propagation *only* as a last resort for the recovery of Cape Sable seaside sparrows.** Captive propagation is to be used only when all other measures employed to maintain or improve the status of Cape Sable seaside sparrows in the wild have failed, and would be used to produce individuals for release back into the wild.

S3.5.1. **Develop a protocol for a controlled propagation program for the Cape Sable seaside sparrow.** Develop protocol for a Cape Sable seaside sparrow controlled propagation program as per Department of Interior and Department of Commerce draft controlled propagation policy. The plan will identify the lead agency responsible for the effort, including the role of FWS facilities, personnel and resources, or those of non-FWS cooperators, as appropriate, and the estimated cost and duration of controlled propagation efforts.

S3.5.2. **Review the controlled propagation protocol developed for the Dusky seaside sparrow, identify weaknesses and inconsistencies, and make the appropriate changes for Cape Sable seaside sparrows.** Protocol established for the Dusky seaside sparrow failed to accomplish the goal of keeping the population from becoming extinct. We can learn from our mistakes and develop a better protocol for Cape Sable seaside sparrows.

S3.5.3. **Develop a genetic management plan for Cape Sable seaside sparrows and submit for approval.** Controlled propagation can only be initiated when supported by an approved genetic management plan.

S4. **Conduct research on aspects of the life history and population ecology of Cape Sable seaside sparrows.** To properly manage habitat and to account for the effects of management actions and natural events, it is necessary to conduct certain studies on Cape Sable seaside sparrows. Overall, the goals of such studies are to understand the species' demographics, limiting factors, and the extent that habitat characteristics limit expansion of the population. This information will also be necessary to determine whether translocation and /or captive propagation is necessary or feasible.

S4.1. **Continue research on the ecology of Cape Sable seaside sparrows outside of the breeding season.** Additional information about the behavior or habitat needs of the sparrow outside of the breeding season is needed. Information on sparrow habitat use throughout the year will lead to better habitat management for the bird.

S4.1.1. **Identify all areas that provide essential habitat for all life stages of the Cape Sable seaside sparrow.** Critical areas should be identified and managed appropriately.

S4.1.2. **Determine seasonal movement patterns and colonizing ability.** Determine the movement patterns of adults outside of the nesting season and the dispersal and mortality of adults and fledglings; this information will aid in understanding how the Cape Sable seaside sparrow colonizes suitable, unoccupied habitat.

S4.2. **Better define the habitat requirements of the Cape Sable seaside sparrow.** The specific habitat needs of the sparrow need better definition. It is necessary to determine habitat correlates of abundance, adult survival, nest placement, predation, and reproductive success. Determine individual patterns of habitat use, time budgets, movements, foraging tactics, nesting, foraging activity areas, and year-to-year changes in territory use.

S4.3. **Determine age-specific survivorship for Cape Sable seaside sparrows.** This information will be necessary to determine species' intrinsic rate of increase and persistence time and will be used to determine whether the species can be reclassified to threatened.

S4.4. **Determine age-specific fecundity for Cape Sable seaside sparrows.** This information will be necessary to determine the species' intrinsic rate of increase and will be necessary to determine whether the species can be reclassified to threatened.

S4.5. **Research predation rates and how water levels and other factors influence predation.** A better understanding of predation on the Cape Sable seaside sparrow and the factors that influence predation rates will assist in developing management strategies.

S4.6. **Continue development of population models for the Cape Sable seaside sparrow.** Development of individual-based population viability analysis and risk assessment models should continue. These models can be used to determine possible population responses to changes in its vital rates, particularly in response to water management, fire, and hurricanes.

S5. **Monitor Cape Sable seaside sparrow subpopulations to assure that further declines in range and numbers do not occur and that recovery actions are being implemented and are effective.** Monitoring will be essential in evaluating the success of management actions.

S6. **Increase public awareness about Cape Sable seaside sparrows.** Produce brochures, signs, and other materials to educate the public about the ecological role of the Cape Sable seaside sparrow in the Everglades and the importance of appropriately managing the limited remaining short hydroperiod marl prairies. The public should understand that the continued existence of Cape Sable seaside sparrows is an indication of a healthy Everglades and that to maintain the sparrow, higher priority should be given to managing the habitat for native faunal species as opposed to flood control.

Habitat-level Recovery Actions

H1. **Prevent degradation of existing Cape Sable seaside sparrow habitat in South Florida.** Work with the COE, Everglades NP, Big Cypress National Preserve, GFC, and SFWMD to determine whether proposed restoration hydropatterns will degrade habitats in areas utilized by Cape Sable seaside sparrows or habitat designated as critical habitat. Habitat management should optimize habitats for all of South Florida's flora and fauna, without risking extinction of the Cape Sable seaside sparrow.

H1.1. **Review the effects of hydrologic restoration in Everglades NP, Big Cypress National Preserve, and the Southern Glades Wildlife and Environmental Area on areas utilized by Cape Sable seaside sparrows and make the appropriate management decisions.** For example, if a specific restoration alternative is found to reduce the ability of the Cape Sable seaside sparrow to breed in that region, we need to determine whether alternatives for hydrologic restoration will be necessary to prevent the extinction of the Cape Sable seaside sparrow.

H1.2. **Develop detailed maps of Cape Sable seaside sparrow habitat.** Collect detailed habitat information and enter this information into a GIS database.

H1.3. **Monitor changes in habitat as a result of changes in hydrologic regimes and fire events.** Using the detailed habitat maps developed per task H1.2, monitor changes in the distribution and suitability of the Cape Sable seaside sparrow's habitats over time to ensure that existing habitat is not degraded.

H1.4. **Determine the necessary management practices to maintain or restore Cape Sable seaside sparrow habitat (as identified by S1.2 above)**.

H2. **Restore habitat in the Everglades and Big Cypress basins.** Some habitats utilized by Cape Sable seaside sparrows in past years are no longer suitable. Restore these areas for recolonization by Cape Sable seaside sparrows.

H2.1. **Define the constituent elements of critical habitat for Cape Sable seaside sparrows. Constituent elements are a pivotal part of any critical habitat designation.** When redefining critical habitat for Cape Sable seaside sparrows, constituent elements must be included to allow the critical habitat designation to function as a tool aiding in recovery of the sparrow. Any new critical habitat designation must include hydrologic criteria and should capture the structure and composition of the sparrow's breeding and nonbreeding habitat.

H2.2. **Establish and implement the appropriate hydrologic regimes necessary to support Cape Sable seaside sparrows.** This should be completed for the area west of Shark River Slough and for any areas identified as potential Cape Sable seaside sparrow habitat, and should include water delivery schedules, operational criteria for water control structures, and adjacent canal water level stages.

H2.3. **Establish and implement the appropriate fire management necessary to support Cape Sable seaside sparrows.** This task will be especially important for the areas of subpopulations B through F.

H2.4. **Remove woody species and/or exotics from disturbed habitats previously used by Cape Sable seaside sparrows.** This will allow sparrows to reoccupy these areas when necessary.

H3. **Conduct research on the habitat needs of the Cape Sable seaside sparrow.** Additional information is needed on habitat selection in relation to vegetative succession and factors that influence vegetative succession.

H3.1. **Conduct a quantitative study to better understand changes in dominant plant species that have occurred within the Cape Sable seaside sparrow's breeding habitat in response to local hydrological conditions in Taylor Slough, northeast Shark River Slough and west of Shark River Slough.** There is evidence that shifts have occurred in plant species composition within these regions as a result of altered hydroperiods. By gaining further information on these shifts and correlating changes in vegetation composition with hydroperiod conditions, we will be able to more effectively manage Cape Sable seaside sparrow habitat.

H3.2. **Implement a study to determine the natural and anthropogenic factors that regulate woody plant growth and colonization in short-hydroperiod prairies.** This information will aid in our ability to control woody invasion in short-hydroperiod marl prairies.

H3.3. **Develop methods to manipulate vegetative communities.** Many communities have shifted as a result of hydrologic practices and are in need of restoration for use by Cape Sable seaside sparrows. Management practices (hydrological, fire, and exotic control) should be developed to restore these communities.

H3.4. **Determine the effects of altered hydrologic patterns on the fire frequency of marl prairies.** This information will enable appropriate management of habitats that have been altered by hydrologic regimes over the past 20 years and development of appropriate burn programs.

H3.5. **Continue research on the effects of fire frequency on Cape Sable seaside sparrow habitat use.** Information on the species' response to fire frequency will better enable us to manage habitats appropriately for Cape Sable seaside sparrows.

H4. **Monitor Cape Sable seaside sparrow habitat by implementing a long-term vegetation monitoring program.** This program should be continued for a minimum of 10 years to incorporate inter and intra-annual variability in hydrologic and fire conditions resulting from different rainfall and water management scenarios.

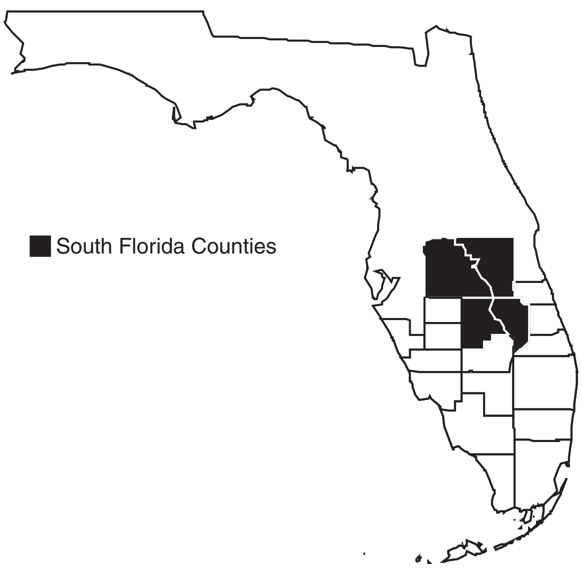
H5. **Increase public awareness about short-hydroperiod marl prairies and their key role in the Everglades ecosystem.** Produce brochures, signs, and other materials to educate the public about the ecological role of the Cape Sable seaside sparrow in the Everglades and the importance of preserving what limited short-hydroperiod marl prairie remains. The public should understand that the continued existence of Cape Sable seaside sparrows is an indication of a healthy Everglades and that functional short-hydroperiod marl prairies are necessary to have a restored Everglades ecosystem.

Florida Grasshopper Sparrow

Ammodramus savannarum floridanus

Federal Status:	**Endangered (July 31, 1986)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of the Florida grasshopper sparrow.



The Florida grasshopper sparrow is a subspecies of grasshopper sparrow that is endemic to the dry prairie of central and southern Florida. This subspecies is extremely habitat specific and relies on fire every two to three years to maintain its habitat. Because of declines in the sparrow's suitable habitat and population size, the National Audubon Society placed the Florida grasshopper sparrow on its blue list in 1974. This species was listed as endangered by the State of Florida in 1977. The FWS listed the Florida grasshopper sparrow as endangered in 1986 because of habitat loss and degradation resulting from conversion of native vegetation to improved pasture and agriculture.

This account represents a revision of the existing recovery plan for the Florida grasshopper sparrow (FWS 1988).

Description

The Florida grasshopper sparrow (*Ammodramus savannarum floridanus*) is a small, short-tailed, flat-headed sparrow averaging 13 cm in total length (M. Delany, GFC, personal communication 1996; Vickery 1996a). The top of its head is mostly blackish with a light median stripe. The remainder of its dorsum is mainly black, edged with gray, and streaked with brown on the nape and upper back. The sparrows are whitish underneath, unstreaked, with buff throat and breast; juveniles have streaked breasts. The grasshopper sparrow's ventral color pattern resembles that of the Bachman's sparrow (*Aimophila aestivalis*). The retrices of the grasshopper sparrow are pointed, its lores are light gray to ochraceous, and the bend of the wing is yellow. Its bill is thick at the base, and its feet are flesh-colored.

This subspecies is marked with a longer bill and longer tarsi than the northern subspecies (*A. s. pratensis*); it also has a darker dorsum. The Florida grasshopper sparrow also lacks the reddish streaks on its nape that are found in the northern subspecies. Adult Henslow's sparrows (*A. henslowii*) and Le Conte's sparrows (*A. leconteii*) are similar to grasshopper sparrows in size and shape; however, unlike adult grasshopper sparrows, adults of these species have ventral streaking (Stevenson and Anderson 1994). Although the juveniles of these species would be difficult to distinguish visually, only the Florida grasshopper sparrow breeds in Florida, so juveniles of these species do not overlap.

During the breeding season, the male and female grasshopper sparrows can be distinguished in the hand by the presence of a cloacal protuberance in the male or brood patch in the female. Gender may also be determined during the breeding season by wing chord length and body weight. Female grasshopper sparrows are smaller and heavier (Delany *et al.* 1994). However, this technique may not work outside of the breeding season (Delany *et al.* 1994, T. Dean, University of Massachusetts, personal communication 1996a).

The song of the Florida grasshopper sparrow is among the weakest of any North American bird (Stevenson 1978). Nicholson (1936) described it as being indistinct and as having a definite insect-like quality, which gave rise to the bird's common name (Sprunt 1954). The song starts as three low pitched notes followed by a longer, higher pitched "buzz" (Delany 1996a). Grasshopper sparrows sing while perched upon dead palmetto leaves, dead oak twigs, staggerbush (*Lyonia* spp.), and tarflower between 15 and 90 cm in height (Nicholson 1936, Delany *et al.* 1995). They may also sing from the ground, particularly after a summer burn event (P. Vickery, University of Massachusetts, personal communication 1998). Male Florida grasshopper sparrows sing throughout the day, although they sing more frequently from sunrise to 9:00 a.m. and at 15 minutes before sunset (Delany 1996a). When they are establishing breeding territories, they only sing the short primary song (Smith 1959). Male grasshopper sparrows begin singing mid- to late March, and their singing usually diminishes by late June. After late summer burns (June and early July) male grasshopper sparrows may extend singing through August (Vickery 1996).

Taxonomy

Grasshopper sparrows (*A. savannarum*) are in the order Passeriformes, family Emberizidae, subfamily Emberizinae (AOU 1983). Twelve subspecies of grasshopper sparrows have been described, including *A. s. floridanus* (Paynter and Storer 1970, Wetmore *et al*. 1984). The Florida grasshopper sparrow was first described by Mearns (1902) as *Coturniculus savannarum floridanus* on the basis of one male and two females that were collected in 1901 in a portion of the Kissimmee Prairie in southern Osceola County, Florida. By 1931, this subspecies had been incorporated into the genus *Ammodramus* (AOU 1931). *Ammodramus savannarum floridanus* has been accepted as a valid subspecies since it was described but has not been examined genetically (AOU 1910, Paynter and Storer 1970, P. Vickery, University of Massachusettes, personal communication 1998).

Florida grasshopper sparrow. *Original photograph by Betty Wargo.*

Distribution

Grasshopper sparrows are found from North to South America, Ecuador, and in the West Indies (Vickery 1996, AOU 1957). They are common breeders throughout much of the continental United States, ranging from southern Canada south to Florida, Texas, and California. Additional populations are locally distributed from Mexico to Colombia and in the West Indies (Delany *et al*. 1985, Delany 1996a, Vickery 1996).

Unlike the migratory, northeastern grasshopper sparrow (*A. s. pratensis*) that overwinters in Florida, the Florida grasshopper sparrow is non-migratory, and is limited to the prairie region of south-central Florida. The Florida subspecies is isolated from *A. s. pratensis* by at least 500 km during the breeding season (AOU 1983). The historic distribution of the Florida grasshopper sparrow is not known with certainty, but there are records from Collier, Miami-Dade, DeSoto, Glades, Hendry, Highlands, Polk, Okeechobee, and Osceola counties (Delany and Cox 1985, Stevenson 1978). An observation of an adult grasshopper sparrow in Manatee County, Florida, recorded by Howell (1932) may have been *A. s. floridanus* (Stevenson and Anderson 1994). This supposition is questionable since *A. s. floridanus* has not been found north of Kenansville in Osceola county (Delany and Cox 1985). Another *A. s. floridanus* was found by J. C. Ogden on the Anhinga Trail, Miami-Dade County, in 1968 (Stevenson and Anderson 1994). The Florida grasshopper sparrow has been extirpated as a breeding bird in Collier, Miami-Dade, and Hendry counties. Recent surveys of known locations have not detected its presence in DeSoto and Glades counties; however other populations may exist in Glades County (Delany and Linda 1994). In 1977, a previously unknown population of 43 Florida grasshopper sparrows was found on Bravo Range at Avon Park AFR (M. Delaney, GFC, personal communication 1998). This species is now known only from Highlands, Okeechobee, Osceola, and Polk counties (Robertson and Woolfenden 1992, Delany 1996a).

Habitat

Florida grasshopper sparrow habitat consists of large (greater than 50 ha), treeless, relatively poorly-drained grasslands that have a history of frequent fires (FWS 1988, Delany 1996a). *A. s. floridanus* occurs in prairies dominated by saw palmetto (*Serenoa repens*) and dwarf oaks (*Quercus minima*) ranging from 30 to 70 cm in height. Bluestem grasses (*Andropogon* spp.), St. John's wort (*Hypericum* spp.), and wiregrasses (*Aristida* spp.) are also components of grasshopper sparrow habitat (Delany *et al.* 1985, FWS 1988).

These dry prairies are relatively flat and are moderately to poorly drained. The soils typically consist of 0.3 to 1.0 m of acidic, nutrient-poor quartz sands overlying a high clay subsoil or organic hardpan (spodic horizon) (FNAI and FDNR 1990, Abrahamson and Hartnett 1990). Both the heavy subsoil and hardpan reduce the movement of water below and above their surfaces (FNAI and FDNR 1990). Thus, dry prairies may become flooded for short periods during the rainy season, but remain dry for the remainder of the year. The water table in these prairies is normally found between several centimeters and a meter below the soil surface.

The main difference between dry prairies and pine flatwoods is that pines and palms are absent or at a density below one tree per acre. Grasshopper sparrows, however, cannot tolerate tree densities as high as one tree per acre. Some dry prairies may be artifacts of clearcutting, unnaturally frequent burning, livestock grazing, and alteration of hydrology (Abrahamson and Hartnett 1990). Prairie habitat may also have disappeared due to infrequent burn regimes from fire prevention, and from planting of slash pine.

When compared with habitat of other grasshopper sparrows, habitat used by *A. s. floridanus* and *A. s. pratensis* is characterized by a larger percentage of shrub and bare ground, a smaller percentage of tall vegetation, and less litter (Delany *et al*. 1985). Because the sparrows are ground-dwelling birds, they usually require at least 20 percent bare ground for unrestricted movement and foraging, but need enough vegetation to provide nesting cover (Whitmore 1979, Vickery 1996). Large areas of prairie habitat between 240-1,348 ha are needed to maintain populations of 50 breeding pairs (Delany *et al.*1995).

The range of the Florida grasshopper sparrow occurs within the area with the greatest number of thunderstorm-days in the continental United States (Chen and Gerber 1990), and the high frequency of lightning generated by these storms historically resulted in fire every few years on the dry prairie ecosystem (FNAI and FDNR 1990). As a result of these frequent fires, the density of trees and other tall vegetation is low and the percentage of bare ground higher.

Little is known about the Florida grasshopper sparrow's post-breeding activities and habitat preferences; however, ongoing radio telemetry research should yield valuable information on this aspect of the sparrow's life history and habitat associations.

Florida grasshopper sparrows are also documented to be reproductively successful in pastures that are overgrown or ungrazed (Vickery *et al*., University of Massachusetts, personal communication 1998). As pastures become heavily grazed, however, sparrow populations have been documented to decrease or disappear (Delany and Linda 1994).

Behavior

Reproduction and Demography

A. s. floridanus is the only subspecies of grasshopper sparrow that breeds in the State of Florida (Stevenson and Anderson 1994). This subspecies usually nests between early April and late June and may produce two broods in a single season (Stevenson and Anderson 1994, Nicholson 1936). Bimodal breeding seasons for *A. s. floridanus* occurred at the Ordway-Whittell Kissimmee Prairie Sanctuary after summer fires set early in the breeding season (late May to late June); the first peak in nesting ranged from March to late June, with the second peak between July and September (Vickery and Shriver 1995, 1996). Bimodal breeding seasons have also occurred at Three Lakes WMA in every year there was an adequate summer burn (Shriver 1996, Vickery *et al*., University of Massachussets, personal communication 1998).

Little information is available on the courtship activities of this secretive bird. Nicholson wrote that "the male Florida grasshopper sparrow has a fluttering mating flight similar to that of the seaside sparrow except that it is low, 3 to 5 feet above the ground for 50 to 100 feet; upon alighting on a twig or saw palmetto it bursts into song." Female grasshopper sparrows "may answer the song with a trill of her own. Then the male responds by singing the sustained song or by flying to her. Even at times, the male pursues the female and sings the sustained song as he gives chase" (Smith 1968).

Florida grasshopper sparrows begin nest-building activities approximately 4 weeks after the onset of territorial singing (Vickery 1996). Nests are located on the ground in shallow (<3.2 cm) excavations in the sand substrate (Delany and Linda 1998a, 1998b). The nest rims are level or slightly above the ground. The nests are dome-shaped, and constructed of narrow-leaved grasses and grass-like monocots, such as wiregrass (*Aristida beyrichina)*, bluestems (*Andropogon* sp.), and yellow-eyed grass (*Xyris* spp.). Delany and Linda (1998a) describe the nest characteristics. The nest outer diameter averages 10.3 cm, the inside diameter averages 6.9 cm, and the height averages 7.7 cm. The mean orifice width is 5.1 cm. These authors also found that nest opening directions are randomly oriented. Nests are typically shielded by dwarf shrubs, (*i.e.* saw palmetto (*Serenoa repens*) and dwarf live oak (*Quercus minima*), rather than grass clumps as reported for other subspecies.

As stated previously, the Florida grasshopper sparrow has been documented to be reproductively successful in pastures that are overgrown and ungrazed (Vickery *et al*., University of Massachusetts, personal communication, 1998). Once a pasture becomes heavily grazed, sparrow populations greatly decrease or disappear (Delany and Linda 1994). Low stocking rates and short duration grazing may be compatible with sparrow nesting requirements; however measures of reproductive success are needed to assess habitat quality (Delany and Linda 1998b).

Female grasshopper sparrows have been observed to leave their nests by running a distance away from the nest and then taking flight (Smith 1963). When the female returns, she does not directly approach the nest, but lands away from the nest and runs along paths back to it (Smith 1963).

Egg-laying may begin as early as late March and breeding activities may extend into September (McNair 1986, Vickery and Shriver 1995). Most nests contain three to five eggs with a mean of 3.71 (Delany 1996a, McNair 1986, Smith 1968). Perkins *et al.* (1998) found mean clutch sizes of 3.29 (n=7) at Avon Park AFR and 3.00 (n=2) at Three Lakes WMA. The eggs are white, smooth, slightly glossy, and lightly speckled and spotted with reddish-brown markings, and measure 1.8 to 1.4 cm (Sprunt 1954). These markings are generally sharp and well-defined, either scattered over the entire egg or concentrated toward the large end. The eggs of grasshopper sparrows are more delicate than those of savannah sparrows (*Passerculus sandwichensis*) or song sparrows *(Melospiza melodia*) (Smith 1968).

Female grasshopper sparrows incubate their eggs for 11 to 12 days (Nicholson 1936). Perkins *et al.*(1998) reported it takes an average of 13.5 days between the fledging of a successful nest and the first egg of a new attempt. T. Dean (University of Massachusetts, personal communication 1997a) found that if a nest is destroyed, the female may make a new one within 10 to 12 days. The chicks are altricial and are brooded by the female for 6 to 8 days (Delany 1996a), up to 9 days (Vickery 1996, Perkins *et al*. 1998). When young hatch, both male and female become more defensive to human and other intrusions (Smith 1963). In Florida, fledglings are known to aggregate in loose flocks with no parental care 3 to 4 weeks post fledging (Vickery 1996). Nonparental attendants have been reported for *A. s. pratensis* (Kaspari and O'Leary 1988); but complete information on their function or the extent of cooperative breeding is not available.

Results of a 3 year banding study indicate an annual survival rate of 0.598 and mean life expectancy of 1.95 years for male birds equal to or greater than 1 year old (n= 48) (Delany *et al.* 1993). There is no information on the survival and life expectancy of females and juvenile birds. Unfortunately this species has low nesting success rates. Perkins *et al*. (1998) found that the overall success rate for the 1996 breeding season was 0.11 at Avon Park AFR and 0.33 at Three Lakes WMA. Annual productivity ranged between 1.38 and 1.73 at Avon Park AFR and between 4.34 and 5.43 at Three Lakes WMA (Perkins *et al.* 1998). The major factor in this low success rate is loss of eggs or nestling from predation, primarily attributable to snakes and mammals (Vickery 1996; Perkins *et al*. 1998).

Territoriality

Average territory sizes are larger for *A. s. floridanus* than those of *A. s. pratensis*, and are well-defined (Kendeigh 1941, Smith 1963, Wiens 1973, Whitmore 1979). Mean territory size for Florida grasshopper sparrows on Avon Park AFR is 1.8 ha with a maximum home range size of 4.82 ha (Delany *et al.* 1995). The territory size of unmated and mated males is not significantly different. As the interval between fire events increases, sparrow home ranges become larger (Delany *et al*. 1992).

Males vigorously defend the boundaries of their territories from the time territories are established through incubation (Delany *et al*. 1995). After the young hatch, territory defense is less rigorous (Smith 1968).

Foraging

Florida grasshopper sparrows forage on the ground or just above it. An examination of the contents of 10 stomachs of Florida grasshopper sparrows from the Kissimmee Prairie found 69 percent "animal matter" (insects and spiders) and 31 percent vegetation (Howell 1932). Insects identified included grasshoppers, crickets, beetles, weevils, moths and their larvae, with a few flies and bugs. Sedge seeds, as well as some star grass (*Hypoxis* spp.) seeds composed most of the vegetation found in the diet (FWS 1988). Grasshopper sparrows may switch to a seed-dominated diet during the non-nesting season (T. Dean, University of Massachusetts, personal communication 1997b).

Movements

Although the Florida grasshopper sparrow is non-migratory, little is known about its localized movements. Movements among populations have not been documented, and the degree of connectivity between them is unknown. Male grasshopper sparrows have been recaptured outside of the breeding season near their breeding season territories (Delany *et al*. 1995, Delany 1996a). On Avon Park AFR, 21 of the 25 resighted males were located on the same territories in consecutive years. Three observed movements were 183m, 336m, and 570 m (Delany *et al.* 1995). The longest movement observed in that study was a 2.0 km movement by a male from his natal territory to a breeding territory. In a more recent study on post-breeding movements and winter ecology using radio-telemetry, T. Dean, (University of Massachusetts, personal communication 1996b) documented several long distance movements (greater than 3 km), though these movements varied on a individual basis. Vickery *et al*., did not observe any movements between any of the six known sites for this species, with over 300 birds banded between 1995 and 1998. A study by Geisel and colleagues in 1998 examined the genetic variability of Florida grasshopper sparrows from blood tissue sampled from the six known populations. Genetic distances were minimal, suggesting that these populations are closely related and either have not been separated for long or are connected by gene flow (M. Delaney, GFC, personal communication 1998).

Relationship to Other Species

Many other sparrow and non-sparrow species are present in dry prairies in the winter, including Bachman's sparrows, Henslow's sparrows, and savannah sparrows (*Passerculus sandwichensis*). However, no information is available on habitat partitioning or competition between these species and the Florida grasshopper sparrow, although grasshopper sparrows in other areas have been displaced from singing posts by meadowlarks (*Sturnella magna*) and bobolinks (*Dolichonyx orizivorus*) (Dean and Vickery 1996, Vickery 1996).

Predator interactions are important to most passerine species, and the Florida grasshopper sparrow is no exception. Although predators of Florida grasshopper sparrows have not been studied in detail, they have been observed for other subspecies. Predators known to take eggs or nestlings include the striped skunk (*Mephitis mephitis*), spotted skunk (*Spilogale putorius*), raccoon (*Procyon lotor*), longtailed weasel (*Mustela frenata*), foxes, cats (*Felis* spp.), feral hogs (*Sus scrofa*), snakes, and possibly armadillos (*Dasypus novemcinctus*) (Vickery 1996). Predators of adult birds include various hawk species as well as loggerhead shrikes (*Lanius ludovicianus*). Since grasshopper sparrows spend the majority of their time on the ground, adults and young birds are, most likely, captured on the ground (Vickery 1996). Studies on Avon Park AFR and Three Lakes WMA have recorded several predation events for radio-instrumented adult grasshopper sparrows. Although not identified to species level, the predators have been identified as mammals, snakes, and birds (Perkins *et al.* 1998, T. Dean, University of Massachusetts, personal communication 1996c, 1997c). As with many other federally-listed endangered species in Florida, the relationship between the Florida grasshopper sparrow and man has been significant. Changes in land use will continue to be a significant factor in the survival and recovery of this species. Conversion of native prairies to row crops and citrus, removal of the subshrub components of the communities, replacement of native bunch grasses with exotic sod-forming grasses, and suppression of a natural fire regime have made much of the historically available habitat unsuitable for *A. s. floridanus*.

Status and Trends

Early records on Florida grasshopper sparrow abundance and distribution are scarce; however, it is believed that the sparrow was more numerous and widespread than it is today (Delany 1996b). Howell's (1932) observations of *A. s. floridanus* suggest that sparrow population numbers were greater during the early 1930s. Colony size at that time appears to have ranged between 3 to 19 pairs although precise survey data for the early 20th century are not available (Howell 1932, Smith 1968, McNair 1986). Apparently, sparrow numbers were never constant or predictable. Nicholson (1936) noted that "grasshopper sparrows do not occupy all apparently suitable habitats, and the species fluctuates considerably in abundance from year to year."

Between 1927 and 1945, many sightings of grasshopper sparrows were recorded for Kenansville in Osceola County, Basinger and a location south of Fort Drum in Okeechobee County, and a site south of Lake Hicpochee and an area southeast of Immokalee in Hendry County. There appears to be a gap in Florida grasshopper sparrow records between 1945 and the early 1960s. Records for the 1960s include a site north of Okeechobee in Okeechobee County, and a site south of Brighton in Glades County. In the early 1970s, records note a site west of Lake Okeechobee with no county specified and a site southwest of Kenansville (FWS 1988).

Before the GFC began conducting surveys for the Florida grasshopper sparrow in the 1980s, the historic sightings identified above gave little insight to the degree of abundance of the species (Delany and Cox 1985, Stevenson and Anderson 1994). The GFC surveys of the early and mid-1980s focused on historically occupied as well as potential breeding sites. The surveys located 182 individuals on nine sites in Glades, Highlands, Okeechobee, Osceola, and Polk counties (Delany *et al*. 1985, Delany and Cox 1985). Cattle grazing on improved pastures (one animal per eight ha) occurred on almost all grasshopper sparrow sites (Delany and Cox 1985). Abandonment on some pasture sites is probably a response to changes in land management toward improved pastures (Delany and Linda 1994).

The results of GFC's surveys led to the Federal listing of the sparrow as endangered on July 31, 1986. The reason for listing was identified as population decline resulting from habitat degradation and loss from pasture improvement (51 FR 27495).

Singing male surveys performed between 1989 and 1993 resulted in a minimum population estimate of 424 adults at seven breeding sites (Delany 1996b). Sparrows were found at three former locations, but were not located at six locations from the previous survey (Delany and Linda 1994). All six abandoned sites were pasture that had been improved for cattle grazing or sod production. The three occupied sites, some of which had been managed to support cattle grazing, had been burned at 2 to 3 year intervals; the fires may have preserved the suitability of these habitats.

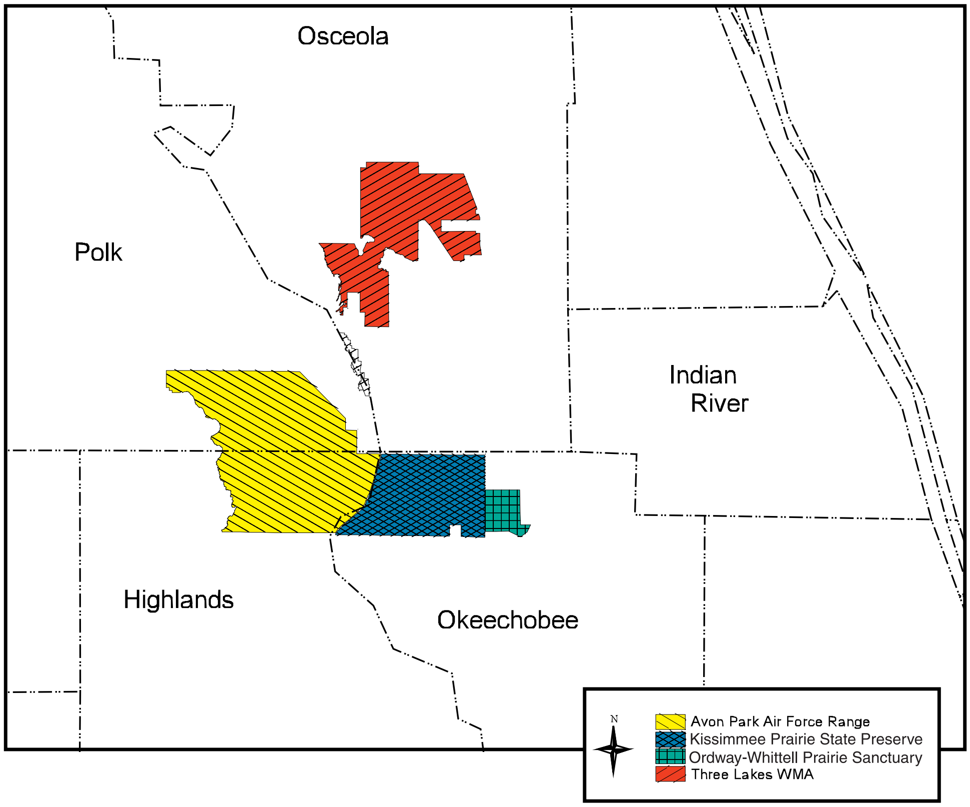
The most recent estimates of Florida grasshopper sparrow numbers indicate that there are fewer than 800 individuals as of the 1997 breeding season; approximately 200 at Avon Park AFR, 150 to 200 at Three Lakes WMA, and at least 200 on Kissimmee Prairie State Preserve (Vickery *et al.* University of Massachusetts, personal communication, 1998).

The Florida grasshopper sparrow is currently protected on four large tracts of land; three are publicly owned, and one is privately owned. Much of the additional suitable habitat for this subspecies is found on a few large, private ranches. The protected sites include: Avon Park AFR (Highlands and Polk counties), Three Lakes WMA (Osceola County), Kissimmee Prairie State Preserve (Okeechobee County), and the National Audubon Society's Ordway-Whittell Kissimmee Prairie Sanctuary (Figure 2). These four sites contain the largest and best-known subpopulations of this bird.

As a general matter, endemic habitat specialists with restricted, limited ranges are sensitive to many environmental factors, including hydrological changes and degradation or loss of habitat. The Florida grasshopper sparrow is one of these habitat specialists, and is threatened by many of these environmental factors. Changes in hydrological management regimes that render nesting areas too wet during the nesting season may affect this species' ability to reproduce. Overgrazing may eliminate plant species necessary for foraging and reproduction as well as limit the amount of available cover to conceal nests. Inappropriate fire management practices can lead to overgrown breeding areas or sites with woody plant invasion.

The greatest threat to the Florida grasshopper sparrow is habitat loss and degradation associated with the conversion of prairies to improved pasture and agriculture (Delany and Cox 1985, Delany and Linda 1994). An examination of Florida wildlife habitat trends from 1936 to 1987 documented this loss. In 1936, 17 percent of the land area in Florida was identified as agricultural and rangelands (nearly 2.5 million ha); by 1987 agriculture and rangelands had grown to represent 30 percent of the land area in Florida (over 4 million ha). Rangeland alone accounted for 2.57 million ha (63 percent) of the identified agricultural land in 1987 (Kautz 1993). Shriver (1996) provides a detailed account of remaining Florida grasshopper sparrow habitat.

Figure 2. Protected sites for Florida grasshopper sparrows.



Some alterations in the vegetative structure and composition within occupied habitat may be tolerated by this species, particularly when the management allows native vegetation to persist (Delany and Cox 1985). However, when agricultural management becomes intensive, the sparrow's ability to survive and reproduce is compromised as a result of the loss of plant species necessary for successful foraging and nesting (Nicholson 1936, Delany *et al.* 1985, Delany 1996b).

In addition, overgrazing may destroy suitable habitat. Grazing at levels at or below one animal per eight ha has not been documented as detrimental to the grasshopper sparrow (Delany and Cox 1985, Delany 1996b), but more research is needed on the potential effects of grazing on sparrow fitness. If fire management programs mimic natural fire frequencies, grazing is not necessary to maintain vegetation in a suitable state for grasshopper sparrow use.

Unfavorable hydrological conditions may also threaten this species. Too much water in prairie areas may prevent nesting and, if improper hydrological conditions continue for extended periods, alter the vegetative composition of the site. During several breeding seasons in the early to mid-1990s, the Ordway-Whittell Kissimmee Prairie Sanctuary and Three Lakes WMA were too wet throughout the nesting season to allow successful reproduction. Improper hydrological management on adjacent properties was identified as the cause of the inundation. The high water levels not only resulted in reproductive failure, but also may have resulted in a severe population decline from a range of 11 to 16 territories in 1993 to 1996, to 7 in 1997, to 2 in 1998.

At least one nest has been documented to have failed due to flood in 1997 at Avon Park AFR (Vickery *et al*. University of Massachusetts, personal communication 1998). In addition to the detrimental effects of long-term inundation on reproductive efforts and vegetative composition, seasonal flooding during the breeding season may be another source of nest failure (Vickery 1996).

Other threats to grasshopper sparrows include predation on nests, young, and adults, and possibly nest parasitism by the brown-headed cowbird (*Molothrus ater*). This species parasitizes grasshopper sparrow nests where the two species are sympatric, though parasitism rates are relatively low (Smith 1968). Although the brown-headed cowbird does not breed within the Florida grasshopper sparrow's range, the shiny cowbird (*M. bonariensis*) has colonized this area since 1990 (Vickery 1996). The extent to which this nest parasite will threaten the Florida grasshopper sparrow has not been determined.

Management

Frequent fire is necessary to maintain an open vegetative community and to prohibit the invasion of pines and hardwoods into dry prairie habitat. Florida grasshopper sparrow densities decline two or more years following a burn event (Delany and Cox 1986, Vickery and Shriver 1995). Prior to European settlement, dry prairies were maintained by lightning-induced fires. These fires occurred primarily during the summer growing season between June and August. Since European settlement, however, the primary fire regime in dry prairies has been human-induced winter fires used by ranchers to improve pasture lands (Vickery and Shriver 1995).

All the protected sites have had similar land use in the past 20 years. Avon Park AFR, Ordway-Whittell Kissimmee Prairie Sanctuary, and Three Lakes WMA have been used for cattle grazing and managed using frequent prescribed winter burns (Vickery and Shriver 1993). The Kissimmee Prairie State Preserve has undergone similar management practices as those employed at the other three sites. Of the four sites, only Avon Park AFR and the Kissimmee Prairie State Preserve continue to have cattle grazing. Avon Park AFR, Kissimmee Prairie Sanctuary, Kissimmee Prairie State Preserve, and Three Lakes WMA have been incorporating summer burns into their grasshopper sparrow management program. Summer burns, as opposed to winter burns, may benefit the sparrow by increasing the length of the breeding season, (Vickery and Shriver 1995) and increasing sparrow breeding densities and possibly reproductive success (Shriver *et al.* 1996). There are also vegetative changes associated with summer fires versus winter fires. The major change is that wiregrass only flowers in the summer after a summer fire, which in turn may allow greater winter forage (Vickery *et al*., University of Massachusetts, personal communication 1998).

At Ordway-Whittell Kissimmee Prairie Sanctuary, experiments with summer burns (late June to early July) on a 3 year cycle are being conducted. There are plans to continue burning on this schedule for 3 more years. Increases in the breeding season length and sparrow breeding densities were observed when summer burns were employed. Sparrows re-established territories within one week of a summer burn at these sites and they continued breeding activities into September (Shriver *et al.* 1996). In unburned areas, however, breeding activity stopped by late July. It is unknown, at this time, whether reproductive success differs between summer-burned and winter-burned areas.

The 42,943 ha Avon Park AFR contains approximately 3,035 ha of suitable Florida grasshopper sparrow habitat distributed in two main areas. Management in the past and present has focused on accommodating low density grazing leases. Staff at Avon Park AFR are currently investigating different management strategies designed to benefit grasshopper sparrows. The first summer burn of the area was completed in 1996 and additional summer burns are planned. Research at the AFR has been directed towards testing summer burns, investigating the sparrow's winter ecology through radio telemetry, and analyzing the genetic structure of this isolated subspecies.

Three Lakes WMA encompasses 24,282 ha, 2,347 ha of which are suitable for the Florida grasshopper sparrow. Another 1,600 ha may be suitable for grasshopper sparrows, but is not currently occupied. Historically, small units were burned in the winter. Since the early 1990s, larger units have been burned in the fall and winter. Summer burns were initiated in 1995; area managers are developing a fire management regime that will call for prescribed fire on a 2 to 3 year rotation (T. Dean, University of Massachusetts, personal communication 1997a).

The Kissimmee Prairie State Preserve is an important parcel of Florida grasshopper sparrow habitat in that it is the largest block of dry prairie (~9,289 ha) in public ownership, and it provides a corridor between other protected sites. Initial surveys indicate that there are at least 100 territories based on 136 point counts (Vickery *et al*., University of Massachusetts, personal communication 1998). These point counts only occupy one-half to two-thirds of the available prairie there, so it is likely there are approximately 200 territories at this site alone, but more work is needed to determine population size at this time. The site has been, and will continue to be, managed for grazing until DEP develops a fire management plan.

In addition to fire, roller chopping may be used to alter the vegetative composition and structure within prairie habitats. Rollerchopping in winter may initially produce the fastest reduction of shrub cover and increased herbaceous growth (Fitzgerald *et al.* 1995). However, the remaining biomass is greater after rollerchopping than after a burn. It is important to note that rollerchopping cannot fully replace the function of fire since wiregrass is dependant on summer fires to complete its reproductive cycle. Allowing wiregrass to bloom results in greater seed production, which may increase winter forage for the Florida grasshopper sparrow. In addition, rollerchopping disturbs the soil which enhances conditions for exotic invasion.

Hydrological management is also important to maintain productive Florida grasshopper sparrow habitat. The Florida grasshopper sparrow cannot successfully nest if water levels are too high. Two of the three protected grasshopper sparrow sites have hydrological issues that have precluded or reduced reproductive efforts and success. Water levels at Ordway-Whittell

Kissimmee Prairie Sanctuary and Three Lakes WMA have been too high since 1995. These hydrological management problems have resulted in flooded nesting areas during the breeding season; as a result, there was essentially no reproduction at Ordway-Whittell Kissimmee Prairie Sanctuary during the 1995, 1996 and 1997 breeding seasons. A hydrological study has been initiated to determine the management regime necessary to restore natural hydrology to this area. Hydrological restoration should alleviate one of the threats to the grasshopper sparrow at this site.

Similar hydrological problems are present at Three Lakes WMA. To address these issues, the COE has developed a settlement agreement with the adjacent landowners. This settlement agreement is a first attempt to ensure that grasshopper sparrow breeding areas are dry enough to allow successful reproduction in the nesting season. Should the first actions taken to alleviate the high-water problem prove inadequate, the COE will look at other mechanisms to rectify the situation.

Although the protected sites discussed above are attempting to optimize management of the prairies under their control, much native prairie habitat still remains on private lands. The cooperation of private landowners in maintaining these native vegetative communities will be an important component in the recovery of this subspecies. Private landowners have an opportunity to improve their pasture land management, while also benefitting the sparrow. Opportunities exist through exotic plant removal, more natural burn regimes, and the maintenance of native plant species necessary for nesting. The development of an incentives program for ranchers who use land management practices that maintain a portion of their properties in functional grasshopper sparrow habitat would constitute an additional recovery opportunity, and should be initiated.

The use of grazing to enhance prairie habitat needs more investigation, particularly where there may be plans to initiate a landowner incentive program for cattle grazing on native range. It is evident from the literature that sparrow populations greatly decrease or disappear when a pasture is heavily grazed (Delany and Linda 1994). Likewise, successful grasshopper sparrow reproduction has been documented in pastures that are overgrown and ungrazed, as in pasture habitat at Kissimmee Prairie State Preserve (Vickery *et al*. 1998).

In order to effect recovery, habitat suitable for grasshopper sparrows on private land should be delineated and prioritized for acquisition or easement. The most appropriate fire and hydrological regimes need to be developed and implemented on public lands with suitable grasshopper sparrow habitat, and incentives for private landowners to restore or maintain prairie habitat need to be developed. A combination of land acquisition, private landowner incentives, and restoration appears to be the means available and necessary for Florida grasshopper sparrow recovery.

Literature Cited

Abrahamson, W.G., and D.C. Hartnett. 1990. Pine flatwoods and dry prairies. Pages 103-129 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

American Ornithologists' Union [AOU]. 1910. Checklist of North American birds. Third edition. American Ornithologists' Union; New York, New York.

American Ornithologists' Union [AOU]. 1931. Checklist of North American birds. Fourth edition. American Ornithologists' Union; Lancaster, Pennsylvania.

American Ornithologists' Union [AOU]. 1957. Checklist of North American birds. Fifth edition. American Ornithologists' Union; Baltimore, Maryland.

American Ornithologists' Union [AOU]. 1983. Checklist of North American birds. Sixth edition. American Ornithologists' Union; Washington, D.C.

Bass, O.L. 1995. Telephone communication. September 1995.

Chen, E., and J.F. Gerber. 1990. Climate. Pages 11-35 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

Dean, T. 1996a. Letter. June 17, 1996. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Dean, T. 1996c. Letter. November 10, 1996. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Dean, T. 1997a. Comments on draft species account. January 1997.

Dean, T. 1997b. Comments on draft species account. March 1997.

Dean, T. 1997c. Letter. March 16, 1997. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Dean, T.F., and P.D. Vickery. 1996. Florida grasshopper sparrow winter ecology project, May 1995 - January 1996. Unpublished annual report prepared for the U.S. Fish and Wildlife Service; Vero Beach, Florida.

Delany, M. F. 1996a. Letter. April 16, 1996. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Delany, M. F. 1996b. Florida Grasshopper Sparrow. Pages 128-136 *in* J. A. Rodgers, Jr., H. W. Kale II, and H.T. Smith, eds. Rare and endangered biota of Florida, volume v. Birds. University Press of Florida; Gainesville, Florida.

Delany, M.F. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. October, 1998.

Delany, M.F., and J.A. Cox. 1985. Florida grasshopper sparrow status survey. Unpublished report prepared for the U.S. Fish and Wildlife Service; Jacksonville, Florida.

Delany, M.F., and J.A. Cox. 1986. Florida grasshopper sparrow breeding distribution and abundance in 1984. Florida Field Naturalist 14(4):100-104.

Delany, M.F., and S.B. Linda. 1994. Characteristics of occupied and abandoned Florida grasshopper sparrow territories. Florida Field Naturalist 22(4):106-109.

Delany, M.F., and S.B. Linda.1998a. Characteristics of Florida grasshopper sparrow nests. Wilson Bulletin 110:136-139.

Delany, M.F., and S.B. Linda.1998b. Nesting habitat of Florida grasshopper sparrows at Avon Park Air Force Range Florida Field Naturalist 26:33-39.

Delany, M.F., C.T. Moore, and J.M. Hamblen. 1992. Florida grasshopper sparrow management needs. Final report to Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Delany, M.F., C.T. Moore, and D.R. Progulske, Jr. 1993. Survival and longevity of adult male grasshopper sparrows. Proceedings of the annual conference of the Southeast Association Fish and Wildlife Agencies 47:366-369.

Delany, M.F., C.T. Moore, and D.R. Progulske, Jr. 1994. Distinguishing gender of Florida grasshopper sparrows using body measurements. Florida Field Naturalist 22(2):48-51.

Delany, M.F., C.T. Moore, and D.R. Progulske, Jr. 1995. Territory size and movements of Florida grasshopper sparrows. Journal of Field Ornithology 66(2):305-309.

Delany, M.F., H.M. Stevenson, and R. McCracken. 1985. Distribution, abundance, and habitat of the Florida grasshopper sparrow. Journal of Wildlife Management 49(3):626-631.

Fitzgerald, S.M., J.M. Wood, and G.W. Tanner. 1995. Small mammal and plant responses to the rehabilitation of a dry prairie grassland association using fire and roller chopping applied in two seasons. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Florida Natural Areas Inventory [FNAI] and Florida Department of Natural Resources [DNR]. 1990. Guide to the natural communities of Florida; Tallahassee, Florida.

Howell, A.H. 1932. Florida bird life. Coward-McCann; New York, New York.

Kaspari, M., and H. O'Leary. 1988. Nonparental attendant in a north temperate migrant. Auk 105:792-793.

Kautz, R. S. 1993. Trends in Florida wildlife habitat 1936-1987. Florida Scientist 56(1):7-24.

Kendeigh, S.C. 1941. Birds of a prairie community. Condor 43(4):165-174.

McNair, D.B. 1986. Clutch information for the Florida grasshopper sparrow from zoological collections. Florida Field Naturalist 14(2):48-49.

Mearns, E.A. 1902. Description of three new birds from the southern United States. Proceedings of the U.S. National Museum 24: 915-926.

Nicholson, W.H. 1936. Notes on the habits of the Florida grasshopper sparrow. Auk 53:318-319.

Paynter, R.A., Jr. and R.W. Storer. 1970. Checklist of birds of the world. Volume XIII. Museum of Comparative Zoology; Cambridge, Massachusetts.

Perkins, D.W., P.D. Vickery, T.F. Dean, and M.D. Scheuerell. 1998. Nesting records and reproductive rates of Florida grasshopper sparrows (*Ammodramus savannarum floridanus*) Florida Field Naturalist 26(1):7-17.

Robertson, W.B. and G.E. Woolfenden. 1992. Florida bird species. Florida Ornithological Society; Gainesville, Florida.

Shriver, W.G. 1996. Habitat selection of Florida grasshopper and Bachman's sparrows. Masters thesis. University of Massachusetts; Amherst, Massachusetts.

Shriver, W.G., P. D. Vickery, and S. A. Hedges. 1996. Effects of summer burns on Florida grasshopper sparrows. Florida Field Naturalist 24(3):68-73.

Smith, R.L. 1959. The songs of the grasshopper sparrow. Wilson Bulletin 71(2):141-152.

Smith, R.L. 1963. Some ecological notes on the grasshopper sparrow. Wilson Bulletin 75(2):159-165.

Smith, R.L. 1968. Grasshopper sparrow. Pages 725-745 *in* A.C. Bent, ed. Life histories of North American cardinals, grosbeaks, buntings, towhees, finches, sparrows, and allies. Part two. U.S. National Museum Bulletin 237. Smithsonian Institution Press; Washington, D.C.

Sprunt, A., Jr. 1954. Florida bird life. Coward-McCann, Inc; New York, New York.

Stevenson, H.M. 1978. Endangered Florida grasshopper sparrow. Pages 15-16 *in* H.W. Kale, ed.. Rare and endangered biota of Florida. Volume two: Birds. University of Florida Press; Gainesville, Florida.

Stevenson, H.M., and B.H. Anderson. 1994. The birdlife of Florida. University Press of Florida; Gainesville, Florida.

U.S. Fish and Wildlife Service [FWS]. 1988. Recovery plan for the Florida grasshopper sparrow. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Vickery, P.D. 1996. Grasshopper sparrow (*Ammodramus savannarum*). *In* Birds of north america, no. 239, A. Poole and F. Gill. II, eds. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union; Washington, D.C.

Vickery, P.D., M.L. Hunter Jr., and J.V. Wells. 1992. Evidence of incidental nest predation and its effects on nests of threatened grassland birds. Oikos 63(2):281-288.

Vickery, P.D., and W.G. Shriver. 1993. Report on the fire history of Florida grasshopper sparrow study sites. Unpublished report prepared for The Nature Conservancy; Lake Wales, Florida.

Vickery, P.D., and W.G. Shriver. 1995. Reproductive success and habitat use of the Florida grasshopper sparrow (*Ammodramus savannarum floridanus*). Unpublished report submitted to U.S. Fish and Wildlife Service; Vero Beach, Florida.

Vickery, P.D., and W.G. Shriver. 1996. Habitat selection of the Florida grasshopper sparrow. Final report to the U.S. Fish and Wildlife Service; Jacksonville, Florida.

Vickery, P.D., G. Shriver, and D. Perkins 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 28, 1998.

Wetmore, A., R. F. Pasquier and S. C. Olson. 1984. The birds of the Republic of Panama, part 4. Smithsonian Institution Press; Washington D.C.

Whitmore, R.C. 1979. Short-term changes in vegetation structure and its effects on grasshopper sparrows in West Virginia. Auk 96:621-625.

Wiens, J.A. 1973. Interterritorial habitat variation in grasshopper and savannah sparrows. Ecology 54(4):877-884.

Recovery for the Florida Grasshopper Sparrow

Ammodramus savannarum floridanus

Recovery Objective: **RECLASSIFY** to threatened.

Recovery Criteria

This objective will be achieved when any further loss, fragmentation, and degradation of habitat within the Kissimmee River basin has been prevented; when at least 10 protected and managed sites contain stable, self-sustaining populations of 50 to 100 breeding pairs of Florida grasshopper sparrows within the historic range of the species; and when Florida grasshopper sparrows on each of these sites exhibit a rate of increase (r) equal-to or greater than 0.0, sustained as a 2-year running average over at least 6 years.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. It may be possible to reclassify the Florida grasshopper sparrow if there is sufficient, restorable habitat that can be recolonized by additional populations; however, the feasibility of such restoration and recolonization is still uncertain. This recovery objective will be reassessed annually based on new research, management, and monitoring information. These criteria will be refined if new information identifies new ways of re-establishing populations of this species or expanding its current range.

Species-level Recovery Actions

S1. Determine the distribution and abundance of the Florida grasshopper sparrow. Additional surveys should be undertaken to more accurately determine current distribution and abundance of the Florida grasshopper sparrow. The locations of remaining dry prairie habitat at Avon Park AFR, Three Lakes WMA, and the Ordway-Whittell Kissimmee Prairie Sanctuary are provided in Shriver (1996). In addition to these maps, LANDSAT data could be used to locate potential habitat on private lands which may contain grasshopper sparrows.

S2. Protect and enhance existing populations of Florida grasshopper sparrows.

S2.1. Encourage natural colonization of restored habitats by Florida grasshopper sparrows. Many areas within the historic range of the Florida grasshopper sparrow are being restored as part of the COE and SFWMD Kissimmee River restoration. Other areas are being restored because of a change in land use in the Kissimmee River valley (such as the expansion of the Three Lakes WMA). There are also efforts underway to connect the Ordway-Whittell Kissimmee Prairie Sanctuary with Kissimmee Prairie SP. Dispersal of the Florida grasshopper sparrow into restored areas from occupied sites should be encouraged by establishing corridors. Corridors may be established by selectively removing pines or other tree species and applying prescribed fire, The removal of pine plantations at Avon Park AFR should be completed to increase prairie size and connectivity between the disjunct populations there.

S2.2. Develop and implement a plan to re-introduce Florida grasshopper sparrows into suitable habitats in the Kissimmee River Valley. Many areas once supported grasshopper sparrows in the past, but are not currently occupied. Some of these areas still have suitable habitat for the sparrows, while others will need restoration. The survival and recovery of the Florida grasshopper sparrow will depend on re-establishing Florida grasshopper sparrow populations in these areas. The second recovery priority is establishing a specific plan to re-introduce and re-establish Florida grasshopper sparrows into areas that currently support suitable habitat. This plan must identify the specific areas that are suitable for such re-introductions, protocols for determining when habitat is suitable for a reintroduction, the size of a reintroduced population, monitoring protocols for re-introduced populations, and land management prescriptions for re-introduction areas.

S2.3. Develop a captive propagation plan for the Florida grasshopper sparrow following DOI guidelines, and implement as warranted. An estimated 600 adult Florida grasshopper sparrows (1996 census) exist in the wild. In the event of further declines in the size or distribution of the Florida grasshopper sparrow, a captive population may provide the difference between survival and extinction for this species. The captive propagation plan should identify specific demographic thresholds that would trigger the establishment of captive populations, facilities that could support a captive propagation program, protocols for selecting and capturing individuals for a captive population, reintroduction protocols, and criteria that clearly state when the captive propagation program could be ended.

S3. Conduct research to determine the basic biological needs of The Florida grasshopper sparrow. Although considerable research has been done on the biology and ecology of the Florida grasshopper sparrow, more information is necessary before the Florida grasshopper sparrow can be properly managed and effects of habitat management actions assessed.

S3.1. Develop information on the Florida grasshopper sparrow's basic biology, including genetic and ecological studies. Biological studies should be continued to expand scientific knowledge of the demographics of Florida grasshopper sparrow populations (survivorship, fecundity, mortality, dispersal) and the relationship of these demographic variables to habitat availability and quality under various management regimes. Continue studies to assess effects of grazing on reproductive success.

S3.2 Continue winter ecology studies. The winter ecology and life history needs of the Florida grasshopper sparrow may be a limiting factor to the recovery of the species. Winter ecology investigations should continue in order to determine if management actions need to be revised in order to maximize survival of wintering birds.

S3.3. Develop a reserve design for Florida grasshopper sparrows using landscape maps, GIS, and spatially-explicit population models. Population viability analyses can be determined from existing demographic data, and can be combined with landscape-coverage GIS data to develop spatially-explicit models. Using these tools, the reserve design will identify large, contiguous areas of prairie habitat necessary for the survival and recovery of Florida grasshopper sparrows in South Florida.

S4. Continue efforts to monitor the status and trends of Florida grasshopper sparrow populations.

S4.1. Develop consistent survey/census protocols and assure continuation and consistency of ongoing monitoring protocols. Evaluate existing monitoring techniques to determine which are best able to identify small changes in Florida grasshopper sparrow populations. Surveys for Florida grasshopper sparrows should be consistent on all sites. At a minimum, population surveys should provide a minimum population estimate plus a relative measure of abundance.

S4.2. Monitor Florida grasshopper sparrow populations on public lands to evaluate management actions. Establish monitoring programs for the Florida grasshopper sparrow on the Avon Park AFR, Kissimmee Prairie SP, and Three Lakes WMA to determine if fire management, water management, and other management actions are consistent with the recovery needs of the sparrow.

S4.3. Monitor the success of reintroduced Florida grasshopper sparrow populations. To determine whether recovery efforts are proving successful, it will be necessary to conduct periodic censuses and surveys of all introduced populations.

S5. Increase public awareness of the biology, ecology, status and trends of the Florida grasshopper sparrow. The public must be made more aware of the status and trends of the Florida grasshopper sparrow, its recovery needs, and opportunities for the public to participate in the sparrow's recovery. This public awareness program must include an effort to contact owners of lands that support populations of Florida grasshopper sparrows; it must also include development and distribution of educational materials developed specifically to inform the public about the Florida grasshopper sparrow.

S6. Assess reclassification criteria based on the results of research projects; revise as necessary.

Habitat-level Recovery Actions

H1. Protect and enhance currently occupied habitat. Alteration and habitat loss are primary threats to prairie species. As much of the remaining prairie habitat as possible must be secured. State and COE efforts to restore the Kissimmee River floodplain might provide useful habitat for prairie dependent species. Habitat must be maintained in an early stage of succession through selective thinning and prescribed burning.

H1.1. Protect and enhance Florida grasshopper sparrow habitat on public and private land. Florida grasshopper sparrows currently occur on the Avon Park AFR, Kissimmee Prairie SP, and Three Lakes WMA; additional populations occur on adjacent private lands. These populations are critical to the survival and recovery of the sparrow. These lands are being managed to support populations of the Florida grasshopper sparrow; these management efforts must continue.

H1.1.1. Maintain and enhance habitat on acquired lands or lands under conservation easements or agreements. Conduct prescribed burns, selective thinning, or mechanical manipulation at periodic intervals to maintain dry prairie and pasture habitat and prevent forest encroachment. Intensive rangeland improvements should be discouraged in prairie areas to maintain as many native plant species as possible.

H1.1.2. **Encourage purchase.** State, county, and local governments and private organizations can purchase lands. The FWS can consider purchase of land to protect endangered or threatened species through its Land Acquisition Planning System.

H1.1.3. **Discourage changes in the present level of cattle grazing where conducive to grasshopper sparrows.** On most private lands, cattle grazing is at the level of one animal per ha. This level of grazing does not seem to be detrimental to prairie species, but it should not be increased until further studies have been conducted. Current land management practices appear to, at a minimum, sustain grasshopper sparrows. Provide additional incentives for private landowners to enhance habitat for Florida grasshopper sparrows.

H1.2. **Protect and enhance habitat on public lands.** Prairie habitat present on public lands should be protected and enhanced for prairie dependent species. Sites that are occupied by these prairie species include Avon Park AFR in Polk and Highlands counties, the Florida Game and Fresh Water Fish Commission's Three Lakes WMA in Osceola County, the Kissimmee Prairie SP property in Okeechobee County, and the National Audubon Society's Kissimmee Prairie Sanctuary in Okeechobee County. Federal land management agencies should try to protect, maintain, and enhance prairie habitat on all lands they manage. Since caracara nesting is minimal on Avon Park AFR and this site is essential for the survival of the Florida grasshopper sparrow, grazing should not be increased in this area, and prairie management should focus on the grasshopper sparrow. Other public lands should use the recommendations obtained from habitat component research on the caracara to determine which management actions are compatible with the survival of both species.

H1.2.1. **Continue prescribed burns at periodic intervals.** Occupied areas should be burned in a mosaic fashion on a periodic rotational basis (generally every 1.5 to 3 years) to maintain early stages of succession. The burn interval may vary depending on site, vegetation, fuel loads, hydrology, *etc.* and may extend from 1 to 4 years at certain locations.

H1.2.2. **Maintain pastures in native vegetation to the extent possible.** Prairie species may be adversely affected if pasture lands are improved to the point where native vegetation is removed. Pastures will not be suitable for grasshopper sparrows if they are heavily grazed or managed heavily for grazing.

H1.2.3. **Do not allow reforestation of prairies.** Prairie species prefer areas devoid of trees. Grasshopper sparrows, especially, cannot breed in forested areas. However, scattered live-oak/ cabbage palm hammocks are valuable components of prairie systems. Although these hammocks are not used by grasshopper sparrows, they are compatible with sparrow management and should not be removed.

H1.2.4. **Establish appropriate burn seasonality.** Fire management should be performed in all seasons, although the majority of prescribed burns to benefit grasshopper sparrows should be done during the season of occurrence of most natural lightning fires: from late spring to early summer.

H1.2.5. **Avoid construction of fences or other structures in grasshopper sparrow habitat.** Fencing or other vertical structures may be used as perches by grasshopper sparrow predators and should be avoided in areas important to the sparrow.

H1.2.6. **Avoid land management and maintenance activities during the nesting season.** Management/maintenance activities such as mowing, rollerchopping, fertilizing, and use of heavy equipment that may affect grasshopper sparrows or native flora should be avoided during the nesting season (15 March to 15 September).

H1.3. **Conduct section 7 consultations on all Federal activities that might affect grasshopper sparrows and their habitat.** The Air Force and the Department of the Interior will consult with the FWS on any activities (authorized, funded, or carried out) that might adversely affect prairie species on land they control in Florida. Such activities include: pesticide use, road building, construction of new facilities, training exercises, clearing for new runways, *etc.*

H2. **Create, restore, or expand habitat wherever possible.** Habitat loss has occurred throughout the range of prairie species, and has been the primary factor threatening the survival of these animals.

H2.1. **Continue to identify areas of suitable unoccupied habitat or potential habitat.** Shriver (1996) provides maps of suitable dry prairie habitat on three of the sites where Florida grasshopper sparrows occur. Continue these efforts using LANDSAT imagery and GIS to locate areas of suitable or suboptimal habitat on private lands. Ground-truth these areas to determine suitablity for sparrows, and determine the feasibility of improving the selected sites for sparrow occupation.

H2.2. **Improve selected areas as needed.** Restore available sites to suitable conditions through fire management and removal of woody plants.

H2.3. **Expand habitat in currently occupied areas, and restore habitat in currently unoccupied areas.** Continue the removal of pine plantations at Avon Park AFR to increase prairie size and connectivity between the disjunct populations there. Continue efforts to connect Kissimmee Prairie SP with the Ordway-Whittell Kissimmee Prairie Sanctuary. Wherever possible, enhance prairie habitat in the vicinity of occupied habitat, through prescribed burning, chopping, and woody vegetation removal to enhance areas to attract grasshopper sparrows.

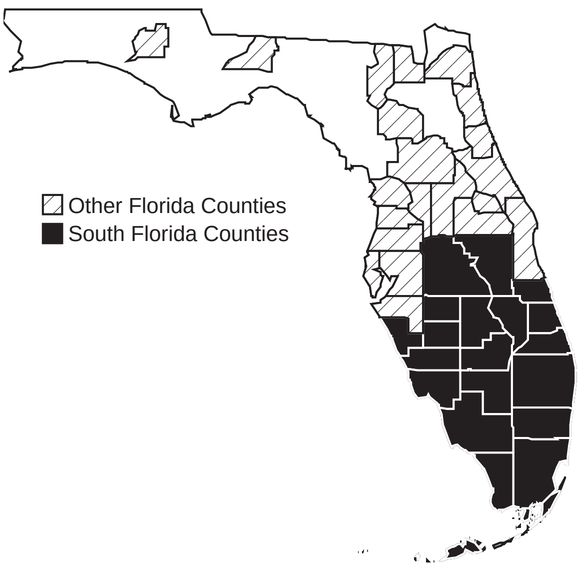
H3. **Continue research on grasshopper sparrow/habitat interactions.** Research should continue to determine how habitat correlates to grasshopper sparrow abundance, and how changes in habitat use relate to fire and plant succession. Information is especially needed on non-breeding ecology and habitat use, as well as on territory shifts as they relate to habitat quality. Information is also needed to determine whether grazing has an effect on sparrow fitness. These studies can be done on any of the protected populations where cattle grazing is occurring on sparrow habitat during any time of the year. Information obtained through these studies will indicate the best management practices for areas important to both breeding and post-breeding survival. This will relate directly to land management activities at occupied sites.

Wood Stork

Mycteria americana

Federal Status:	**Endangered (Feb. 28, 1984)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. Florida distribution of the wood stork.



Wood storks (*Mycteria americana*) are one of two species of storks that breed in North America. This large, long-legged inhabitant of marshes, cypress swamps, and mangrove swamps reaches the northern limit of its breeding range in the southeastern U.S., where it breeds in colonies with great egrets, snowy egrets, white ibises, and many other species. The unique feeding method of the wood stork gives it specialized habitat requirements; the habitats on which wood storks depend have been disrupted by changes in the distribution, timing, and quantity of water flows in South Florida. The population declines that accompanied this disruption led to its listing as an endangered species and continue to threaten the recovery of this species in the U.S.

This account represents South Florida's contribution to the rangewide recovery plan for the wood stork (FWS 1997).

Description

The wood stork is a large, long-legged wading bird, with a body length (head to tail) of 85 to 115 cm and a wingspan of 150 to 165 cm. Their plumage is white, except for iridescent black primary and secondary feathers and a short black tail. On adult wood storks, the rough scaly skin of the head and neck is unfeathered and blackish in color. Their legs are dark with dull pink toes. The bill color is blackish. Male and female wood storks are similar in appearance, although male wood storks tend to be larger, have longer wingspans and weigh more.

Immature storks, up to the age of about 3 years, differ from adults in that their bills are yellowish or straw colored and they exhibit varying amounts of dusky feathering on the head and neck. During courtship and the early nesting season, adults have pale salmon coloring under the wings, fluffy undertail coverts that are longer than the tail, and toes that brighten to a vivid pink.

In the field, wood storks are distinctive among North American wading birds due to their long, heavy bills, black primary and secondary feathers, and black tails. Few other North American wading birds, except sandhill cranes (*Grus canadensis)*, whooping cranes (*Grus canadensis americana*), white ibises (*Eudocimus albus)*, and roseate spoonbills (*Ajaia ajaja)* fly with their necks and legs extended. Wood storks can be distinguished from sandhill cranes by their white plumage; they can be distinguished from whooping cranes by their size (the body of wood storks are 89 to115 cm while whooping cranes are 127 to151 cm), black secondary feathers, and black tail feathers. White ibises and wood storks both have black flight feathers on the wing tips. However, the wood stork is easily distinguished by its black head and its heavy bill. The roseate spoonbill is characteristically pinkish in color and has a spoonbill. At large distances, soaring white pelicans (*Pelecanus erythrorhynchos*) and storks appear similar; both soar in flocks at great heights and have similar color patterns.

Taxonomy

The wood stork is one of 17 species of true storks (Ciconiidae) in the world. The wood stork is one of three stork species found in the western hemisphere and is the only one that breeds north of Mexico (Ogden 1990). The wood stork has no described subspecies, races, or distinctive subpopulations (Palmer 1962).

Distribution

Breeding populations of the wood stork occur from northern Argentina, eastern Peru, and western Ecuador north to Central America, Mexico, Cuba, Hispaniola, and the U.S. (AOU 1983). In the U.S., wood storks historically nested in all coastal states between Texas and South Carolina (Wayne 1910, Bent 1926, Howell 1932, Oberholser 1938, Dusi and Dusi 1968, Cone and Hall

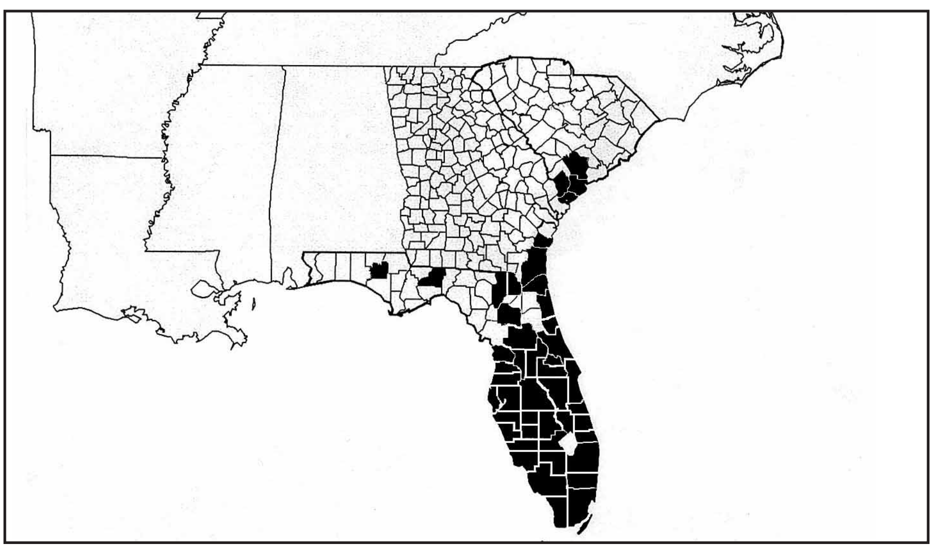


Figure 2. Breeding distribution of the wood stork in the United States (FWS 1996).

Wood stork.
Original photograph by Brian Toland.

1970, Oberholser and Kincaid 1974). Currently, wood storks breed in Florida, Georgia, and coastal South Carolina (Figures 1 and 2). Post breeding storks from Florida, Georgia, and South Carolina disperse occasionally as far north as North Carolina and as far west as Mississippi and Alabama.

In the U.S., the post breeding dispersal of the wood stork is extensive, with annual variation. The wood stork has been reported both as a casual and regular visitor, ranging from southern California and southern Arizona, north to northern California, southern Idaho, Montana, Colorado, Nebraska, southeastern South Dakota, Missouri, Illinois, southern Michigan, and southern Ontario, Canada; from the Gulf of Mexico north to Arkansas and western Tennessee; and along the Atlantic coast to Maine, southern New Brunswick, Canada, and New York, south to its breeding range in Florida, Georgia, and South Carolina. It is suspected that most wood storks sighted in Arkansas, Louisiana, Texas, and points farther west are birds that have dispersed from colonies in Mexico (FWS 1997). Some of the sightings in this region may also be wood storks dispersing from southeastern U.S. breeding colonies, but the amount of overlap or interchange between populations in the southeastern U.S. and Mexico is unknown.

In South Florida, breeding colonies of the wood stork occur in Broward, Charlotte, Collier, Miami-Dade, Hardee, Indian River, Lee, Monroe, Osceola, Palm Beach, Polk, St. Lucie, and Sarasota counties. Wood storks have also nested in Martin County, and at one time or another, in every county in South Florida. It is believed that storks nesting in north Florida, Georgia, and South Carolina move south during the winter months (December through February). Bancroft *et al* (1992) have shown that the number of storks feeding in the three WCA's of the central and northern Everglades varied greatly among winters, ranging from a low of 1,233 birds in a high-water year to 7,874 birds in a low-water year. In most of the study years, 1985 to 1989, the total number of storks in the WCA's increased substantially between December and January, and dropped off sharply after March. In some years, the inland marshes of the Everglades have supported the majority (55 percent) of the U.S. population of wood storks (FWS 1997).

Habitat

The wood stork is primarily associated with freshwater and estuarine habitats for nesting, roosting, and foraging. Wood storks typically construct their nests in medium to tall trees that occur in stands located either in swamps or on islands surrounded by relatively broad expanses of open water (Palmer 1962, Rodgers *et al.* 1996, Ogden 1991). Historically, wood storks in South Florida established breeding colonies primarily in large stands of bald cypress (*Taxodium distichum*) and red mangrove (*Rhizophora mangle*). The large, historic Everglades NP nesting colonies were in estuarine zones. These estuarine zones are also an important feeding habitat for the nesting birds. In one study of wood stork nesting throughout Florida, which was conducted prior to the 1960s, more than half of all wood stork nests were located in large bald cypress stands, 13 percent were located in red mangrove, eight percent in partially harvested bald cypress stands, six percent in dead oaks (*Quercus* spp.), and five percent in small pond cypress (*T. distichum* var. *nutans*) (Palmer 1962). Wood storks have also been observed constructing their nests in custard (pond) apple (*Annona glabra*), black gum (*Nyssa biflora*), buttonwood (*Conocarpus erectus*), black mangrove (*Avicenna germinans*), strangler fig (*Ficus aurea*), and southern willow (*Salix carolina*). Coastal nest sites occur in red mangroves and, occasionally, Brazilian pepper (*Schinus terebinthifolius*), cactus (*Opuntia stricta*), and Australian pine (*Casuarina equisetifolia*).

During the nonbreeding season or while foraging, wood storks occur in a wide variety of wetland habitats. Typical foraging sites for the wood stork include freshwater marshes and stock ponds, shallow, seasonally flooded roadside or agricultural ditches, narrow tidal creeks or shallow tidal pools, managed impoundments, and depressions in cypress heads and swamp sloughs. Because of their specialized feeding behavior, wood storks forage most effectively in shallow-water areas with highly concentrated prey (Ogden *et al.* 1978, Browder 1984, Coulter 1987). In South Florida, low, dry-season water levels are often necessary to concentrate fish to densities suitable for effective foraging by wood storks (Kahl 1964, Kushlan *et al.* 1975). As a result, wood storks will forage in many different shallow wetland depressions where fish become concentrated, either due to local reproduction by fishes, or as a consequence of seasonal drying.

The loss or degradation of wetlands in central and South Florida is one of the principal threats to the wood stork. Nearly half of the Everglades has been drained for agriculture and urban development (Davis and Ogden 1994). The Everglades

Agricultural Area (EAA) alone eliminated 802,900 ha of the original Everglades, and the urban areas in Miami-Dade, Broward and Palm Beach counties have contributed to the loss of spatial extent of wood stork habitat. Everglades NP has preserved only about one-fifth of the original extent of the Everglades, and areas of remaining marsh outside of the Everglades NP have been dissected into impoundments of varying depths.

The U.S. Army Corps of Engineers' (COE) Central and Southern Florida (C&SF) Project encompasses 4,660,000 ha from Orlando to Florida Bay and includes about 1,600 km each of canals and levees, 150 water control structures, and 16 major pump stations. This system has disrupted the volume, timing, and direction of fresh water flowing through the Everglades. The natural sheet flow pattern under which the Everglades evolved since about 5,000 years ago has not existed for about 75 years (Leach *et al*. 1972, Klein *et al.* 1974). The diversion of natural sheet flow to canals, the loss of fresh water to seepage and to pumping to tidal waters, and the extraction of fresh water for irrigation and urban water supply has led to saltwater intrusion in coastal counties from St. Lucie County on the east coast to Sarasota County on the west coast.

Although the major drainage works completed the conversion of wetlands to agriculture in the EAA by about 1963, loss of wetlands continues to the present at a slower, but significant rate. In the entire State of Florida between the mid-1970s to the mid-1980s, 105,000 ha of wetlands (including marine and estuarine offshore habitats) were lost; we do not have an estimate for freshwater wetlands in central and south Florida (Hefner *et al.* 1994).

Behavior

Courtship

Mating occurs after a period of highly ritualized courtship displays at the nest site (Kahl 1972). As a female bird approaches, male birds establish themselves at potential nest sites and perform ritualized preening behavior. Rival males will extend their necks, grab their opponents' bills, and clatter their bills loudly a few times. Females respond by bill gaping and a spread-winged balancing posture. Females will be turned away initially, but after repeated approaches, will respond by swaying their heads, preening, or playing with nearby twigs (Kahl 1972). During copulation, males loudly clatter their bills. Mated pairs greet each other with exaggerated, mutual up-down head movements and hissing calls.

Reproduction

Wood storks tend to use the same colony sites over many years, as long as the sites remain undisturbed and sufficient feeding habitat remains in the surrounding wetlands. Site turnover rates for the colonies in South Carolina are very low at 0.17 colonies per year. Current year colonies have an 89 percent likelihood of remaining active in consecutive years. However, many of these South Carolina colonies are relatively recent.

Traditional wetland nesting sites may be abandoned by storks once local or regional drainage schemes remove surface water from beneath the colony trees. Maintaining adequate water levels to protect nests from predation is a critical factor affecting production of a colony. The lowered water levels allow nest access by raccoons and other land-based predators. As a result of such drainages and predation, many storks have shifted colony sites from natural to managed or impounded wetlands. The percentage of wood storks that nested in either altered wetlands (former natural wetlands with impounded water levels) or artificial wetlands (former upland sites with impounded water) in central and north Florida colonies increased from about 10 percent in 1960 to between 60 and 82 percent between 1976 and 1986.

Wood storks are seasonally monogamous, probably forming a new pair bond every season. Three and 4-year-old birds have been documented to breed, but the average age of first breeding is unknown. Once wood storks reach sexual maturity they are assumed to nest every year; there are no data on whether they breed for the remainder of their life or whether the interval between breeding attempts changes as they age (FWS 1997).

Wood storks construct their nests in trees that are usually standing in water or in trees that are on dry land if the land is a small island surrounded by water. The nest are large rigid structures usually found in the forks of large branches or limbs. Storks may add guano to the nest to stabilize the twigs. (Rodgers *et al*. 1988). The nest may be constructed in branches that are only a meter above the water or in the tops of tall trees. They construct their nests out of sticks, with a lining of finer material. Their nests are flat platforms, up to 1 m in diameter, and are maintained by the adult storks throughout the breeding season. Although both adults maintain the nest, the male wood stork usually brings nest material to the female after they complete their courtship (Palmer 1962).

The date on which wood storks begin nesting varies geographically. In Florida, wood storks lay eggs as early as October and as late as June (Rodgers 1990). In general, earlier nesting occurs in the southern portion of the state (below 27°N). Storks nesting in the Everglades and Big Cypress basins, under pre-drainage conditions (1930s to 1940s), formed colonies between November and January (December in most years) regardless of annual rainfall and water level conditions (Ogden 1994 and 1998). In response to deteriorating habitat conditions in South Florida, wood storks in these two regions have delayed the initiation of nesting, approximately two months, to February or March in most years since the 1970s. This shift in the timing of nesting is believed to be responsible for the increased frequencies of nest failures and colony abandonment in these regions over the last 20 years; colonies that start after January in South Florida risk having young in the nests when May-June rains flood marshes and disperse fish.

Female wood storks lay a single clutch of eggs per breeding season. However, they will lay a second clutch if their nests fail early in the breeding season (M. Coulter 1996). Wood storks lay two to five (usually three) eggs depending on environmental conditions; presumably larger clutch size in some years are responses to favorable water levels and food resources. Once an egg has been laid in a nest, one member of the breeding pair never leaves the nest unguarded. Both parents are responsible for incubation and foraging (Palmer 1962). Incubation takes approximately 28 days, and begins after the first one or two eggs are laid; therefore egg-hatching is asynchronous.

Younger, smaller chicks are often the first to die during times of food stress (FWS 1997). It takes about 9 weeks for the young to fledge; once they fledge, the young stay at the nest for an additional 3 to 4 weeks to be fed by their parents. Parents feed the young nestlings by regurgitating whole fish into the bottom of the nest; parents feed the young three to 10 or more times per day. Larger nestlings are fed directly bill to bill. Feedings tend to be more frequent when young are small. Ogden *et al.* (1978) reported that only one to two feedings per day, per nest, have been recorded in South Florida colonies when adults were forced to fly great distances to locate prey. Kahl (1964) calculated that an average wood stork family (two adults and two nestlings) requires 201 kg (443 lbs) of fish during a breeding season, and that a colony of 6,000 nests therefore requires 1,206,000 kg of fish during the breeding season. A similar calculation for a typical Everglades NP or Corkscrew Swamp colony with 200 nests would require 40, 200 kg (88,600 lbs) of fish during the breeding season.

The production of wood stork colonies varies considerably between years and locations, apparently in response to differences in food availability; colonies that are limited by food resources may fledge an average of 0.5 to 1.0 young per active nest; colonies that are not limited by food resources may fledge between 2.0 and 3.0 young per active nest (Ogden 1996a).

Foraging

Wood storks use a specialized feeding behavior called tactolocation, or grope feeding. A foraging wood stork wades through the water with its beak immersed and partially open (7 to 8 cm). When it touches a prey item, a wood stork snaps its mandibles shut, raises its head, and swallows what it has caught (Kahl 1964). Regularly, storks will stir the water with their feet, a behavior which appears to startle hiding prey (Rand 1956, Kahl 1964, Kushlan 1979). Tactolocation allows storks to feed at night and use water that is turbid or densely vegetated. However, the prey must be concentrated in relatively high densities for wood storks to forage effectively. The natural hydrologic regime in South Florida involves seasonal flooding of extensive areas of the flat, low-lying peninsula, followed by drying events which confine water to ponds and sloughs. Fish populations reach high numbers during the wet season, but become concentrated into smaller areas as drying occurs. Consumers, such as the wood stork, are able to exploit high concentrations of fish in drying pools and sloughs. In the pre-drainage Everglades, the dry season of South Florida provided wood storks with ideal foraging conditions by concentrating prey species in gator holes and other drainages in the Everglades basin. In coastal areas, the tidal cycle strongly influences use of saltwater habitats by wood storks. The relatively great tidal amplitudes characteristic of coastal marshes in northeast Florida, Georgia, and South Carolina serve to concentrate prey. similarly to the seasonal drawdowns found in freshwater systems (FWS 1997).

Storks forage in a wide variety of shallow wetlands, wherever prey reach high enough densities, and in water that is shallow and open enough for the birds to be successful in their hunting efforts (Ogden *et al.* 1978, Browder 1984, Coulter 1987). Good feeding conditions usually occur in relatively calm water, where depths are between 10 and 25 cm, and where the water column is uncluttered by dense patches of aquatic vegetation (Coulter and Bryan 1993). In South Florida, dropping water levels are often necessary to concentrate fish to suitable densities (Kahl 1964, Kushlan *et al.* 1975). In east-central Georgia, where stork prey is almost twice as large as the prey in Florida, wood storks feed where prey densities are significantly lower than foraging sites in Florida (Coulter 1992, Coulter and Bryan 1993, Depkin *et al.* 1992). Typical foraging sites throughout the wood stork's range include freshwater marshes and stock ponds, shallow, seasonally flooded roadside or agricultural ditches, narrow tidal creeks or shallow tidal pools, managed impoundments, and depressions in cypress heads and swamp sloughs. Almost any shallow wetland depression that concentrates fish, either through local reproduction or the consequences of area drying, may be used as feeding habitat.

Wood storks feed almost entirely on fish between 2 and 25 cm in length (Kahl 1964, Ogden *et al.* 1976, Coulter 1987). In South Florida, Ogden *et al.* (1976) found that certain fish species were taken preferentially. Mosquito fish (*Gambusia affinis*) were under represented in the diet in proportion to abundance, whereas, flagfish (*Jordanella floridae)*, sailfin mollies (*Poecilia latipinna)*, marsh killifish (*Fundulus confluentus*), yellow bullheads (*Ictalurus natalis)*, and sunfish (*Centrarchidae*) were over represented. Wood storks also occasionally consume crustaceans, amphibians, reptiles, mammals, birds, and arthropods. Fish densities at stork foraging sites varied from 15.6 individuals/m^2 in east-central Georgia to 40 individuals/m^2 in South Florida (Ogden *et al.*1978, Depkin *et al.* 1992).

Because wood storks rely on concentrated food sources which are patchily distributed over large areas, they need to be able to find new feeding grounds with minimal energy expenditure. Wood storks have soaring abilities that allow them to reach high altitudes and many kilometers without the energy expenditure of wing-flapping. A recent study suggested that soaring flight by storks can be accomplished at one-tenth the energetic cost of flapping flight (Bryan and Coulter 1995). The long distances they travel, however, shortens the time available to wood storks for feeding and reduces the number of times an adult stork can return to its nest to feed young (Kahl 1964). During the breeding season, feeding areas proximal to wood stork breeding colonies may play an important role in chick survival and provide enhanced opportunities for newly fledged birds to learn effective feeding skills.

Movements

During the non-breeding season (the summer to fall rainy season in South Florida), juvenile wood storks from South Florida colonies have been located throughout the Florida peninsula, southern Georgia, coastal South Carolina, central Alabama, and east-central Mississippi (Ogden 1996a). Additionally, marked individuals from a colony in east-central Georgia were found in the central Everglades during the winter. This information suggests that the southeastern population of wood storks is a single population that responds to changing environmental conditions through temporal relocation. Rodgers' (1996) data analysis of genetic variation in wood stork populations in South Florida, central Florida, north Florida, Georgia, and South Carolina support this evaluation.

Relationship to Other Species

Although the majority of nesting by the southeastern wood stork population no longer occurs in South Florida, the wetlands of the Everglades remain as important feeding areas for large numbers of storks during the dry season (winter-spring) (Bancroft *et al.* 1992). Wood storks may nest with many other wading bird species including white ibis (*Eudocimus albus*), tricolored herons (*Hydranassa tricolor*), snowy egrets *(Egretta thula),* great egrets (*Casmerodius albus*), great blue herons (*Ardea herodias*), little blue herons (*Egretta caerulea*), and cattle egrets (*Bubulcus ibis*).

Suitable foraging habitat for the wood stork occurs in a specific band of the hydrologic and vegetative gradient of South Florida's landscape (see preceding discussions on foraging habitat and foraging behavior). Wood storks share that landscape with other species that occupy different (adjacent) positions along the same hydrologic and vegetative gradients. The endangered snail kite *(Rostrhamus sociabilis plumbeus)* is a nomadic species which moves throughout the South Florida landscape in response to changing habitat conditions. Optimal foraging conditions for the snail kite include areas of variable water depth that support apple snails. Conditions that provide good foraging habitat for the snail kite are too deep to provide optimal foraging conditions for the wood stork. The Cape Sable seaside sparrow (Ammodramus maritimus mirabilis) is another endangered species that utilizes the South Florida landscape and whose breeding success is dependent on hydrologic conditions that differ from those of the wood stork and the snail kite. The Cape Sable seaside sparrow requires short-hydroperiod dry marl prairie communities that are dominated by muhly grass (Muhlenbergia filipes) for their nesting cycle.

Historically, the large spatial extent and diverse environmental conditions of the South Florida landscape provided the different habitat requirements of these species (Davis and Ogden 1994). In the past century, draining and clearing activities dramatically reduced the spatial extent of the South Florida Everglades. At the same time, humans began to control the timing, distribution, and volumes of water in the South Florida landscape. These practices have resulted in a reduced diversity of environmental conditions and a resultant loss of heterogeneity in the South Florida landscape. The combination of reduced spatial extent and reduced landscape diversity now causes the environmental needs of these species to "conflict" in the current, less-diverse, managed landscape.

Status and Trends

The wood stork appears to be experiencing human population pressure throughout its entire New World range. Although specific information on the status and trends of breeding colonies is not available throughout its range, information that has been collected on specific colonies suggests that breeding and foraging habitats of the wood stork are declining in area and quality. Mexico listed its breeding population of the wood stork as endangered in 1991 because of dramatic population declines. The size of the most important breeding colonies for the wood stork in Mexico, which are located in the Usumacinta and Grijalva River Deltas in the states of Tabasco and Campeche, had declined from 10,000 to 15,000 pairs in 1979 (Luthin 1987) to 3,000 to 3,500 pairs by 1990. Ogden *et al.* (1988) report 6,000-8,000 pairs as the range from 1971 to 1979. The wood stork is considered an endangered species in Belize where all colonies that were identified in the 1970s had disappeared by the late 1980s (Luthin 1987). Only one stable breeding colony is known to exist in Costa Rica; elsewhere in Central America, its status is unknown. Wood storks in South America face similar threats; in Cienaga de Zapatosa (Colombia), wood storks are threatened by pollution in the Rio Magdalena; in the Santa Rosa wetlands of Machalilla NP (Ecuador), wood storks may be affected by the construction of an oil terminal. The enormous wood stork rookeries in the Pantanal (primarily in Brazil), which is the world's largest wetland, are threatened by expanding agriculture, water pollution, and a massive project to drain, dike, and channelize this massive wetland ecosystem (Alho *et al.* 1988).

The U.S. population of the wood stork was listed as endangered in 1984 because it had declined by more than 75 percent since the 1930s (49 FR 7335). At the time, the FWS believed that the U.S. breeding population would be extirpated by the turn of the century if it continued to decline at the same rate. The original listing recognized the relationship between the declining wood stork population, the loss of suitable foraging habitat, and colony nesting failures, particularly in the breeding colonies in South Florida where human actions have reduced wetland areas by about 35 percent (Ogden and Nesbitt 1979).

Table 1. Wood stork breeding population in the southeast U.S., 1991-1995 (1997 wood stork recovery plan).

Year	Number of nests in southeast U.S.	Number of nests in South Carolina	Number of nests in Georgia	Number of nests in Florida	Number of nests in South Florida Ecoregion
1991	3,933	664	942	2,327	1,339
1992*	4,084	475	1091	2,518	2,518
1993	7,278	806	1649	4,823	2,546
1994	5,768	712	1468	3,588	2,015
1995	7,853	829	1501	5,523	2,639

* No data available for central or north Florida

We are uncertain about the size of the U.S. breeding population of wood storks before the statewide surveys of the late 1950s. Published and unpublished estimates of the size of the U.S. breeding population of wood storks prior to the statewide surveys are contradictory. For example, Allen (in Palmer 1962) wrote that the number of breeding wood storks in Florida exceeded 150,000 individuals during the 1930s. However, Ogden *et al.* (1978) believed this number was an overestimate resulting from an inflated estimate of the Lane River colony. Ogden (1978, 1996a) concluded that the wood stork population in the 1930s was probably less than 100,000 individuals, or between 15,000 and 25,000 pairs. More recent survey data provided by FWS (1997) in the wood stork recovery plan give a U.S. breeding population of 4,073 nests in 1991, 4,084 nests in 1992, 6,729 nests in 1993, 5,768 nests in 1994, and 7,853 nests in 1995 (Table 1). These data suggest that the breeding population of wood storks is increasing although the number of nests per year varies considerably. The next regionwide census of the wood stork population is scheduled for completion in 1999.

Since the 1960s, the wood stork population has shown a substantial decline in southern Florida and a substantial increase in northern Florida, Georgia, and South Carolina (Ogden et al. 1987). The number of pairs nesting in the traditional colony sites located in the Everglades and Big Cypress regions of southern Florida

Table 2. Pairs of nesting wood storks in Florida, 1991-1995 (from FWS 1997 wood stork recovery plan).

Colony Name	GFC Number	County	1991	1992	1993	1994	1995
Micanopy River Styx	605011	Alachua	40		55	175	250
Moore Creek	612007	Brevard					
U.S. 192 East & West	612138	Brevard	12		60		75
Grant Farm	616004	Brevard	60		150	100	
Micco North & South	616102	Brevard					48
Valkaria	616119	Brevard					25
SW Lake Washington	No Number	Brevard	60		185	105	300
Bluebill		Brevard	4				
Hall Island		Brevard	1				
	612127	Brevard			110	140	275
Lake Mary Jane	612037	Orange			100	105	175
Subtotal - Central Florida East Coast			**177**	**0**	**660**	**625**	**1,148**
Croom	611015	Hernando					175
Weeki Wachee		Hernando			12	16	
Hillsboro River	611163	Hillsborough				8	115
Lake Yale	612027	Lake	40		275	90	65
Ayers Point		Manatee			140		33
Devils' Creek	611021	Pasco			120	160	210
Little Gator Creek	611024	Pasco			60	9	200
Subtotal - Central Florida West Coast			**40**	**0**	**607**	**283**	**798**
Oleno	605103	Columbia	42				
Falling Creek		Columbia	80		150	110	110
Dee Dot	594004	Duval	250		260	300	325
Cedar Point	594105	Duval	9		85	30	120
Nassauvillo	594103	Nassau	5				
	606109	St. Johns			170		60
Subtotal - North Central Florida			**386**	**0**	**665**	**440**	**615**
Ochlocknee River	592003	Leon	160		115	95	144
Chaires	592001	Leon	225		230	130	179
Subtotal - North Florida			**385**	**0**	**345**	**225**	**323**
El Clair Ranch	616016	Hardee	400		320	240	415
Reedy Creek	612048	Polk			230	230	190
Lake Rosalie	616037	Polk	20		80	50	115
Mulberry NE	616114	Polk			75	130	110
	28048122	Polk			230	210	
Subtotal - SFER Central Florida			**420**	**0**	**935**	**860**	**830**
Pelican Island	616007	Indian River	110		225	110	230
Sewel Point	616025	Martin					65
Wescott Grove	616108	St. Lucie	40		25		8
Cypress Creek	616047A	St. Lucie	150		375	265	10
Subtotal - Central Florida East Coast			**300**	**0**	**625**	**375**	**313**
Tamiami Trail East	620122	Dade		130			
Cuthbert Lake	620139	Dade	150	275			
L-28 Crossover		Dade		158			
Tamiami Trail West		Dade		123			
East River		Dade			15		
Rookery Branch		Monroe		9			
Rodgers River Bay		Monroe		22		50	
Lane River		Monroe		1			
Paurotis Pond		Monroe			25	110	105
Loxahatchee 1&2	619139	Palm Beach	34				
SWA Catchment	No Number	Palm Beach					27
Corkscrew	619018	Collier	300	1800	426	450	864
Subtotal - Everglades and Big Cypress			**484**	**2,518**	**466**	**610**	**996**
Morgantown	616165	Charlotte	60				
North Port Charlotte	615040	Sarasota	75		520	170	500
Subtotal - Central Florida West Coast			**135**	**0**	**520**	**170**	**500**
Florida Population			**2,327**	**2,518**	**4,823**	**3,588**	**5,523**
North Florida			**988**	**0**	**2,277**	**1,573**	**2,884**
South Florida			**1,339**	**2,518**	**2,546**	**2,015**	**2,639**

declined from 8,500 pairs in 1961 to fewer than 500 pairs from 1987 through 1995. During the same years, the number nesting in Georgia increased from 4 pairs in 1965 to 1,501 pairs in 1995, and the number nesting in South Carolina increased from 11 pairs in 1981 to 829 pairs in 1995.

Between 1957 and 1960, the Florida and National Audubon Societies conducted a series of statewide aerial wood stork surveys of all known or suspected stork nesting colonies. In 1974, Florida statewide aerial surveys were initiated and repeated, annually, until 1986 (Ogden and Nesbitt 1979, Ogden and Patty 1981). In 1959, 14 breeding colonies in Florida supported an estimated 7,657 pairs of wood storks ; in 1960, 15 breeding colonies supported 10,060 breeding pairs; in 1975, 15 breeding colonies supported 5,382 breeding pairs; and in 1976, 17 breeding colonies supported 5,110 breeding pairs. More recent data provided in the wood stork recovery plan (FWS 1997) give a Florida breeding population of 2,327 pairs in 1991, 4,823 pairs in 1993, 3,588 pairs in 1994, and 5,523 breeding pairs in 1995. Twenty-one breeding colonies were present in 1991, 28 breeding colonies were present in 1993, 26 in 1994, and 30 in 1995. Data collections in 1992 did not include north and central Florida populations and are not included for comparisons.

The South Florida Ecosystem's contribution to the Florida population of wood storks is presented in Table 1. On the average the South Florida subpopulation represents 53 percent of the Florida population and 34 percent of the southeastern U.S. population. These data show a nesting population of 1,339 nests in 1991, 2,546 nests in 1993, 2,015 nests in 1994, and 2,639 nests in 1995.

The historical data and the recovery goals in the wood stork recovery plan reference the South Florida population as the Big Cypress Basin system and the Everglades Basin system. These two basins account for, on the average, between 30 to 37 percent of the South Florida Ecosystem sub-population. Table 2 provides a breakdown of the wood stork colonies listed in the recovery plan by general basin boundaries. Based on this general categorization of the colonies, four South Florida Ecosystem colony groupings are identified. These are the Central Florida East Coast colonies, the Everglades and Big Cypress (ECB) basin colonies, the Central Florida West Coast colonies, and the Central Florida colonies.

Historical data on colony locations identify the Everglades basin colonies and the Corkscrew colonies as the primary nesting locations for wood storks in South Florida (Ogden and Nesbitt 1979). In the late 1950s and early 1960s, wood storks nesting in the Everglades basin accounted for 12 percent [1,000 out of 8,609 nests (two-year average)] of the Florida population. The 1991 to 1995 survey data reveal that the Everglades basin colonies represents on the average, 3 percent [129 out of 4,065 nests (four-year average)] of the Florida population. In the late 1950s and early 1960s data, the Corkscrew colonies accounted for 51 percent [4,350 out of 8,609 nests (two-year average)]. The survey data also show that the Corkscrew colonies represent on the average, 12 percent [510 out of 4,065 nests (four-year average)] of the Florida population. More recent data provided by Ogden (1998) on three-year averages on nesting pairs of wood storks in the Everglades Basin (Loxahatchee NWR, WCAs 2 and 3, and mainland Everglades NP) show 343 pairs for the 1994 to 1996 average, 283 pairs for the 1995 to 1997 average, and 228 pairs for the 1996 to 1998 average. These averages are higher than the three-year average for the base years, 1986 to 1995. The base year averages were a low of 130 pairs and a high of 294 pairs. In the 1998 nesting year, only 25 pairs of wood storks were recorded nesting in ENP.

Rodgers *et al.* (1995) pointed out shortcomings in the aerial surveys used to generate population estimates for storks in Florida, Georgia, and South Carolina. Rodger's study compared ground surveys of wood stork colonies with aerial surveys of the same colonies. The variability of the aerial estimates was very large. For example, an approximately 95 percent confidence interval for the 1993 Florida statewide nesting population was 3,807 to 12,653 nests. The aerial count was 4,262 nests. The greatest variability occurred in large colonies with a high proportion of other white-plumage nesting birds. The FWS acknowledges the limitations involved in relying on aerial surveys for developing population estimates. However, over the long-term, aerial surveys are the most cost-effective method for estimating population trends. Ground surveys, while providing greater individual colony accuracy, are more time consuming and expensive on a regionwide basis. Rodgers recommended the incorporation of ground counts at selected colonies, training observers in presurvey flights, and replicating counts for each colony as actions to minimize variability in aerial surveys.

Historically, wood storks were recorded nesting in all coastal states between Texas and South Carolina (Ogden et al. 1987, FWS 1997); however, the largest colonies were located in South Florida. Since the 1960s, the decline in the U.S. population size of wood storks has been accompanied by a change in the size and distribution of their breeding colonies. Since the 1970s, the number of wood storks breeding in South Florida has substantially decreased. In north Florida, Georgia, and South Carolina the number of breeding wood storks has significantly increased (Ogden et al. 1987). From 1958 to 1960, 80 to 88 percent of wood stork nesting pairs were located at six sites in South Florida. Surveys from 1976 showed a decline to 68 percent, with a further decline to 13 percent in 1986. Since the late 1970s, a majority of wood storks have nested in central and north Florida, and an increasing number have nested in coastal colonies in Georgia and South Carolina. Between 1965 and 1995, the number of wood storks nesting in Georgia increased from four pairs to 1,501 pairs; between 1981 and

1995, the number of wood storks nesting in South Carolina increased from 11 pairs to 829 pairs. Since the 1970s, associated with this shift to the north, the U.S. southeast wood stork population appears to be gradually increasing, from a low of 3,000 to 4,000 pairs in the late 1970s, to over 7,800 pairs in the mid-1990s.

From 1991 through 1995, the FWS coordinated a systematic multi-state survey of wood stork nesting colonies. The results of these surveys suggest that, on average, from 1991 to 1995, approximately 35 percent of the total nesting effort in the southeast U.S. occurred in South Florida (Table 1). Historically, South Florida supported greater than 70 percent of the total nesting effort in the southeast U.S.; if these data are indicative of the ability of degraded South Florida ecosystems to support wood stork nesting, then South Florida ecosystems are functioning at approximately 50 percent of their previous capabilities.

Both 1992 and 1995 were years with high nesting effort. In 1995, nesting effort in South Florida improved from the previous two years, most likely in response to improved foraging conditions as a result of a rapid dry-down following the high-water years. In Everglades NP, Big Cypress National Preserve, Corkscrew National Sanctuary, and Florida Panther NWR, there were a total of approximately 996 nesting pairs. The North Port Charlotte nesting colony, which is north of the Corkscrew National Sanctuary had a breeding population of 500 nest pairs.

Since the 1970s, wood storks have also shifted their nest sites to areas that are artificial impoundments or where islands have been created by dredging activities (Ogden 1991). The percentage of nests in artificial habitats in central and north Florida has increased from approximately 10 percent of all nesting pairs in 1959 to 1960 to 60 to 82 percent between 1976 and 1986 (Ogden 1991). Nests in these artificially impounded sites often support exotic species such as Brazilian pepper (*Schinus terebinthifolius*) or Australian Pine *(Casuarina spp.)*. Ogden (1996a) has suggested that the use of these artificial wetlands indicates that wood storks are not finding suitable conditions within natural nesting habitat or that they are finding better conditions at the artificial wetlands.

The 1960s and 1970s were a period of transition for wood storks breeding in South Florida. The most significant change was a delay in the timing of colony formation, from November and December in most years prior to the 1970s, to a pattern of colony formation between January and March. During the late 1970s, delayed colony formation by wood storks became the norm (Ogden 1994). Historically, wood storks formed colonies in November and December and concentrated the majority of their feeding efforts within the estuaries at the time of traditional colony formation (J. Ogden, SFWMD, personal communication 1996b).

The November/December feeding efforts appear to historically correspond to the annual mullet runs that occur on both of Florida's coastal systems. Before spawning, which usually peaks from November through January, large schools and concentrations of mullet form in the estuarine habitat (J. Cato, et al. 1976). During low tide, these large schools of mullet, which are concentrated in the shallow estuarine bays and mud flats, provide a concentrated food source for the wood stork during the early nesting cycle.

By the time the young of the year were ready to fledge and begin foraging independently, the dry season in South Florida was well underway and fish were being concentrated in the interior freshwater sloughs, making feeding easy. Presently, wood storks in South Florida appear to be initiating nesting in response to the drying of the interior marshes in February to April; by the time the young fledge and begin foraging on their own, the wet season is underway, water levels in the interior marshes are rising, and many young starve. Such a change suggests that the estuarine habitats no longer provide suitable foraging conditions during the early dry season months, November to January.

The reproductive success of storks requires habitats that provide high concentrations of certain size-classes of fish, over a 125 to 150 day breeding cycle. Because seasonal and annual rainfall patterns are so variable in South Florida, the quantity of these foraging habitats also varies among years (J. Ogden, SFWMD, personal communication 1998). As a result, wood storks probably have always had highly variable reproductive success throughout their history, a phenomenon that is mitigated by the relatively long life spans of adult storks. Nevertheless, most authors agree that the decline of the U.S. wood stork population far exceeds the range of historic variability in total population size, and is correlated with water management activities in South Florida (Palmer 1962, Frederick 1993, Ogden 1996). During wet years, current water management practices prevent the formation of shallow pools that concentrate the fish on which wood stork forage. During dry years, current water management practices overdrain the freshwater sloughs, reduce freshwater flows into the mainland estuaries and reduce their ability to produce the fish on which wood storks forage.

As a result of these water management practices, wood storks in South Florida have experienced increased frequencies of nest failure. For example, in 1962, 1978, and 1983, wood storks in Everglades NP did not initiate nesting. In 1990, all nestlings in the Cuthbert Lake colony starved. In 1995, none of 250 nestlings survived in the Paurotis Pond colony. In the 1998 nesting year, only 25 pairs of wood storks were recorded nesting in ENP.

The threat of mercury contamination in the Everglades food web and its impact on the success of wood storks in South Florida is not clearly understood. Researchers have suggested that declines in wading bird populations may be partially a result of mercury toxicity (Frederick and Spalding 1994, Sundlof *et al.* 1994). In 1991, mercury contamination was documented in a wood stork carcass found in the Big Cypress basin (Facemire and Chlebowski 1991). The average mercury contents in the liver and feathers of the wood stork were 10.1 and 9.93 mg mercury per kg weight, respectively. The report concluded that, although the documented levels were generally less than those noted in the literature for fish-eating birds from mercury-contaminated freshwater systems, they were, most likely, sufficient to cause an adverse effect to the population. More recently, Beyer *et al.* (1997) found mercury concentrations in the livers of four wood storks collected in South Florida that were higher than the concentrations reported in seven other species of wading birds from South Florida. Frederick and Spalding (1994) reviewed the current knowledge on mercury contamination in wading birds, and concluded:

> In light of work that has been done in other species, it is not unreasonable to assume that high concentrations of mercury found recently in Everglades wading birds could result in the sublethal effects of reduced foraging and courtship ability. Each of these

> symptoms could result in reduced breeding effort and success and could be a powerful factor in explaining the reduced reproduction observed in the Everglades. The current state of knowledge on the effects of specific concentrations of mercury on wading bird behavior and survival is nonexistent.

Clearly much more specific research needs to be conducted on the levels of mercury in wood storks in the Everglades and the effects of these levels on the population. Potential impacts from contaminants need to be reconsidered in light of recent findings concerning the amount of mercury present in the Everglades ecosystem and the discovery of severe impacts of DDT/DDE-based estrogen-mimicking compounds on wildlife in a large Florida wetland (Guillette *et al*. 1994). The Science Sub-Group of the Interagency Task Force on the South Florida Ecosystem has acknowledged this in the section of their report dealing with threatened and endangered species. For the wood stork, the report calls for "a detailed study of the effects of mercury, other toxins, and parasites on the survivorship and reproductive success of wood storks" (Science Sub-Group, 1996).

Prognosis of the U.S. wood stork population between 1996 and 2020 is partially dependent on the success of the overall South Florida Ecosystem restoration effort. The freshwater flows need to be restored to more closely mimic the pre-drainage system; it is believed that by restoring the quantity, quality, timing, and distribution of flows in the remaining Everglades wetlands that the prey base so critical to wood storks during the breeding season will be recovered in both the estuarine and freshwater systems. Although we have lost approximately 35 percent of the original foraging grounds and the quality of much of the remaining wetlands has become degraded as foraging habitats, if our efforts to restore the South Florida Ecosystem are successful, we will re-create a system with heterogeneity and inherent variability, which should provide the prey base necessary to restore the wood stork in South Florida.

Management

South Florida has been severely degraded by the C&SF Project, which encompasses 4,660,000 ha from Orlando to Florida Bay and includes about 1,600 km each of canals and levees, 150 water control structures, and 16 major pump stations. This system has disrupted the natural volume, timing, quality and distribution of surface and ground water throughout South Florida. In recognition of the detrimental effects that this flood control system has had on the ecosystems in South Florida, numerous hydrologic projects, whose purposes are to aid in the restoration of South Florida's ecosystems, while maintaining flood control, are in varying stages of planning and implementation.

The 1992 Water Resources Development Act (WRDA) authorized the Kissimmee River and the Kissimmee River Headwaters Revitalization Project. In 1994, a Project Cooperative Agreement between the COE and the local sponsor, the SFWMD, combined the two authorized projects into one project, the Kissimmee River, Florida Project. The purpose of the project is to provide the flows necessary to restore the Kissimmee River ecosystem. We have the ability to increase the spatial extent and quality of foraging habitat available to wood storks by returning the natural functions to the Kissimmee River basin.

The C-111 and Modified Water Deliveries Projects were congressionally authorized in 1994 and 1990, respectively. The purpose of these two projects is to begin the process of restoring freshwater flows into Everglades NP. This will be accomplished by modifying the structures, canals and levees that deliver water to Everglades NP, and by changing the operational schedules. The future breeding success of the wood stork in Everglades NP is closely tied to the success or failure of these two projects. While other aspects of the overall Everglades restoration will be necessary to re-establish pre-drainage-like flows, these two projects will set the precedent for the restoration of South Florida, including the restoration of the prey base available to breeding wood storks in the southern Everglades.

The Experimental Program of Water Deliveries to Everglades NP was authorized in 1983; its purpose is to provide a vehicle to field-test water delivery methods into ENP. Each iterative test builds on the results of the previous tests and is aimed at furthering the goal of restoring, to the extent practicable, the ecological integrity of the native fauna and flora within Everglades NP, including Florida Bay. As operational flexibility increases with the completion of the Modified Water Deliveries, C-111, and other restoration projects, the ability to implement an operational plan that optimizes ecological restoration will substantially increase, and with it, our ability to recover the wood stork in South Florida.

Water supply and water delivery programs are also addressing habitat degradation of wood stork nesting and foraging areas in the Big Cypress basin and in the Corkscew Regional Ecosystem Watershed. The hydrologic restoration of Southern Golden Gate Estates, a 113 square miles rehydration project being jointly designed by the SFWMD and the Corps of Engineers, will provide surface storage and aquifer recharge and water quality enhancement in the Big Cypress Basin.

WRDA further authorized a comprehensive review of the Central and Southern Florida Project. The purpose of the review is to develop a comprehensive plan to restore, preserve, and protect the South Florida ecosystem. This is to be accomplished through the restoration of more natural flows to the southwest coastal areas, including the Big Cypress basin, and through the Everglades NP to Florida Bay. The WRDA of 1996 accelerated this process and calls for a plan to be sent to Congress for authorization by September 30, 1999. This project, in combination with previously authorized projects, should result in the enhancement of nesting and foraging habitat that is necessary for the recovery of the wood stork subpopulations in South Florida.

In addition to hydrologic restoration projects, the State of Florida administers land acquisition programs that may enhance opportunities to restore wood storks in South Florida. The Save Our Rivers program identifies lands of environmental significance and prioritizes their acquisition. Of these lands identified, the Model Lands and Pennsuco wetlands in Miami-Dade County, the Golden Gate Estate wetlands in Collier County, and CREW wetlands in Lee and Collier counties are of significance to the wood stork for foraging. Public acquisition of these lands will increase our ability to manage them in an ecologically-sensitive fashion. The Conservation and Recreation Lands Acquisition program is an additional program that may provide some opportunities for wood stork recovery in South Florida, and should be acknowledged and incorporated into long-term planning efforts. Nesting habitat should be protected from disturbance and human alteration through purchase into the public lands system, easements, partnerships and private landowner/government assistance and agreements. Watersheds supporting natural nesting habitat should remain unaltered, or be restored to function as a natural system if previously altered.

Lands can be purchased by Federal agencies through section 104 of the Everglades NP Protection and Expansion Act of 1989 (P.L. 101-229) and section 390 of the Federal Agriculture Improvement and Reform Act of 1996 (P.L. 104-127).

The Everglades NP Protection and Expansion Act of 1989 authorized the purchase of lands to be added to the park that encompass approximately 44,379 ha within northeast Shark River Slough (NESS) and the East Everglades. The purchase of these lands and the hydrological improvements to these lands are critical to restoring ecosystem productivity in the southern Everglades and maintaining adequate freshwater inflow to the downstream estuaries along the Gulf of Mexico and Florida Bay. The purchase of these lands is necessary to limit further habitat destruction outside former boundaries and to restore natural water flow patterns that are critical to the long-term viability of the park.

Section 390 of the Federal Agriculture Improvement and Reform Act of 1996, referred to as Farm Bill 390, provides two distinct funding programs for land acquisition to support restoration of the Everglades. The first program provided $200,000,000 to the Secretary of the Interior to conduct restoration activities in the Everglades Ecosystem in South Florida, including acquisition of real property and interests in real property and resource protection and resource maintenance activities. An additional $100,000,000 is available under the Farm Bill 390 authorization from the sale of Federal surplus lands to purchase lands necessary for the Everglades restoration efforts.

The Corkscrew colony in Collier County continues to occasionally produce large numbers of young in South Florida (Table 2). The acquisition or preservation of this colony's habitat and recovery of more natural hydropatterns within the foraging grounds surrounding this colony, are critical to the recovery of wood storks in South Florida. Wood storks nesting at Corkscrew now show a similar pattern of delayed nesting in many years. Private lands initiatives, conservation easements, and mitigation banking should all be considered as viable opportunities for managing these lands.

Ogden (1990) developed a set of management guidelines for the FWS on wood stork nesting, feeding, and roosting habitats. The guidelines recommend buffer zones that may be necessary to reduce human disturbance of storks in feeding and roosting habitats. These efforts have substantially contributed to the protection of stork habitat, particularly where new developments have been proposed in areas used by storks. The buffer zones recommended in the management guidelines are larger than those recommended by Rodgers and Smith (1995) in their analysis. At the time the guidelines were developed, little empirical data were available on the response of wood storks to human activities. Rodgers and Smith analyzed only three types of human activities: walking, canoeing, and a small motorboat with two persons. They did not evaluate responses to other activities such as construction or aircraft. The current guidelines recommend buffer zones to protect colonies from many kinds of activities including human disturbance. Rodgers and Smith, (1997) study of human disturbance to foraging and loafing waterbirds recommends a buffer of about 100 meters.

An understanding of the relationships between storks and water conditions in the Everglades has provided a basis for restoration planning for the region. Wood storks have been recommended by the Science Sub-Group of the South Florida Ecosystem Restoration Task Force as a species to be used for measuring the success of the overall South Florida Ecosystem restoration. Everglades NP and SFWMD staff have used a 64-year record of stork nesting in the Everglades basin (1932-1995) for this purpose. The C-111 Project, Modified Water Deliveries Project, the Experimental Program of Water Deliveries to Everglades NP, and the regional water management plans being developed for the EAA, the Big Cypress basin and the CREW should eventually result in much improved habitat conditions for storks in South Florida. It is currently assumed, as a part of the restoration planning, that the recovery of increased volumes of freshwater flows through the Everglades marshes and into the estuaries of Florida Bay will increase primary and secondary production in these regions.

Regional surveys of nesting colonies conducted from 1957 through 1961, and again in the mid-1970s, have been essential for locating important habitats, and for understanding the threats to the southeastern population of storks. These surveys were the first to measure the status of the regional population of storks, and have been used to measure responses by nesting storks to water management practices in the Everglades region. Over the 5 years from 1991 to 1995, the FWS coordinated a systematic multi-state survey of stork nesting colonies (L. Finger, FWS, personal communication 1996). The census continued through the 1995 nesting season. After a 5-year hiatus where financial efforts were directed towards research, a new series of censuses began again in the year 1999.

Stangel *et al*. (1990) employed starch gel electrophoretic techniques to examine genetic variation in Florida wood stork colonies. This study did not indicate significant allozyme differences within or between colonies. In 1994, a genetics study incorporating DNA microsatellites of breeding storks in Florida, Georgia, and South Carolina was initiated to further investigate the geographic and genetic origins of wood stork colonies in the three states. By assessing the degree of genetic interrelatedness among wood stork colonies, vital information may be obtained concerning population movements, allowing us to determine whether the increase in numbers of storks breeding in the northern portion of their range is the result of high productivity in those colonies, increased immigration from Florida colonies, or both. However, the increase in the size and number of “northern” colonies almost certainly occurred too rapidly to be explained by local recruitment.

An effort should be made to place transmitters on juvenile wood storks in South Florida. This will help us to identify critical foraging grounds and gain insight into post-fledging survivorship.

A Wetlands-Wood Stork Summit was held on October 13-14, 1994 in Georgia. The Georgia Conservancy and Zoo Atlanta convened this summit to initiate a coordinated regionwide effort in wetlands education focusing on the wood stork. The initiative would be comprised of both an education and a research component. A grant proposal was submitted in early 1995 requesting support for this effort.

The informal Wood Stork Management Group, formed 3 years ago by the Georgia Conservancy and more recently hosted by the FWS, should continue to meet annually as a means for reviewing trends and assessing the influences of Everglades restoration projects relative to patterns by total stork populations in the Southeast.

Literature Cited

Alho, C.J.R., T.E. Lacher, Jr., and H.C. Gonçalves. 1988. Environmental degradation in the Pantanal ecosystem. BioScience 38:164-171.

American Ornithologists' Union [AOU]. 1983. Checklist of North American birds. Sixth Edition. American Ornithologists' Union; Baltimore, Maryland.

Bancroft, G.T., W. Hoffman, R.J. Sawicki and J.C. Ogden. 1992. The importance of the Water Conservation Areas in the Everglades to the endangered wood stork (*Mycteria americana*). Conservation Biology 6:392-398.

Bent, A.C. 1926. Life histories of North American marsh birds. U.S. National Museum Bulletin 135; Washington, D.C.

Beyer, W.N., M. Spalding, and D. Morrison. 1997. Mercury concentrations in feathers of wading birds from Florida. Ambio 26:97-100.

Brouwer, K., M.L. Jones, C.E. King, and H. Schifter. 1992. Longevity and breeding records of storks. International Zoo Yearbook 31:131-139.

Browder, J.S. 1984. Wood stork feeding areas in southwest Florida. Florida Field Naturalist 12:81-96.

Bryan, A.L. Jr., and M.C. Coulter. 1995. Wood stork use of the Kathwood foraging ponds: 1986-1993. Pages 53-56 *in* R.R. Shortland (coordinator). Proceedings of the wood stork symposium, 19-20 October 1993. The Georgia Conservancy; Savannah, Georgia.

Cato, James C., P. B. Youngberg, and R. Raulerson. 1976. *in* J.C. Cato and E. McCullough (editors). Economics, biology, and food technology of mullet. Florida Sea Grant Program. Report Number 25. August. pp 15-47.

Cone, W.C. and J.V. Hall. 1970. Wood ibis found nesting in Okeefenokee Refuge. Oriole 35:14.

Coulter, M.C. 1987. Foraging and breeding ecology of wood storks in east-central Georgia. Pages 21-27 *in* R.R. Odom, KA. Riddleberger, and J.C. Ozier, eds. Proceedings of the third southeastern nongame and endangered wildlife symposium. Georgia Department of Natural Resources; Atlanta, Georgia.

Coulter, M.C. 1992. Foraging ecology of American wood storks (*Mycteria americana*) in east-central Georgia, USA. Pages 411-416 in Proceedings of the seventh Pan-African Ornithological Congress.

Coulter, M.C. 1996. Revised recovery plan for the U.S. breeding population of the wood stork. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Coulter, M.C., and A.L. Bryan, Jr. 1993. Foraging ecology of wood storks (*Mycteria americana*) in east-central Georgia: Characteristics of foraging sites. Colonial Waterbirds 16:59-70.

Davis, S.M. and J.C Ogden. 1994. Toward ecosystem restoration. Pages 769-796 *in* S.M. Davis and J.C. Ogden, eds. Everglades: the ecosystem and its restoration. St. Lucie Press; Delray Beach, Florida.

Depkin, F.C., M.C. Coulter, and A.L. Bryan, Jr. 1992. Food of nestling wood storks in east-central Georgia. Colonial Waterbirds 15:219-225.

Dusi, J.L., and R.T. Dusi. 1968. Evidence for the breeding of the wood stork in Alabama. Alabama Birds 16:14-16.

Facemire, C.F. and L. Chlebowski. 1991. Mercury contamination in a wood stork. U.S. Fish and Wildlife Service Publication No. VBFO-91-CO3; Vero Beach, Florida.

Finger, L. 1996. Personal communication, 15 October 1996.

Frederick, P.C. 1993. Wading bird nesting success studies in the Water Conservation Areas of the Everglades, 1992. Unpublished draft final report prepared for the South Florida Water Management District in fulfillment of contract No. C3138. South Florida Water Management District; West Palm Beach, Florida.

Frederick, P.C. 1994. Wading bird nesting success studies in the Water Conservation Areas of the Everglades, 1994. Unpublished draft final report prepared for the South Florida Water Management District in fulfillment of contract No. C3138. South Florida Water Management District; West Palm Beach, Florida.

Frederick, P.C. and M.G. Spalding. 1994. Factors affecting reproductive success of wading birds (Ciconiiformes) in the Everglades Ecosystem. Pages 659-691 *in* S.M. Davis and J.C. Ogden, eds. Everglades: the ecosystem and its restoration. St. Lucie Press; Delray Beach, Florida.

Guillette, L.J. Jr., T.S. Gross, G.R. Masson, J.M. Matter, H.F. Percival, and A.R. Woodward. 1994. Developmental abnormalities of the gonad and abnormal sex hormone concentrations in juvenile alligators from contaminated and control lakes in Florida. Environmental Health Perspectives 102:680-688.

Hefner, J.M., B.O. Wilen, T.E. Dahl, W.E. Frayer. 1994. Southeast wetlands: Status and trends, mid-1970s to mid-1980s. U.S. Department of the Interior, Fish and Wildlife Service; Atlanta, Georgia.

Howell, A.H. 1932. Florida bird life. Coward-McCann; New York, New York.

Kahl, M.P., Jr. 1964. Food ecology of the wood stork (*Mycteria americana*) in Florida. Ecological Monographs 34:97-117.

Kahl, M.P., Jr. 1972. Comparative ethology of the Ciconiidae. The wood storks (Genera *Mycteria* and *Ibis*). Ibis 114:15-29.

Klein, H., J.T. Armbruster, B.F. McPherson, and H.J. Freiberger. 1974. Water and the south Florida environment. South Florida environmental proceedings: ecological report number. DI-SFEP-74-75. U.S. Geological Survey; Atlanta, Georgia.

Kushlan, J.A. 1979. Prey choice by tactile foraging wading birds. Proceedings of the Colonial Waterbird Group 3:133-142.

Kushlan, J.A., J.C. Ogden, and A.L. Higer. 1975. Relation of water level and fish availability to wood stork reproduction in the southern Everglades, Florida. U.S. Geological Survey open file report 75-434. U.S. Government Printing Office; Washington, D.C.

Leach, S.D., H. Klein, and E.R. Hampton. 1972. Hydrologic effects of water control and management of southern Florida. Bureau of Geology, Florida Department of Natural Resources; Tallahassee, Florida.

Luthin, C.S. 1987. Status of and conservation priorities for the world's stork species. Colonial Waterbirds 10: 181-202.

Neotropical Bird Club. 1996. Mexico: Stork surveys in Mexico. Neotropical News 1 [Excerpt from Specialist Group on Storks, Ibises, Spoonbills Newsletter 7(1/2) 1995]. Neotropical Bird Club homepage on World Wide Web [http://www.netlink.co.uk/users/aw/nbchome.html].

Oberholser, H.C. 1938. The bird life of Louisiana. Louisiana Department of Conservation, Bulletin 28.

Oberholser, H.C. and E.B. Kincaid, Jr. 1974. The bird life of Texas. University of Texas Press; Austin, Texas.

Ogden, J.C. 1990. Habitat management guidelines for the wood stork in the southeast region. Prepared for the U.S. Fish and Wildlife Service; Atlanta, Georgia.

Ogden, J.C. 1991. Nesting by wood storks in natural, altered, and artificial wetlands in central and northern Florida. Colonial Waterbirds, volume 14: 39-45.

Ogden, J.C. 1994. A comparison of wading bird nesting colony dynamics (1931-1946 and 1974-1989) as an indication of ecosystem conditions in the southern Everglades. Pages 533-570 *in* J.C. Ogden and S.R. Davis, eds. Everglades: the ecosystem and its restoration. St. Lucie Press; Delray Beach, Florida.

Ogden, John C. 1996a. Wood Stork *in* J.A. Rodgers, H. Kale II, and H.T. Smith, eds. Rare and endangered biota of Florida. University Press of Florida; Gainesville, Florida.

Ogden, J.C. 1996b. Personal communication, U.S. Fish and Wildlife Service Multi-Species Recovery Team meeting, 26 April 1996.

Ogden, J.C. 1998. Personal communication, Comments on technical/agency draft multi-species recovery plan for South Florida. September 30. 1998.

Ogden, J.C. 1998. Status of Wading Bird Recovery - 1998. Pages 13-14 *in* D. E. Gawlik, eds. South Florida wading bird report, volume 4, Issue 1, September 1998. South Florida Water Management District. Everglades System Research Division. West Palm Beach, Florida.

Ogden, J.C. and S.A. Nesbitt. 1979. Recent wood stork population trends in the United States. Wilson Bulletin 91(4):512-523.

Ogden, J.C. and B.W. Patty. 1981. The recent status of the wood stork in Florida and Georgia. Pages 97-102 *in* R.Q. Odom and J.W. Guthrie, eds. Proceedings of the nongame and endangered wildlife symposium, August 13-14, 1981. Georgia Department of Natural Resources, Game and Fish Division, Technical Bulletin WL5; Athens, Georgia.

Ogden, J.C., J.A. Kushlan, and J.T. Tilmant. 1976. Prey selectivity by the wood stork. Condor 78(3):324-330.

Ogden, J.C., J.A. Kushlan, and J.T. Tilmant. 1978. The food habits and nesting success of wood storks in Everglades National Park in 1974. U.S. Department of the Interior, National Park Service, Natural Resources Report No. 16.

Ogden, J.C., D.A. McCrimmon, Jr., G.T. Bancroft and B.W. Patty. 1987. Breeding populations of the wood stork in the southeastern United States. Condor. 89:752-759.

Ogden, J.C., Knodler, and A. Sprunt, III. 1988. Colonial Wading Bird Populations in the Usumacinta Y Grijalva. Gobiernodel Estado de Tabasco.

Palmer, R.S. 1962. Handbook of North American birds, Volume 1, Loons through Flamingos. Yale University Press; New Haven, Connecticut.

Rand, A.L. 1956. Foot-stirring as a feeding habit of wood ibis and other birds. American Midland Naturalist 55:96-100.

Rodgers, J.A., Jr. 1990. Breeding chronology and clutch information for the wood stork from museum collections. Journal of Field Ornithology 61(1):47-53.

Rodgers, J.A., Jr. 1996. Population genetics of wood storks in Florida. Final report. Florida Game and Fresh Water Fish Commission. On file at U. S. Fish & Wildlife Service South Florida Field Office, Vero Beach, Florida.

Rodgers, J.A., Jr. 1998. Personal communication. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30. 1998.

Rodgers, J.A., Jr., and Henry T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. Conservation Biology 9(1):89-99.

Rodgers, J.A., Jr., and Henry T. Smith. 1997. Buffer zone distances to protect foraging and loafing waterbirds from human disturbance in Florida. Wildlife Society Bulletin. 25:139-145.

Rodgers, J.A., Jr., A.S. Wenner, and S.T. Schwikert. 1987. Population dynamics of wood storks in north and central Florida. Colonial Waterbirds 10:151-156.

Rodgers, J.A., Jr., A.S. Wenner, and S.T. Schwiker. 1988. The use and function of green nest material by wood storks. Wilson Bulletin, 100(3); 411-423.

Rodgers, J.A., Jr., S.T. Schwikert, and A.Shapiro-Wenner. 1996. Nesting habitat of wood storks in north and central Florida, USA. Colonial Waterbirds 19:1-21.

Rodgers, J.A. Jr., and S.T. Schwikert. 1997. Breeding success and chronology of wood storks in northern and central Florida, U.S.A. Ibis 139:76-91.

Science Subgroup. 1996. South Florida ecosystem restoration: scientific information needs. Report to the Working Group of the South Florida Ecosystem Restoration Task Force.

Stangel, P.W., J.A. Rodgers, Jr. and A.L. Bryan. 1990. Genetic variation and population structure of the Florida wood stork. Auk 107:614 -619.

Sundlof, S.F., M.G. Spalding, J.D. Wentworth and C.K. Steible. 1994. Mercury in livers of wading birds (Ciconiiformes) in southern Florida. Archives of Environmental Contaminants and Toxicology 27:299-305.

U.S. Fish and Wildlife Service [FWS]. 1997. Revised recovery plan for the U.S. breeding population of the wood stork. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Wayne, A.T. 1910. Birds of South Carolina. Contributions to the Charleston Museum No.1.

Recovery for the Wood Stork

Mycteria americana

Recovery Objective: RECLASSIFY to threatened, then delist.

South Florida Contribution: The former Science Subgroup (now Science Coordination Team) of the South Florida Ecosystem Restoration Task Force and Working Group prepared a set of recommendations for success measures for the South Florida Ecosystem restoration program. Included in these recommendations are targets for the recovery of nesting wading birds in the Everglades basin (WCAs and ENP). The Science Subgroup's measure of success for the wood stork is a breeding population between 1,500 to 2,500 pairs. The goal for wood stork recovery in South Florida is to support 2,500 nesting pairs in the Everglades and Big Cypress Basin systems and to support, as a South Florida Ecosystem component, 35 percent (3,500 nesting pairs) of the southeast United States recovery and delisting nesting population of 10,000 pairs.

Recovery Criteria

South Florida will contribute to the recovery of the total population, if the wood stork foraging and nesting habitat in the Everglades watershed is restored and/or enhanced as a result of the modified water storage and delivery programs being developed by the SFWMD and the COE. The recovery criteria as identified in the wood stork recovery plan, for the Everglades and Big Cypress Basin is a population of 2,500 nesting pairs. The recovery criteria for the South Florida Ecosystem populations, which also includes nesting colonies in coastal counties in central Florida and nesting colonies in the Kissimmee Basin, is 35 percent (3,500 nesting pairs) of the total recovery population of 10,000 pairs.

Species-level Recovery Actions

S1. **Determine the distribution and status of wood storks in South Florida**. All evidence suggests that the wood stork population in the southeast U.S. is a single population, with individuals moving throughout the landscape in response to habitat conditions; the recovery of wood storks depends on the success of the birds throughout their range. Historically, South Florida supported greater than 70 percent of the nesting wood storks in the Southeast. Recent nesting populations in South Florida average around 10 to 13 percent with the major nesting occurring at the Corkscrew colony. More recent data provided by Ogden (1997) also present evidence that South Florida provides winter foraging grounds for many of the recently developed northern breeding colonies in north Florida, Georgia, and South Carolina. The restoration and enhancement of the South Florida foraging habitat is important to the overall recovery of the wood stork population and the reversal of the decreasing nesting trends in South Florida. Distribution must be monitored into the future to determine wood stork response to Everglades restoration activities.

S1.1. Conduct wood stork annual nesting surveys within the Everglades and Big Cypress Basins and the east and west coast populations. The health and productivity of colonies must be known to evaluate the status and recovery of the wood stork. Long-term wading bird nesting data in South Florida suggest that the number of pairs of birds initiating nesting in a given year is a better indicator of ecosystem health than is nesting success. The number of pairs of wood storks attempting to breed in South Florida should be monitored annually to determine wood stork response to ecosystem conditions in South Florida. Conducting annual nesting surveys within these basins will provide information on annual nesting patterns for wood storks in South Florida and will allow us to best respond with the appropriate management strategies for the species. Much could be learned about wood stork ecology in the Everglades by detailed review of the multi-year systematic reconnaissance flight data. Detailed evaluation of these data is necessary.

S1.2. Locate foraging and roosting habitat. Wood storks take several years to mature to breeding age. The survival of birds during these years is critical. Research that gains a better understanding of where non-breeding birds go in Florida needs to be conducted. Research on what habitats are critical to their survival and what factors may be limiting their survival is also necessary. Identifying important foraging and roosting habitat is critical to the recovery of the wood stork. Recent studies along the Georgia and South Carolina coast have provided valuable information on roosting and foraging behavior (Bryan and Coulter 1995); additional work of this sort is needed in South Florida.

S1.3. Develop standardized census procedures for wood storks nesting in South Florida. Systematic nesting survey protocol should be developed for both the Everglades and Big Cypress basins. This protocol will allow for comparison between years and between basins.

S2. Protect and enhance wood storks in the South Florida Ecosystem through provisions of section 7 of the ESA. The majority of management activities to protect and enhance wood storks in the South Florida ecoregion must occur at an ecosystem level (see habitat-level recovery actions), not a species-specific level; wood storks respond to changing environmental conditions by integrating habitat conditions over a large geographic area and therefore will be more affected by large-scale management practices. However, the review of Federal water management practices through section 7 consultations is one vehicle whose implementation will be imperative to the survival and recovery of the wood stork. Much of the landscape utilized by wood storks in South Florida is subject to Federal and State water management practices; water management of the COE's C&SF project is critical to the survival and recovery of the wood stork. The FWS needs to provide conservation recommendations to enhance habitat conditions for the wood stork throughout the C&SF project. Specific guidance should include operational schedules (water regulation) for Lake Okeechobee, the WCAs, Everglades NP, and Big Cypress National Preserve. The Kissimmee River basin also supports important colonies of wood storks. The water management goals of the Kissimmee River basin may affect foraging and nesting success in these colonies. Proposed land management actions on these restoration lands need to be examined in relation to wood stork habitat requirements.

S3. Conduct research on the biology and life history of wood storks. Recovery efforts for wood storks will be more effective with a complete understanding of population biology, movement patterns, foraging ecology and behavior, the importance of roost sites, and the possible impacts of contaminants on South Florida wood storks. To date, information on nesting patterns and the number of wood storks initiating nesting in South Florida has been collected for some regions in some years. Additional information is needed on wood stork demographics and movement patterns between the colonies and foraging and roosting sites.

S3.1. Determine the productivity of wood storks nesting in South Florida. To estimate the productivity of wood storks, the number of fledged young per nest and the number of fledged young per successful nest must be determined for the major nesting colonies in South Florida during the same breeding cycle.

S3.2. Determine survivorship of wood storks in South Florida. This parameter is one of the least understood, and research on this topic may provide more new insights into population dynamics than any other effort. We need to determine survivorship of fledged young to adulthood to better gauge what amount of productivity is required to maintain or increase wood storks nesting in South Florida. This might be accomplished through a massive multi-year leg banding (or wing tagging) effort in multiple colonies, radio-instrumenting a certain number of birds (with mortality sensors) or possibly by surveys during the non-breeding season to determine the adult:sub-adult ratio.

S3.3. Determine the age structure of the wood stork population in the southeast U.S. This information will be necessary to determine whether the population is sustainable and can be delisted.

S3.4. Determine the movement patterns of South Florida wood stork fledglings and post-breeding South Florida adult wood storks. Movement patterns will provide information on behavior, habitat utilization, and potential critical foraging areas. The survival of fledgling wood storks is dependent on their ability to find suitable foraging areas when they first begin to forage independently. If fledglings must travel great distances to forage, their survival may be hampered. Additionally, understanding the movement patterns of adult wood storks after they complete breeding will answer questions such as: 1) Do adult wood storks “help” fledglings to find suitable foraging sites, and 2) Are there foraging sites within a “critical” distance from breeding colonies in South Florida, or do adult storks, upon completion of breeding, move out of South Florida?

S3.5. Determine foraging ecology and behavior of wood storks. The number of wood storks nesting in South Florida has greatly declined. Information on foraging by wood storks in South Florida needs to be completed to determine the inter-dependence of successful nesting by wood storks in South Florida and the availability of suitable foraging sites. Information from the systematic reconnaissance flights should provide information on foraging distribution for multiple years and should help to answer some questions on the foraging ecology of the wood stork, but additional work must be completed to understand the characteristics of the forage base that are necessary to provide functional wood stork foraging habitat in South Florida.

S3.5.1. **Re-evaluate wood stork foraging studies in Everglades NP**. Studies on the forage base available and utilized by storks in Everglades NP were done in the 1970s. A comparative study should be completed to determine if changes have occurred in the prey base available to wood storks. This issue should again be addressed since this ecosystem is vital to recovery goals, is important as a wintering area for all storks, and has recently been documented to have problems with mercury contamination (Sundlof *et al.* 1994).

S3.5.2. **Conduct studies on the prey base available in areas identified as critical foraging sites during the breeding season.** We need to collect information on the prey base available to wood storks at foraging areas receiving high use during the breeding season. This information should be compared to identical information collected at sites not utilized by wood storks during the same time period.

S3.5.3. **Determine foraging requirements of wood storks during the non-breeding season.** Research concerning the foraging ecology of this species should also examine foraging requirements during the wintering or non-breeding period. In some years, the inland marshes of the Everglades have supported the majority of the U.S. population of wood storks. During the non-breeding seasons in 1985 to 1989, up to 55 percent of the entire U.S. population may have relied on the WCAs (which comprise only a portion of the Everglades system) to meet their foraging requirements (Bancroft *et al.* 1992). Understanding the processes that determine whether storks in the non-breeding season are concentrated on a small area of habitat or dispersed throughout their entire winter range will provide management flexibility and decrease the likelihood of negative impacts to a large proportion of the population during a single season.

S3.5.4. **Continue studies on wood stork nocturnal foraging activities.** Preliminary studies by Bryan (1995) indicate that storks in South Carolina and Georgia are active nighttime feeders. The prevalence of nocturnal foraging activities by this species needs to be studied both seasonally and geographically in South Florida. Nocturnal feeding may be more important for wood storks feeding in tidal marshes than in freshwater marshes, but, if nocturnal feeding by wood storks is significant, regulatory decisions may need to reflect this information to protect wood stork foraging grounds from disturbance "around the clock".

S3.6. **Determine the importance of wood stork roost sites.** Recent surveys of the Georgia and South Carolina coast documented the presence of a large number of stork roost sites, but only a limited number of roosts were inhabited repeatedly by numerous storks. Research concerning the function and use of such sites and habitats in South Florida is needed. If important roost sites are identified in South Florida, protective measures should be developed. These studies could also assess foraging habitats utilized from these sites, thus providing important information about the non-breeding season.

S3.7. Determine the impacts of contaminants on wood storks in South Florida. Potential impacts from contaminants need to be reconsidered in light of recent findings concerning the amount of mercury present in the Everglades Ecosystem and the discovery of severe impacts of DDT/DDE-based estrogen-mimicking compounds on wildlife in a large Florida wetland (Guillette *et al.* 1994).

S3.7.1. Conduct mercury studies on wood storks in South Florida. Studies should be conducted in the South Florida E cosystem to document effects of mercury on wood storks.

S3.7.2. Conduct contaminant studies on wood storks throughout the region. Develop baseline contaminant information from a variety of colony sites throughout the region to determine if further studies are needed.

S3.8. Complete models for the wood stork population. Population viability assessment and risk analysis models should be performed for the wood stork population once the necessary information is acquired. Once completed, the relative importance of the South Florida Ecosystem, and the ability of the wood stork to successfully breed in South Florida, should be determined.

S3.9. Develop models of wood stork colony dynamics in South Florida wetlands. These models are needed as planning tools for improved ecosystem restoration programs. Potentially one important ecological model for the Everglades is a wood stork population dynamics model that is a part of the "Across-Trophic-Level System Simulation" (ATLSS) set of models being developed by the South Florida/Caribbean Field Station of the USGS, BRD.

S4. Monitor wood storks in South Florida. Annual nesting and foraging surveys should be completed for wood storks in South Florida. These surveys will provide the information necessary to monitor the success of ecosystem and species-specific recovery actions. Surveys should be performed on an annual basis within both the Everglades and Big Cypress basins until the species is delisted.

S4.1. Conduct long-term monitoring of the number of wood storks initiating nesting in South Florida, as described by tasks 1.1. and 1.2.

S4.2. Organize systematic censuses of wood stork foraging habitat in the Big Cypress region, comparable to existing censuses (systematic reconnaissance flights) in the Everglades basin. The fact that declines in nesting effort and delays in timing of colony formation have shown similar trends in the Big Cypress basin have been well documented in the Everglades basin suggests that the Big Cypress colonies are dealing with similar kinds of habitat deterioration on the foraging grounds. The location and relative importance of stork foraging grounds in the Big Cypress basin are much less known, and should be determined as a basis for developing protection strategies in this region; this survey would provide the information necessary to monitor the success of both ecosystem and species-specific recovery actions.

S4.3. Continue foraging surveys in the Water Conservation Areas and Everglades NP. This information is necessary to follow the trends of wood storks in South Florida and should be continued until the species is delisted.

S4.4. Initiate and continue demographic surveys, such as colony surveys to determine productivity; additionally, studies to determine survivorship should be continued until enough data have been collected to determine wood stork rates of growth, reproduction, and survival. This information will be critical to determine whether or not the species can be delisted.

S5. Increase public awareness. Wood storks are an indicator species of the Everglades Ecosystem; the health of the Everglades can be measured by the ability of the wood stork to successfully breed in the Everglades. The Maine coastal seabird colony restoration program uses the puffin as its symbol. The wood stork is a symbol of the health of the Everglades and Big Cypress basins and could be used as a barometer of the success of Everglades restoration projects.

S5.1. Increase awareness and appreciation of wood storks through educational materials. Wood storks utilize a variety of wetland habitats and have been identified as an indicator species for the Everglades. Additionally, they are visually unique and generate interest from the general public. Make the wood stork a symbol of the Everglades through the use of environmental education materials and programs.

S5.1.1. Develop and distribute educational materials. Currently, there are several brochures, videos, and educational packets available that focus on wood storks. This information needs to be kept up to date. New educational material should be developed to increase the awareness of a larger audience.

S5.1.2. Develop information for private landowners. Wood storks breeding in the Corkscrew Swamp and in the northern and central Big Cypress basin in South Florida forage in surrounding wetlands, many of which are on private lands. Material explaining wood stork ecology and suggesting management practices benefiting storks should be distributed to private landowners.

S5.1.3. Develop educational materials for schools. Since wood storks occur in Florida, Georgia and South Carolina, it would be cost-effective to develop educational materials that could be used in schools in all three states.

S5.1.4. Develop material for policy makers and elected officials. The wood stork should be included as part of a larger effort to inform and educate South Florida policy makers and elected officials of the importance of maintaining and protecting wetland habitats throughout the Big Cypress and Everglades basins.

S5.2. Provide opportunities for the public to view wood storks in captivity. Maintaining wood storks in captivity should be for the sole purpose of public education, awareness, and research to enhance survival of the species. Currently, there are nearly two dozen American wood storks in captivity in North American zoos and related facilities.

S5.2.1. Maintain captive populations for the purpose of education, awareness, and research. FWS draft policy on controlled propagation sanctions captive propagation of listed species when recommended in an approved recovery plan and supported by an approved genetics management plan. Captive propagation of wood storks is not considered necessary for the purpose of supplementing wild populations through reintroduction programs. Captive breeding and rearing efforts will not be made for this purpose. However, good captive management of wood storks may result in reproduction. The resulting progeny may be used to supplement other captive populations under approval of the FWS. If available space within captive facilities becomes saturated, further production of offspring should be prevented within the scope of laws governing captive endangered wildlife.

S5.2.2. **Develop policy on rescue, rehabilitation and release of injured wood storks.** The FWS, in conjunction with the American Zoological Association, should develop a policy for dealing with wood storks that are rescued from the wild. Adult wood storks are not as frequently received by licensed wildlife rehabilitators as other wetland bird species. Opportunities for rescue may most likely occur when field personnel are in the colonies and witness distress. This may be as a result of nest abandonment when food sources become scarce or when chicks fall out of the nest for reasons such as adult bird interactions or wind storms. Where possible, field personnel should return downed chicks to the nest. When replacement is not viable, the usual protocols for triage and rehabilitation should be followed in placement with a licensed wildlife rehabilitator.

Habitat-level Recovery Actions

H1. **Prevent degradation of existing wood stork habitat in South Florida through identification and protection.** At a minimum, for continued survival of the U.S. population, currently occupied nesting, foraging, and roosting habitat in South Florida must be protected from further loss or degradation. Watersheds supporting natural nesting habitat should remain unaltered, or be restored to function as a natural system if previously altered.

H1.1. **Create distribution maps of important wood stork colony, foraging, and roosting sites in South Florida for protection and restoration.** Important colony sites have been identified for the WCAs and Everglades NP. However, colony sites in the Big Cypress basin are not as well known. Very little is known about roosting sites in South Florida. Identifying all important colony sites, roosting sites, and foraging habitat is critical to the recovery of the wood stork. A GIS database should be developed from data collected by colony, roosting, and foraging surveys, as delineated by species-specific tasks **S1.1** and **S1.3**; a GIS database will aid recovery biologists in targeting areas in need of protection, restoration, or management, and will allow managers and private landowners to more efficiently protect and manage these lands for wood storks.

H1.2. **Prioritize habitats that need protection**. Develop a prioritization scheme to focus protection and restoration efforts on colonies and feeding sites with the greatest degree of threat. Efforts should be made to identify important foraging and roost sites associated with high priority colonies.

H1.3. **Work with private landowners to protect habitat**. Conservation agencies need to recognize the significant contributions that private landowners can make for the protection of wood storks. For example, many of the foraging grounds utilized by storks breeding at the Corkscrew colony in South Florida are in private ownership and are threatened by conversion to citrus farming; the future success of this colony is dependent on maintaining viable foraging habitat within the region.

H1.3.1. **Inform landowners.** Inform all landowners having critical foraging and roost sites (as defined in task **H1.2.**) on their properties. Encourage compliance with existing regulatory mechanisms (see task **H1.6.**).

H1.3.2. **Provide assistance and support to landowners in managing their property for the benefit of wood storks**. Assistance can be in the form of written material explaining best management practices, site visits, local recognition, tax and/or monetary incentives. State and Federal agencies should work with private landowners in an effort to incorporate wood stork feeding habitat into current management practices.

H1.3.3. **Develop management plans for private lands.** Conservation agencies should assist landowners in developing specific management plans for their properties. These management plans should adequately protect sites yet be flexible enough to respond to the changing needs of the landowner. The success or failure of management prescriptions for nesting, roosting, and foraging areas should be clearly documented and reported.

H1.4. **Protect sites from disturbance.** The FWS developed habitat management guidelines for wood storks (Ogden 1990) in an effort to reduce disturbance to colony sites. These management guidelines discuss various types of activities known to disturb nesting wood storks. Additionally, certain types of habitat management activities can adversely impact colony sites. Cypress logging is a potential threat to some colonies. Human disturbance causes wood storks to leave nests, exposing eggs to predation and exposure. Posting or other appropriate protection may provide some benefit to storks nesting or foraging within the Big Cypress and Everglades basins.

H1.5. **Use existing regulatory mechanisms to protect foraging habitat in South Florida.** The central and northern Big Cypress basin historically supported large numbers of nesting wood storks. Presently, much of this historic range is being converted to citrus and pasture for cattle grazing. Coordinated efforts should also be used to seize opportunities to provide enhanced feeding areas through the mitigation process.

H1.5.1. **Review Federal actions for impacts to wood storks.** Wetlands are altered for mining, agriculture, and residential purposes. Permitting authority over such activities is held by local governments, agencies in the State of Florida (DEP, SFWMD) and the Federal government (COE, EPA). Important feeding areas should be included as a category of waters for which the FWS receives COE pre-discharge notification pursuant to section 404 of the Clean Water Act. section 7 of the Endangered Species Act requires that all Federal agencies ensure that their actions are not likely to jeopardize the continued existence of any listed species or destroy or modify their critical habitat. Federal agencies conducting actions that may affect the continued existence of wood storks must consult with the Service.

H1.5.2. **Encourage conservation of wood stork habitat in conservation plans**. Section 10(a) (1)(B) of the Endangered Species Act provides for incidental take permits that have the potential to contribute to the conservation of listed species. If appropriate, applicants should be encouraged to consider conservation of wood stork habitat when preparing Habitat Conservation Plans.

H2. Restore and enhance habitat. A prerequisite for the recovery of wood storks in the southeastern United States is the restoration and enhancement of suitable habitat throughout the mosaic of habitat types used by this species. Historically, South Florida supported greater than 70 percent of the nesting by wood storks in the Southeast. The deterioration of the Everglades and Big Cypress basins has resulted in decreased nesting by wood storks in South Florida and increased nesting in northern Florida, Georgia, and South Carolina.

H2.1. Restore the South Florida Ecosystem. Recover traditional Everglades and Big Cypress colony locations. The water delivery formula and schedules developed by the Experimental Water Deliveries Program, the structural modifications to canals and levees proposed for ecosystem restoration of Everglades NP through the Modified Water Deliveries and C-111 Projects, and the regional Everglades restoration planning process (C&SF Restudy) conducted by the COE, should address the recovery of the ecological processes that made it possible for the pre-drainage Everglades basin to support large numbers of storks and other wading birds. These ecological processes were made possible by the large spatial scale of the pre-drainage Everglades, the strong between-year variation in surface water patterns, and the strong flows of surface water into the estuaries.

H2.1.1. Reevaluate the effectiveness of all authorized projects on restoring habitat in the Everglades basin. The Southern Everglades Restoration Alliance (SERA), a group of cooperating agencies, was created to oversee the implementation of authorized ecosystem restoration projects associated with the C&SF Project. SERA is presently re-evaluating projects in the southern Everglades for their effectiveness in ecosystem restoration. The FWS should be involved in project evaluations, and should determine whether recovery efforts will improve habitat conditions for the wood stork. If any authorized projects are found to lack the necessary components (including the appropriate operational schedules and regulatory components) to increase the ability of the wood stork to successfully nest or forage in South Florida, the FWS should help in the development of alternative designs that maximize ecosystem benefit.

H2.1.2. Develop operational criteria that re-establish hydropatterns of the pre-drainage system. Operational schedules will be the most important component of Everglades restoration efforts. Operational schedules must truly balance the needs for flood protection with those of the Everglades ecosystem.

H2.1.3. Restore the timing of nesting by wood storks in the southern Everglades through ecosystem restoration measures. Develop a restoration plan that includes the necessary addition or removal of structures, levees, and canals, to restore hydropatterns throughout the Everglades system; depths, period of inundation and sheetflow patterns should more closely match those of the pre-drainage system.

H2.1.4. **Provide feedback for adaptive restoration planning.** Monitor stork colony patterns during implementation and testing of future efforts to improve hydrologic conditions. Use information on the location, timing, size and success of stork colonies in the Everglades and Big Cypress basins to evaluate ecological responses to the restoration programs and as a basis for designing future iterations in the restoration process.

H2.1.5. **Analyze and report on existing record of stork colony patterns in the Everglades basin**, including the effects of initial restoration programs on the ecological recovery of Everglades NP. A report should be completed that incorporates all stork colony data from the Everglades basin and which assesses the impacts of past and current restoration programs, such as the Experimental Program of Water Deliveries to Everglades NP, on wood stork and wading bird colony patterns in Everglades NP; this report should be used to evaluate restoration efforts to date, and to improve future restoration programs.

H2.2. **Protect and enhance wood stork foraging habitat in private ownership in South Florida through partnership agreements**. Historically, South Florida supported greater than 70 percent of the wood stork nesting effort in the southeast U.S.; the number of wood storks nesting in South Florida has been reduced to a fraction of the historic number. Every effort should be made to protect and enhance that portion of the population that continues to breed and winter in South Florida. For example, the Corkscrew Swamp colony has consistently supported a significant number of nesting wood storks in South Florida. Many of the surrounding wetlands used for foraging by wood storks in this colony are in private ownership and are in danger of being converted to other land uses, such as citrus farming. Protecting these wetlands will be critical to protect the Corkscrew colony and help to preserve wood stork colonies in South Florida.

H2.3. **Acquire land identified as important habitat for wood storks in South Florida.** Federal and State conservation agencies and private conservation organizations should continue efforts to acquire important habitat utilized by wood storks in South Florida. Initial land acquisition efforts should be carefully targeted to sites having the greatest potential for maintaining storks over time. Large, stable colonies that are in immediate threat from disturbance either through direct threat to the colony site or through a loss of surrounding foraging habitat, should be of highest priority. Priority should also be given to larger colonies with a history of annual use, sites most in need of management, and colony sites where alternate habitat is not available.

H3. **Conduct research on the critical habitat components necessary to trigger successful nesting by wood storks in South Florida.** We do not know what specific habitat characteristics are necessary to trigger nesting by wood storks in South Florida. Wood storks could be responding to a suite of habitat characteristics such as water depth, photoperiod, rainfall patterns, prey densities, *etc*. Projects should be completed that will help to identify some of these habitat characteristics.

H3.1. **Determine the densities, species composition and size classes of fishes necessary to result in successful nesting by wood storks in South Florida.** Use information gathered in task **S3.5** (species-level) to establish study locations. Water management practices may have resulted in fish populations that no longer represent "natural" populations. This information may aid us in developing the appropriate operational criteria for the Everglades restoration. It will also establish a baseline from which to compare the effects of ecosystem restoration activities.

H3.2. **Determine the effects of natural and human-caused hydrologic events on the ecology of the prey base utilized by wood storks in South Florida.** This information can be used to determine the optimal operational schedules for South Florida's public lands.

H3.3. **Determine if reduced freshwater flows into the northern Florida Bay mainland estuaries, as a result of the South Dade Conveyance System and the Experimental Program of Water Deliveries to Everglades NP, have caused wood storks to delay nesting in South Florida.** These mainland estuaries historically provided important early dry season foraging habitat; reduced freshwater flows may have significantly altered available prey base.

H4. Monitor the status of areas identified as important wood stork habitat in South Florida. Monitor habitats identified by task **H1.1**. annually to determine whether changes are occurring in response to management actions. For example, habitats likely to be affected by hydrologic restoration projects should be monitored to determine impacts, both beneficial and adverse, on wood storks. The appropriate management decisions need to be considered, discussed, and implemented if adverse impacts are detected.

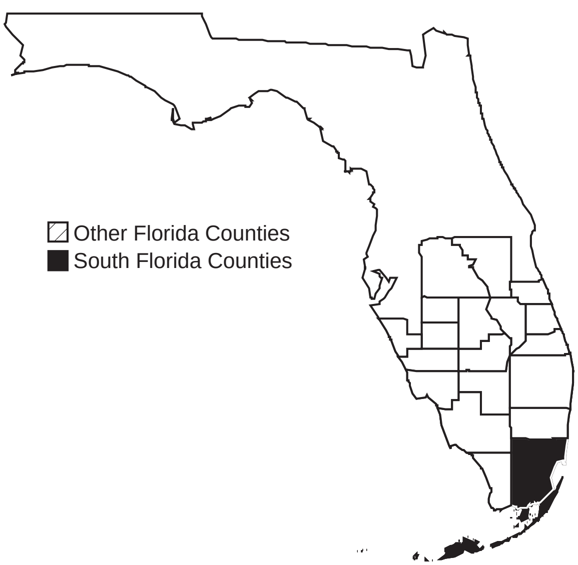
H5. Increase public awareness about wood storks as an indicator of the health of the Everglades Ecosystem. Educational materials should be developed that identify the importance of the wood stork as an indicator of the health of the Everglades Ecosystem. This information will be key to gain the necessary public support for the restoration of the Everglades. The wood stork is a highly visible component of the Everglades and is perfect to serve as an indicator species to the public.

Roseate Tern

Sterna dougallii dougallii

Federal Status:	**Threatened (November 2, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. Florida distribution of the roseate tern; this species occurs from the Florida Keys to the Dry Tortugas.



The roseate tern is a medium-sized, colonial-nesting, marine waterbird with a deeply forked tail. This species is distributed worldwide in a variety of coastal habitats. The North American subspecies is divided into two separate breeding populations, one in the northeastern U.S. and Nova Scotia, and one in the southeastern U.S. and Caribbean. Wintering areas are concentrated along the north and northeastern coasts of South America. It is not known if these two populations winter in proximity to each other. The roseate tern was listed as endangered in northeastern North America and threatened in the Caribbean and Florida in 1987 in response to nesting habitat loss, competition from expanding gull populations, and increased predation. Although both populations experienced severe population declines, it is believed that the northeastern breeding population is under greater threat.

This account represents South Florida's contribution to the range-wide recovery plans for the roseate tern (FWS 1989, 1993).

Description

The roseate tern is a slender bird with a body that is approximately 35 to 40 cm in length. Its tail is deeply forked with white streamers, 15 to 25 cm in length. The wing chord averages 23 cm in length; its wingspan is about 60 cm. The culmen is about 40 mm and the length from the nostril to bill tip averages 28 mm. Both the upper and lower body surfaces are paler than that of the common tern (*S. hirundo*), which is similar in appearance. The three or four outer primaries of their wings are frosted with silver-grey and edged with black. The long tail streamers are pure white.

Common terns and Forster's terns (*S. fosteri*) are similar in size, but are more widely distributed, have less pronounced grayish streamers (Forster's tern) or gray with black margins (common tern), and have different amounts of orange coloration on the bill. Arctic terns (*S. paradisaea*) are also similar in appearance to roseate terns, but are only rare spring migrants in Florida. Roseate terns also have a more rapid wingbeat than these other tern species. Roseates may also be distinguished from these other species by the tail length of a loafing bird, which extends far beyond the wing tips in the roseate (J. Andrew, FWS, personal communication 1996).

Breeding adults are gray above with black caps. The underparts are creamy-white with a blush of pink during the breeding season, the coloration for which this bird was named. The bill is black with varying amounts of the basal portion in orange-red during the breeding season. The amount of red present distinguishes the two breeding populations (Donaldson 1968, Gochfeld 1983, FWS 1989, Nisbet 1989b, Smith 1996). The legs are also red during the breeding season. As with most terns, there is little sexual dimorphism.

In winter, most of the adults lose the tail streamers, the forehead becomes white, the pink blush on the underparts all but disappears, and the legs and bill become black. Both common terns and roseate terns have a dark carpal bar over the bend of the wing in winter plumage, although it is slightly lighter in roseate terns (FWS 1989).

Newly hatched chicks are gray to brown with dark brown or black spots. The legs are purplish at hatching and become black within a few days. Juveniles are brown and gray above with black bill and legs.

Roseate terns can be distinguished by their vocalizations which render it possible to pick them out of a noisy crowd of other seabirds (including common terns). They have loud pure "pink" and "pi-vik" notes as well as a very harsh grating "yaaach" note. Superficially, the call notes of the Caribbean birds sound similar to those of the northeastern population.

Taxonomy

This species is in the order Charadriiformes, family Laridae, subfamily Sterninae. The roseate tern was originally described by Montagu in 1813 from specimens found in the Cumbrey Islands in Firth of Clyde, Scotland (AOU 1983).

There are five subspecies of roseate tern recognized. These five subspecies occur on six continents (Gochfeld 1983) with *S. d. dougallii* being the subject of this species account. The five subspecies described in Gochfeld are: *S. d. dougallii*, *S. d. bangsi* (Malayan peninsula eastward including China, the Phillipines, Molluccas, Straits of Malacca, New Guinea, Solomon Islands, and New Caledonia), *S. d. korustes* (India and Ceylon eastward to the Malayan peninsula), *S. d. arideensis* (Seychelles and Madagascar), and *S. d. gracilis* (Australia).

Distribution

The global distribution and status of the roseate tern is summarized in more detail in Nisbet (1980) and Gochfeld (1983). The Caribbean population of the roseate tern breeds from Florida through the West Indies to islands off Central America and northern South America. Roseate terns also breed in the Palearctic, Indian Ocean, southern Africa, and Australia. In addition to the North American population, roseates occur in Europe and southern Africa.

These populations are also endangered (Randall and Randall 1980). The status of the species in Florida has been reviewed by Robertson (1978) and Smith

Roseate tern.
Original photograph courtesy of Mark Robson.

(1996). Approximately 300 pairs currently breed between Marathon and the Dry Tortugas (Figure 1), though none have nested at the Dry Tortugas for over ten years (W.B. Robertson, Jr. former NPS and USGS/BRD biologist, personal communication 1998).

Nisbet's analysis of band returns confirmed that the northeastern roseate terns winter from western Columbia to eastern Brazil between 11 degrees north latitude and 13 degrees south latitude. Most of the Caribbean birds probably winter further to the south; two birds banded in the Virgin Islands were recovered in Guyana (Nisbet 1984).

Habitat

Strictly a coastal species, this bird is usually observed foraging in nearshore surf. In the winter, the roseate tern is pelagic in its habits. Open sandy beaches isolated from human activity are optimal nesting habitat for the roseate tern. A variety of substrates, including pea gravel, open sand, overhanging rocks, and salt marshes are used. In the northeastern U.S., roseates nest on beaches, barrier islands, and offshore islands (FWS 1989). In extreme southern Florida, roseate terns typically nest on isolated islands, rubble islets, dredge-spoil, and rooftops (M. Robson, GFC, personal communication 1994, Smith 1996). Caribbean birds use a variety of substrates, including open sand and coral rubble, rocky cliffs, and low islands. Nesting sites may be densely vegetated or bare (J.Saliva, FWS, personal communication 1997). Varying amounts of debris and vegetation may be present in the nesting area.

Roseate terns sometimes nest on open sand with minimal vegetative cover in much of the tropics, as on the Great Barrier Reef, Australia (Hulsman 1977). They occasionally do this in the northeast, but some cover (*e.g.*, rocks, crevices, vegetation, old tires) seems to be preferred (Spendelow 1982, Burger and Gochfeld 1988a). Artificial structures have been used as well; at least three rooftops in the middle and lower Florida Keys have been exploited by nesting roseates in the past (P. Frank, GFC, personal communication 1996, Smith 1996).

Behavior

Courtship

No information is available on courtship behavior of roseate terns. However, least terns (*S. antillarum*) engage in various pair bonding and courtship activities including: courtship flights, fish flashing and feeding, courtship dances, nest site selection behaviors, and test scraping prior to copulation.

Reproduction

In the Caribbean, roseate terns breed primarily on small offshore islands, or marine rocks, cays, and islets (Burger and Gochfeld 1988b, Norton 1988). Rarely do they breed on large islands (*e.g.*, Punta Soldado, Culebra in 1989 and 1991). On Culebra and the Virgin Islands, the birds constantly shift locations from year to year, both within the U.S. Virgin Islands (USVI) and between the USVI and British Virgin Islands (BVI). The occurrence of large numbers of breeding birds in the USVI has coincided with lower numbers in the BVI and vice-versa, suggesting intermixing between these populations (FWS 1993). Fidelity to a natal colony, or site tenacity to a previously used colony where the birds have reproduced successfully, may be as important as preference for a particular habitat (Spendelow 1989).

In Florida, breeding site location is dependent on the distribution and abundance of islands with open sandy or broken coral substrates (Robertson 1978, Smith 1996). Other important factors include absence of predators and minimal amounts of human disturbance.

Nisbet (1980 and 1989a) reviewed accounts of roseate tern habitat use in the northeast. Although the northeastern roseate terns typically nest under vegetation or other shelter (Spendelow 1982), this is not characteristic of the Caribbean birds. Roseate terns in the Caribbean have been reported nesting near vegetation or jagged limestone rock (Robertson 1978, Voous 1983, Burger and Gochfeld 1988b), on open sandy beaches (Robertson 1978), close to the waterline on narrow ledges of emerging rocks, or among coral rubble (FWS 1993). Although they may nest on slopes with up to a 70 degree angle, they generally seek flat or even back-sloping ledges for their nests. Most of them add little or no material to the nests, but lay their eggs directly on the ground, rock, or vegetation (FWS 1993).

In the northeastern U.S., clutch size ranges from 1.2 to 1.8 with one and two egg clutches most common (Gochfeld 1983). Average clutch sizes for the Caribbean population have been reported between 1.31 to 1.71 (Nisbet 1981, Norton 1988) eggs per nest. Roseate terns in Puerto Rico and the USVI usually lay one or two eggs. Three-egg clutches are a rarity. Voous (1983) reported clutch sizes of one to two with a single nest containing three eggs. Robertson (1978) reported a usual clutch of two eggs in the Dry Tortugas. Hartert (1893) reported a full clutch size of three eggs, but this was probably unusual.

Shelter for chicks may be found near nests (*e.g.*, short vegetation, rocks, crevices); however, most nests are completely exposed. Therefore, eggs and young chicks are vulnerable to predators when the parents are off the nest. On some islands, there is basically no shelter or they are occupied by other tern species (*e.g.*, Cayo Molinos, Culebra), whereas in other islands plenty of cover is available (*e.g.*, Cayo Turrumote, southwest Puerto Rico). This may account in part for the differences in breeding success and site fidelity among colonies.

In general, roseate terns in the Caribbean begin egg laying in May and have downy chicks in June. In Culebra and the USVI, egg laying usually begins in mid-May and hatching occurs from mid-June through early July. Chicks that hatch in May usually fledge in July. Roseate terns may abandon a nesting area, re-lay on the same island, or move to as many as three different islands in one breeding period. Sometimes laying may be reinitiated as late as mid-July, after the terns have attempted to nest on several islands (FWS 1993). In 1988 and 1989, unsuccessful nesters on Cayo Raton and Cayo Yerba apparently moved to Cayo Molinos late in the season to renest. The factors influencing abandonment of a colony site are not well known and need further study. Roseate terns tend to be late nesters for terns; nest initiation usually occurs in the latter part of May or early June (Robertson 1978). Renesting attempts have occurred as late as early to mid July (W.B. Robertson, Jr., former USGS/BRD biologist, personal communication 1996).

Roseate tern eggs are quite variable in color, but are generally brownish with speckles and streaks of blackish brown. The eggs are cryptic on the rocky substrate. Voous (1957) describes them as lighter, more finely spotted, more pointed, and less conical in shape than *S. hirundo* eggs.

Both sexes incubate, brood, and feed their young. In the Puerto Rican colonies, incubation lasts 23 to 25 days (FWS 1993). Wagner and Safina (1989) discuss the role of the male and female in caring for chicks.

Roseate tern chicks grow rather rapidly. In the northeast, they reach a maximum weight of about 100 to 108 g by 22 days, very close to the time at which they fledge. The young birds fledge between 22 and 29 days of age (Nisbet 1981). Chick growth has been considered a useful indicator of food availability. Safina *et al.* (1988) documented prey abundance through the use of sonar and established that roseate tern chicks grew more quickly in a year with greater food availability.

Burger and Gochfeld (1988a) suggest that breeding roseate terns, which are much less aggressive than common terns, gain anti-predator benefits from associating with more aggressive species. However, roseates in the Caribbean often associate with less aggressive species, such as sandwich and sooty terns. Roseate terns at Culebra approached closer to people and made three times as many dives, while twice as many birds dove at intruders compared with roseate terns of the northeastern population at Cedar Beach (Burger and Gochfeld 1988a). This same aggressive behavior towards human intruders has been observed in roseate terns elsewhere in the Caribbean (FWS 1993). Similarly, Voous (1983) found roseate terns in Aruba quite aggressive, although they did not actually strike humans. These differences in aggressive behavior may be related to the presence of potential predators (*e.g.*, frigatebirds), the degree of predation at the different colonies, or the absence of a more aggressive species nesting in the same breeding area.

Foraging

Northeastern roseate terns tend to specialize in small, schooling marine fish (Bent 1921, Richards and Schew 1989). At the Parguera colonies (southwestern Puerto Rico), roseate terns feed on a variety of fish species such as dwarf herring (*Jenkinsia lamprotaenia*), thread herring (*Opisthonema oglinum*), halfbeak (*Hyporamphus unifasciatus*), young mackerel, and small squid (Nisbet 1981, Duffy 1986, Kirkham and Nisbet 1987, Safina *et al.* 1988, FWS 1993).

Feeding roseates tend to fly into the wind or hover over schools of fish at heights of up to 20 m (FWS 1989). Feeding is accomplished by plunge-diving to seize the fish in the bill, with feeding birds sometimes submerging completely. If feeding chicks, adult terns return to the colony carrying the single fish in their beaks. Nisbet (1989a) noted that roseate terns in the northeast may fly up to 20 km from the colony to fish, returning with a single fish, usually in the size range of 60 to 100 mm. Safina *et al.* (1988) found that roseate terns laid earlier, delivered more fish to the nest, and had better chick survival in a year with greater fish availability. Additionally, some roseate terns specialize in piracy from other terns (Dunn 1973).

Post-breeding

The few observations obtained on the post-breeding activities of the Caribbean roseate terns suggest that their post-breeding behavior is similar to that of roseate terns in the northeast. Chicks move with their parents to offshore cays near their natal colonies (FWS 1993) and accompany adults during feeding excursions. Chicks continue to be fed by the adults for at least a week after fledging. Aggregations of up to 130 post-breeding roseate terns, were observed near Mary Point on the north coast of St. John, USVI, and 40 adult and juvenile roseates at Great Thatch Island, not far from a suspected roseate colony at jost Van Dyke, BVI (FWS 1993).

The northeastern population stages in large flocks on barrier beaches in August with most birds departing on their southward migration by mid-September (FWS 1989). Migrants have been found in the West Indies in September and October. Nisbet (1984) summarized band recoveries of wintering roseate terns in South America. In Guyana, most band recoveries occurred in October through the winter, whereas in Brazil, they occurred in November.

Migration and Wintering Habits

Very little is known about the spring migration and arrival of the roseate terns to their Caribbean colonies. Roseate terns are absent from most of the Caribbean after the breeding season, returning in late April or early May.

They have been identified during migration in several coastal counties in Florida. Cruickshank noted them moving through Brevard County between April 23-June 29 and August 31-October 1 (Stevenson and Anderson 1994).

Nisbet (1984) suggested that Caribbean roseate terns mingle with the northeastern birds in South American waters. The fact that three out of the five recoveries are from Guyana, where many of the northeastern birds apparently winter, is consistent with his suggestion. “Leapfrogging” in migratory birds is well-established, with the more northern populations wintering further south. Hence, Caribbean roseate terns may maintain a discrete wintering area, perhaps in the southern Caribbean. The northeastern birds are known to winter from Colombia to Brazil (Hamilton 1981, Trull 1988). Bands have been recovered from birds trapped at night for food, particularly in Guyana. Immature birds and most first year birds generally do not migrate northward, but remain on wintering areas (Nisbet 1984).

Saliva reported a flock of about 55 roseate terns and a common tern approximately half a mile off Mary Point, St. John, on October 8, 1992 (FWS 1993). Most roseates in that flock were adults in winter plumage. He also observed a flock of some 65 roseate terns, one common tern, and two black terns (*Chlidonias niger*) feeding about 3 km off the coast of Ponce, Puerto Rico, on October 9, 1992. Roseates in that group were mostly adults in winter plumage, although several had tail streamers and bright orange legs. During January 1993, Saliva observed, on several occasions, roseate terns in a mixed group of roosting sandwich terns (*S. sandvicensis*), brown pelicans (*Pelecanus occidentalis*), snowy egrets (*Egretta thula*), and ruddy turnstones (*Arenaria interpres*) at Mayaguez Bay, Mayaguez, Puerto Rico. These observations suggest that at least some roseate terns remain in the vicinity of the coast of Puerto Rico, rather than traveling to South America.

Bent (1921) reported that roseate terns winter in the Caribbean and in northern South America, based on the distribution of collected specimens. Through the end of 1978, more than 94,000 roseate terns had been banded in North America, mostly as chicks (Nisbet 1989a), and 1,185 bands had been reported. Birds banded before and after 1958 show different patterns of recoveries (Nisbet 1989a). A total of 358 roseate terns have been reported in the Caribbean or South America, 51 in the Greater Antilles (most before 1957), 12 in the Lesser Antilles (most after 1946), and 295 in South America (60 percent in Guyana from 1967 to 1976). By contrast, only 1,678 roseate terns have been banded in the Caribbean, all but one were chicks of various ages. Of these, only five have been recovered, and for one of these taken at sea there is no locality data. In 1991, a total of 287 roseate terns were banded in Puerto Rico, 16 at Culebra and the rest at La Parguera. Continued banding of adults and chicks in the northeast and Caribbean regions will increase the likelihood of recoveries of banded birds. This might permit determination of migratory pathways, staging areas, and wintering areas as well as intercolony movement within the Caribbean population (FWS 1993).

Relationship to Other Species

As a colonial nester, roseate terns have been observed nesting among least terns at Truman Annex in Key West (A. Scheutz, USN, personal communication 1994) and on roofs in Marathon (P. Frank, GFC, personal communication 1996). Nesting roseates in the northeast most often nest in association with common terns (Nisbet 1981, 1989b; FWS 1989). Caribbean birds are known to nest in association with sooty or bridled terns (*S. fuscata* and *S. anaethetus*) (Robertson 1978, Nisbet 1981 and 1989b). In southern Asia, roseates occur in mixed colonies of swift and black-naped terns (*S. bergi* and *S. sumatrana*). In East Africa, roseates nest in colonies dominated by sooty, bridled, and white-cheeked terns (*S. repressa*). Britain's roseate terns nest with other terns or black-headed gulls (*Larus ridibundus*); Australian birds are known to nest with Australian fairy terns (*S. nereis*) and black-naped terns.

Status and Trends

Nisbet (1980) and Gochfeld (1983) have compiled the available information on the worldwide distribution and status of roseate terns, however, no recent compilation of status has been made. Data on population trends for North American and European populations (both belonging to subspecies *dougallii*) clearly document the drastic decline of the species. Some of these data are quantitative in nature; some inconsistency with the level of decline may be due to sampling techniques (Gochfeld 1983). Data on most tropical populations are less extensive; it cannot be ascertained whether populations are stable or declining (Halewyn and Norton 1984).

In the Caribbean, there are few published data on colony sizes and the only long-term history is that recorded for the Dry Tortugas population (Robertson 1964). The history of the northeastern population has been summarized (Nisbet 1980; 1989a, Gochfeld 1983, Kirkham and Nettleship 1987). These accounts document the dramatic reduction of all species of terns in the late l9th century due to market hunting, egging, and harvest for the millinery trade. In the U.S., nearly universal bird protection was instituted in 1918 with the passage of the Migratory Bird Treaty Act, which significantly curtailed exploitation. Following protection, roseate tern populations slowly recovered until the 1950s and 1960s when a somewhat erratic decline began. In the 1970s, the decline became alarming, particularly in the face of a general increase in the population of common terns with which the roseates nest (Buckley and Buckley 1981).

Although historical estimates for the Caribbean population of the roseate tern have been poorly documented, Nisbet (1980) estimated the total West Indies breeding population at greater than 2,000 pairs in 1976 and less than 1,500 pairs in 1979. Robertson (1978) estimated the Florida breeding population at 250 to 300 breeding pairs. Kushlan and White (1985) censused three sites in the Florida Keys in 1976 and found 370 nests. Robertson and Wolfenden (1992), estimated the number of breeding pairs in Florida at 350. Robson and Kalla reported counts ranging from 137 pairs in 1991 to 278 pairs in 1992 at Pelican Shoal off Key West; Ricardo Zambrano reported 317 pairs at Pelican Shoal in 1998 (GFC, personal communication 1998).

The decline in roseate tern during the 1970s led to its listing in 1987 for both the northeastern and Caribbean populations (54 FR 2068). The final rule for this listing identifies the loss of nesting sites, competition from other colonial nesters, and predation as threats to the species.

Breeding terns confront a variety of adversities, some of which directly affect adult birds, nests, eggs, and young. Others affect the ability of the adults to obtain sufficient food to produce a large clutch or to feed their young. Among the direct impacts are predation, storms, tidal inundation, flooding, or prolonged periods of cold wet weather which destroy the nests, eggs, or young. In addition, habitat alteration or destruction is a major factor affecting roseate terns in Florida.

In the Caribbean, potential predators include magnificent frigatebirds (*Fregata magnificent*), laughing gulls (*L. atricilla*), red-tailed hawks (*Buteo jamaicensis*), peregrine falcons (*Falco peregrinus*), American kestrels (*F. sparverius*), short-eared owls (*Asio flammeus*), cattle egrets (*Bubulcus ibis*), night herons (*Nycticorax nycticorax* and *N. violaceus*), ruddy turnstones, American oystercatchers (*Haematopus palliatus*), mockingbirds (*Mimus gilvus*), hermit crabs (*Coenobita clypeatus*), land crabs (*Geocarcinus ruricola*), marine or sally lightfoot crabs (*Grapsus grapsus*), feral cats, rats, and snakes (*Alsophis* spp.) (FWS 1989). Shealer and Burger (1992) observed at Cayo Raton, Culebra, several successful attacks on roseate tern chicks by laughing gulls and American kestrels. In addition, Saliva (FWS, personal communication 1997) observed an oystercatcher feeding repeatedly on roseate tern eggs in 1995.

One of the most significant and recurrent mortality factors is human interference during nesting. Humans may take eggs for food or linger on nesting islands during critical phases of the nesting cycle (FWS 1993). Human-related disturbance, such as camping, has been a problem at Pelican Shoal (P. Frank, GFC, personal communication 1996, H. Smith, DEP, personal communication 1989).

Nisbet (1989a) reported that roseate terns tend to shift colonies quickly in response to predation or reproductive failure. The number of potential predators found in or near some of the Caribbean roseate tern colonies may be an important factor explaining the poor colony-site fidelity, aggressive behavior, and lower reproductive success of this species in some of those areas.

Egging, the collecting of eggs for food or sale, is perhaps the greatest factor threatening many of the Caribbean colonies (Halewyn and Norton 1984, FWS 1993). Human residential, commercial, and recreational activity in proximity to tern colonies is a potentially significant source of disturbance to breeding terns. Although terns can acclimate to such activity, it may nonetheless cause chicks to run from nesting ledges or may keep adults off their nests, thus increasing the likelihood of egg predation or exposure of the eggs to heat or cold. Human presence in proximity to nesting colonies may also increase the number of human-associated predators, such as black rats and feral cats.

Management

In South Florida, the GFC, DEP, and National Audubon Society have worked cooperatively to designate Pelican Shoal as a Critical Wildlife Area under GFC rule-making authority. This designation, in July 1990, affords the site the maximum protection available under Chapter 39 of the Florida Administrative Code.

Staff at Everglades NP have instituted a rat control program on Bush Key. Though this on-going effort has benefitted brown noddies (*Anous stolidus*) and possibly sooty terns, roseate terns have not nested. Historically, this site was the primary nesting location for roseate terns in South Florida. Continuing this management action may eventually restore Bush Key as a safe alternate nesting site for roseate terns.

The FWS, DOT, and DEP are developing plans to establish a roseate tern nesting colony on a section of the abandoned U.S. 1 bridge near Pigeon Key just west of Marathon, Florida.

Literature Cited

American Ornithologists Union [AOU]. 1983. Checklist of North American birds. American Ornithologists Union, Baltimore, Maryland.

Andrew, J. 1996. Comments on draft species account. December 5, 1996.

Bent, A.C. 1921. Life histories of North American gulls and terns. U.S. National Museum Bulletin 113:1-337.

Buckley, P.A., and F.G. Buckley. 1981. The endangered status of North American roseate terns. Colonial Waterbirds 4:166-173.

Burger, J., and M. Gochfeld. 1988a. Defensive aggression in terns: effect of species, density, and isolation. Aggressive Behavior 14:169-178.

Burger, J., and M. Gochfeld. 1988b. Nest-site selection by roseate terns in two tropical colonies on Culebra, Puerto Rico. Condor 90:843-851.

Donaldson, G. 1968. Bill color changes in adult roseate terns. Auk 85:662-668.

Duffy, D.C. 1986. Foraging at patches: interactions between common and roseate terns. Ornis Scand. 17:47-52.

Dunn, E.K. 1973. Robbing behavior of roseate terns. Auk 90:641-651.

Florida Game and Fresh Water Fish Commission [GFC]. 1998. Comments on the Technical Agency Draft Multi-Species Recovery Plan for the threatened and endangered species of South Florida. October 27, 1998.

Frank, P. 1996. Telephone communication. June, 1996.

Gochfeld, M. 1983. World status and distribution of the roseate tern, a threatened species. Biological Conservation 25:103-125.

Halewyn, R. van, and R. Norton. 1984. The status and conservation of seabirds in the Caribbean. Pages 169-222, *in* J.P. Croxall, P.G.H. Evans and R.W. Schreiber, eds. Status and Conservation of the World's Seabirds, ICBP Tech Publ. No. 2.

Hamilton, J. 1981. Recoveries of wintering roseate terns. Journal of Field Ornithology 52:36-41.

Hartert, E. 1893. On the birds of the islands of Aruba, Curacao, and Bonaire. Ibis 5:289-338.

Hulsman, K. 1977. Breeding success and mortality of terns at One Tree Island. Great Barrier Reef. Emu 77:49-60.

Kirkham, I.R., and D.N. Nettleship. 1987. Status of the roseate tern in Canada. Journal of Field Ornithology 58:505-515.

Kirkham, I.R., and I.C.T. Nisbet. 1987. Feeding techniques and field identification of Arctic, common and roseate terns. British Birds 80:41-47.

Kushlan, J.A., and D. White. 1985. Least and roseate tern nesting in the Florida Keys. Florida Field Naturalist 13:98-99.

Nisbet, I.C.T. 1980. Status and trends of the roseate tern (*Sterna dougallii*) in North America and the Caribbean. U.S. Fish and Wildlife Service, Contract Report 50181-084-9, Newton Corner, Massachusetts.

Nisbet, I.C.T. 1981. Biological characteristics of the roseate tern *Sterna dougallii.* Unpublished report prepared for the U. S. Fish and Wildlife Service; Newton Corner, Massachusetts.

Nisbet, I.C.T. 1984. Migration and winter quarters of North American roseate terns as shown by banding recoveries. Journal of Field Ornithology 55:1-17.

Nisbet, I.C.T. 1989a. Status and biology of the northeastern population of the roseate tern *Sterna dougallii*: a literature survey and update 1981-1989. Report prepared for U.S. Fish and Wildlife Service, Massachusetts.

Nisbet, I.C.T. 1989b. The roseate tern. Pages 478-497 *in* W.J. Chandler and L. Labate, eds. Audubon Wildlife Report 1989/1990. Academic Press, Inc.; San Diego, California.

Norton, R.L. 1988. Extra-egg clutches and interspecific egg-dumping of the roseate tern (*Sterna dougallii*) in the West Indies. Florida Field Naturalist 16:67-70.

Randall, R.M., and B.M. Randall. 1980. Status and distribution of the roseate tern in South Africa. Ostrich 51:14-20.

Richards, S.W., and W.A. Schew. 1989. Species composition food brought to roseate tern chicks on Falkner Island, Connecticut in summer 1984. Connecticut Warbler 9:1-5.

Robertson, W.B., Jr. 1964. The terns of the Dry Tortugas. Bulletin of the Florida State Museum of Biological Science 8:1-95.

Robertson, W.B., Jr. 1978. Roseate tern. Pages 39-40 *in* H.W. Kale, ed. Rare and Endangered Biota of Florida vol. II: Birds, University Presses of Florida; Gainesville, Florida.

Robertson, W.B., Jr. 1996. Telephone communication, 1996.

Robertson, W.B., Jr. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. August, 1998.

Robertson, W.B., Jr., and G.E. Woolfenden. 1992. Florida bird species: an annotated list. Florida Ornithological Society; Gainesville, Florida.

Robson, M. 1994. Telephone communications, 1994.

Safina, C., J. Burger, M. Gochfeld and R.H. Wagner. 1988. Evidence for prey limitation of common and roseate tern reproduction. Condor 90:852-859.

Saliva, J. 1997. Comments on draft species account, 1997.

Scheutz, A. 1994. Telephone communication and site inspection, April 1994.

Shealer, D.A., and J. Burger. 1992. Differential responses of tropical roseate terns to aerial intruders throughout the nesting cycle. Condor 94:712-719.

Smith, H.T. 1989. Memorandum to A. Lazar, Florida Department of Natural Resources, 11 December 1989.

Smith, H.T. 1996. Roseate tern. Pages 246-256 *in* J. A. Rodgers, H. W. Kale, and H. T. Smith, eds. Rare and Endangered Biota of Florida vol. V: Birds. University Press of Florida; Gainesville, Florida.

Spendelow, J.A. 1982. An analysis of temporal variation in, and the effects of habitat modification on, the reproductive success of roseate terns. Colonial Waterbirds 5:19-31.

Spendelow, J.A. 1989. Post-fledging survival and natal vs. non-natal colony-site recruitment of breeding roseate terns (*Sterna dougallii*) at Falkner Island, Connecticut. Colonial Waterbirds 14:108-115.

Stevenson, H.M., and B.H. Anderson. 1994. The birdlife of Florida. University Press of Florida; Gainesville, Florida.

Trull, P. 1988. The roseate tern in Massachusetts. Massachusetts Wildlife 38(3):22-31.

U.S. Fish and Wildlife Service [FWS]. 1989. Roseate tern recovery plan-northeast population. U.S. Fish and Wildlife Service; Newton Corner, Massachusetts.

U.S. Fish and Wildlife Service [FWS]. 1993. Caribbean roseate tern recovery plan. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Voous, K.H. 1957. The Birds of Aruba, Curacao and Bonaire. Studies Fauna Curacao and Other Caribbean Islands No. 29:1-250.

Voous, K.H. 1983. Birds of the Netherlands Antilles. De Walburg Pers; Utrecht.

Wagner, R.H., and C. Safina. 1989. Relative contribution of the sexes to chick feeding in roseate and common terns. Wilson Bulletin

Recovery for the Roseate Tern

Sterna dougallii dougallii

Recovery Objective: DELIST the species once recovery criteria are met.

South Florida Contribution: MAINTAIN and increase the South Florida population.

Recovery Criteria

The current population estimate for the roseate tern in Florida is 300 breeding pairs. The objective of this recovery plan is to maintain or increase this number. This objective will be achieved when: the four major colony sites (Pelican Shoal, Vaca Rock, Truman Annex, and the Marathon Governmental Center) are protected from existing threats; these colony sites are managed to reduce losses of eggs, young, and adult roseate terns, and increase colony productivity; potential nesting habitat is restored or rehabilitated to provide additional colony sites for the roseate tern; conservation programs to maintain, protect, and enhance these and additional colony sites are implemented; and studies of the breeding biology and reproductive success of roseate terns in Florida indicate the population has sustained a rate of increase (r) equal-to or greater-than 0.0 as a 2-year running average for five consecutive years.

Species-level Recovery Actions

S1. **Search for colony sites. Given the intercolony movement reported for some roseate terns in the Caribbean, it is possible that other colony sites may be used.**

S1.1. **Identify and evaluate potential colony sites.** Based on characterization of the preferred habitat type, and on an evaluation of areas that have not been thoroughly surveyed, potential colony sites should be identified and surveyed to determine their level of use and value as alternate sites.

S1.2. **Resurvey historical colony sites throughout South Florida.** Conduct surveys during the nesting season throughout the Florida Keys and the Marquesas Keys and continue annual surveys in the Dry Tortugas.

S2. **Protect and enhance roseate terns in South Florida.**

S2.1. **Control predators.** The presence of predators at roseate tern colonies may result in nest abandonment or direct predation on eggs, young, or adult terns. Therefore, the effect of potential predators on breeding roseate terns should be evaluated and appropriate management techniques implemented to prevent or deter predators.

S2.1.1. **Control avian predators**. Individual avian predators may specialize in preying on terns, and may regularly visit tern nesting areas to feed. Whenever possible, these nuisance birds should be scared off or trapped and relocated away from tern colonies. If these measures prove unsuitable, shooting or poisoning of the nuisance bird may be considered. Federal and State permits are required to remove these birds.

S2.1.2. **Control mammalian predators.** The remoteness of roseate tern nesting colonies provides protection to the terns against mammals. However, in the Florida Keys, raccoons and rats may be able to swim out to colony sites. Also, rats may be a factor in most South Florida colonies except the Outer Tortugas, Keys, and probably Pelican Shoal. Trapping, removal, and poisoning of these animals are some of the protective measures necessary to prevent loss of terns to these predators.

S2.1.3. **Control crabs. Hermit and land crabs prey upon hatchlings and very young terns.** However, it seems as if chicks are vulnerable to these predators only when the adult terns are absent from the nest area. Otherwise, adults usually prevent crabs from getting close to the nests. In cases where crabs are too abundant, or when other disturbances keep adult terns away from the nests, trapping and relocation of crabs may be desirable.

S2.1.4. **Control ants.** Some species of ants (e.g., *Solenopsis invicta*) may kill young terns when eggs are pipping or soon after hatching. The use of ant poisons or traps in areas of high densities of these insects may be necessary.

S2.1.5. **Prevent human disturbance of tern nesting colonies.** Providing law enforcement personnel prior to, and during, the nesting season should be combined with education of Florida Keys residents and tourists to prevent human disturbance on important sites.

S3. Conduct research on the biology and life history of the roseate tern in Florida.

S3.1. **Develop a color banding program.** Color banding would help assess the relationship between the roseate terns found in Florida and those found in the Caribbean. Localized movements and site fidelity would also be identified.

S3.2. **Conduct studies of the breeding biology and reproductive success of roseate terns in Florida.** More intensive studies including food availability, hatching success, fledging success, causes of mortality, interspecific interactions, and impacts of contaminants on breeding terns should be included in these studies.

S3.3. **Determine food availability.** Where possible, prey species favored by roseate terns should be ascertained. This may involve direct observations of feeding birds, observations at the nesting colony, fish brought to chicks or dropped at nests, or regurgitation samples.

S3.4. **Determine hatching and fledging success.** Clutch size, and hatching and fledging success should be determined. The number of eggs hatched, as well as the number of chicks surviving to the fledging stage, should be monitored throughout the breeding season.

S3.5. **Determine causes of mortality and colony failure.** For each colony, the causes of reproductive failure should be documented. After determination of the causes of mortality, the best method to protect the site should be identified, and a plan drawn up which can be implemented effectively.

S3.6. **Determine post-breeding dispersal**. To date we have no information on this important aspect of roseate tern life history.

S3.7. **Assess post-breeding dispersal of adult and young roseate terns.** A survey of non-breeding roseate terns will be useful in determining important post-breeding sites. Where roseate terns are sighted, species identification should be confirmed, and whenever possible, bill coloration and color band combinations, if present, should be documented.

S4. **Conduct annual surveys and monitor colony sites to determine the number of nesting roseate terns.** The monitoring protocol should be compatible with that for the Caribbean basin. Surveys should include estimates of nests or nesting pairs, and estimates of adult and young terns present at the colony.

S5. **Educate the general public on roseate terns.** The public, especially locals need to be informed of the need to avoid roseate tern colony sites during the nesting season. Pelican Shoal is particularly subject to this disturbance. An educational program should be developed to target Lower Keys residents on the duration of the roseate tern nesting season, and the need for cooperation in eliminating human disturbance from this site.

S6. **Refine recovery goals**. As additional information on the biology, ecology, and management of roseate terns is gathered, it will be necessary to better define, and possibly modify, recovery goals.

S6.1. **Determine the importance of Florida's colonies to the Caribbean population and adjust recovery goals accordingly.**

S6.2. **Determine what additional actions, if any, are required to achieve recovery objectives.** If there are any actions not included in this recovery plan which, during the recovery process become recognized species' needs, they must be incorporated into the plan.

Habitat-level Recovery Actions

H1. **Protect and manage roseate tern nesting sites to prevent population decline and increase productivity.** A stable population of roseate terns can only be obtained when breeding colonies are appropriately protected. The protection of currently known breeding areas should be given the highest priority.

H1.1. **Develop protection programs for known colony sites.** A conservation program should be developed for the protection of Florida's roseate tern colony sites. Posting, regular patrolling during the breeding season, limiting recreational use, and techniques for predator control are examples of programs necessary to achieve protection of breeding terns.

H1.2. **Educate the public on protection and conservation of roseate terns and their habitat, and regulations pertaining to this species' survival.** Governments and agencies with jurisdiction over roseate tern colonies should become involved in the education of the public on the importance of protecting this species and adhering to Federal or local regulations. This could involve the preparation of an illustrated brochure to be distributed to local groups, schools, and organizations.

H1.3. **Implement management strategies at breeding colonies, if necessary.** Management of breeding habitat may be necessary to increase tern reproductive success, particularly when coupled with predator control programs.

H1.3.1. **Manipulate vegetation.** Based on the available information on roseate tern habitat selection in Caribbean colonies, it appears as if the preferred nesting areas have little or no vegetative cover. Therefore, vegetative encroachment in nesting areas should be controlled by removing excessive vegetative cover.

H1.3.2. **Provide chick shelters, if appropriate.** Chick shelters may be important at some colony sites to afford the chicks an opportunity to avoid heat stress and predators. They may be constructed of 4 inch diameter PVC pipe, Spanish roofing tiles, or scrap wood.

H2. **Provide suitable nest sites where necessary.** In otherwise suitable areas where roseate terns breed, sometimes nearby shelters such as rocks, boulders, or logs are not available. This situation renders eggs and younger chicks vulnerable to predators. Artificial shelters (e.g., nest boxes, tires, logs, coral crevices, ceramic roof tiles) should be provided were natural shelters are scarce. Roseate terns usually select areas where a depression can be excavated (soft terrain), or where a natural cavity exists. In cases where these are not available, artificial shelters can be provided.

H2.1. **Promote nesting at former colony sites**. Areas known to have harbored roseate tern colonies should be evaluated to determine what management techniques may be necessary to bring the habitat to its former state, or to conditions suitable for nesting roseate terns. Once this is achieved, roseate tern decoys may be placed in these areas prior to the arrival of breeding terns to attract them to nest at these locations.

H2.2. **Identify and evaluate potential colony sites.** Based on characterization of the preferred habitat type and on an evaluation of areas that have not been thoroughly surveyed, potential colony sites should be identified and surveyed to determine their level of use and value as alternate sites.

H2.3 **Continue to create additional colony sites. Roseate terns may use artificial colony sites.** A trial project using a raft capped with nesting substrate placed in a borrow pit is underway in the Florida Keys. These structures would also provide nesting opportunities to least terns, a state-listed threatened species in Florida.

H3. **Research habitat preferences in Florida.** Compare the habitat preferences of Florida's colonies with those of Caribbean colonies.

Bachman's Warbler

Vermivora bachmanii

Federal Status:	**Endangered (March 11, 1967)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Not Applicable**
Geographic Coverage:	**South Florida**

Bachman's warbler (*Vermivora bachmanii*) is the rarest songbird native to the U.S. Historically, this species was known for dramatic changes in population size, possibly in response to the irregular reproductive cycle of the bamboo (*Bambusa* spp.). Loss of breeding and wintering habitat, as well as harvest for the millinery trade, led to a severe decline of this species. Bachman's warbler was the seventh most common migrant along the lower Suwannee River in earlier times.

The last sighting of Bachman's warbler in Florida was reported in 1977. The last confirmed sighting anywhere in the U.S. was in 1988.

Description

Bachman's warbler is one of the smallest warblers with a total length of 10 to 11 cm. The bill is slender with a slightly downward curve. The male is olive-green above with yellow forehead, lores, eye-ring, chin, and underparts, a black throat and crown, and dusky wings and tail. Males also have a yellow shoulder patch and bright rump. The female lacks any black coloration and has olive green upperparts with yellow forehead and underparts. The eye-ring is whiter than in the males, and the crown is grayish. Immature males resemble females. Males are not difficult to distinguish from other warblers, however, the drab coloration of the females and immatures makes positive identification difficult (Hamel and Gauthreaux 1982, World Wildlife Fund 1990, Curson *et al*. 1994, Stevenson and Anderson 1994, Hamel 1995, Anderson 1996). In his description of Bachman's warblers viewed at long distances, Brewster (1891) described the crown of both sexes as being always carried in a slightly raised fashion, giving the head of the bird a "fluffy" appearance.

The song of the Bachman's warbler is a *zeep* or buzzy *zip* given by both sexes (Hamel 1995). It is somewhat reminiscent of the pulsating trill of the Northern Parula (*Parula americana*) (Brewster 1891, Curson *et al*. 1994).

Taxonomy

Bachman's warbler is in the order Passeriformes, family Emberizidae. It is thought to be closely related to the blue-winged warbler (*V. pinus*) and golden-winged warbler (*V. chrysoptera*) (Hamel 1995, Anderson 1996). It was first named as *Sylvia bachmanii* by John James Audubon who, in 1833, described the bird discovered by Reverend John Bachman in a swamp near Charleston South Carolina (Terres 1980, AOU 1983).

Distribution

Bachman's warbler breeds in the southeastern U.S. and winters in western Cuba and the Isle of Pines (now known as Isla de Juventud or Island of Youth) (Figure 1). There are no breeding records for Florida; this species is an early spring and fall transient. Breeding has been documented in northeastern Arkansas, southeastern Missouri, southwestern Kentucky, central Alabama, and southeastern South Carolina and possibly in northeastern Oklahoma. Most authorities agree that if the Bachman's warbler still exists it is most likely in the I'on Swamp area in Charleston and Berkeley Counties, South Carolina. There has been one winter record for Florida (Hamel 1995, Anderson 1996).

Habitat

The habitat associations most often used by breeding Bachman's warblers are uncertain since very small numbers of Bachman's were left when habitat investigations began (Hamel 1995). The information available indicates that migratory habitat preferences differ from winter and breeding habitat preferences in that the bird seems to tolerate a wider range of conditions and uses a greater variety of vegetative associations. Migratory and winter records are scarce, especially since the rapid decline in the early 1900s. As a result, information on the preferred types of migratory and winter habitat are almost nonexistent.

Historic records indicate the Bachman's warbler typically nested in low, wet, forested areas containing variable amounts of water, but usually with some permanent water. Although these areas were described in general as being forested, characteristic tree species included: sweet gum (*Liquidambar stryaciflua*); oaks (*Quercus* spp.); hickories (*Carya* spp.); black gum (*Nyssa sylvatica*); and other hardwoods. Openings in the forest canopy with a ground cover consisting of dense thickets of cane (*Arundinaria gigantea*), palmetto (*Serenoa mino*r), blackberry (*Rubus cuneifolius*), gallberry (*Ilex glabra*), and other shrubs and vines are also characteristic of nesting habitat. The nests are located near the ground. The debate on nesting habitat associations seems to center on whether or not Bachman's warbler is dependent on old-growth bottomland forest or areas that have been disturbed with dense understories of palmetto and cane. In the Mississippi alluvial valley and other breeding areas, the birds were known to use a variety of habitats including upland forest (Hamel 1995).

Migratory habitat preference is unclear; however, Bachman's warblers have been known to use a wide range of habitat types during migration, including forest canopy (Anderson 1996). Many of the museum collection records that provide general habitat and location information may be imprecise. It is apparent, however, that floodplain forest is an important habitat for migrating Bachman's warblers. Records from the Florida Keys in the late 1800s state that the birds were seen in scrub vegetation on the "immediate" coast (Hamel 1995).

Winter habitat use may include a broader array of vegetative communities since Bachman's warblers have been found in dry, semi-deciduous forest, forested wetlands, and forested urban areas. Winter specimens have been collected from a variety of lowland and other habitats throughout Cuba (Hamel 1995). Specifics concerning habitat preference of this species in winter are not available.

Behavior

Reproduction

The only confirmed nest observations for Bachman's warbler were recorded from 1897 to 1937. Of these, 26 were from the I'on Swamp area of South Carolina, and several others were reported from Louisiana, Kentucky, Maryland, and near the Long/McIntosh County line in Georgia (Hooper and Hamel 1977). Nesting was documented in southern Alabama as late as 1937 (Stevenson and Anderson 1994).

Bachman's warblers nest in spring, following spring flooding, between late March and early June. Information on courtship and pair bonding is lacking although, like other *Vermivora,* it is assumed this species is monogamous. In 1939, a male was observed displaying by flitting in low bushes and spreading his tail; since no female was noted, however, it is not known if this was a courtship display (Stevenson and Anderson 1994). All known nests have been located in dense undergrowth within a meter of the ground. Usual clutch size consists of three or four eggs, although clutches of five have occasionally been recorded. Although nest construction has not been observed, females are the only gender to have been observed carrying nesting material. Information on renesting or second broods is not available. It is not known if incubation duties are shared, however, females have been observed on nests. Nest parasitism has not been documented, but this species is likely subject to nest parasitism by brown-headed cowbirds (*Molothrus ater*) (Hamel 1995).

Hatchling descriptions and data, as well as age to fledging, and the nature and extent of parental care, are not available for this species. Both parents apparently feed young fledglings. No additional information is available regarding reproductive success or survivorship (Hamel 1995, Anderson 1996).

Males are known to defend a small (<1 ha) breeding territory and are assumed to breed in the first spring following hatching. Life span and lifetime reproductive success information are also unavailable (Hamel 1995).

Foraging

Information on food habits of Bachman's warbler is unavailable; however, an insect diet similar to other *Vermivora* is suspected. A 1924 record of five specimens from Alabama noted that stomach contents included the remains of caterpillars and a few fragments of Hymenoptera, probably ants (Howell 1932). Bachman's warbler appears to be a foliage gleaner; migrants have been observed feeding on dead clustered leaves of hackberry *(Celtis laevigata*) and the terminal leaflets of other tree branches. These warblers have also been observed feeding on the wing in the manner of a flycatcher (Brewster 1891). Feeding behaviors appear rather slow and deliberate, with the birds sometimes hanging upside down from the branches (Brewster 1891). In migration, they may foliage glean high in canopy habitats. Brewster (1891) describes abundant flocks of migratory birds feeding high in cypress *(Taxodium* spp.) trees in the Suwannee River.

Migration

Bachman's warbler is a neotropical migrant. Records indicate this species migrates southward in late summer and returns to the breeding grounds in early spring. One group of birds moves generally along the East Coast, and another skirts the Gulf Coast and continues up the Mississippi Valley. Birds migrating along the East Coast begin to move southward during July and apparently pass through Key West by early September. Historically, a good portion of these migrants funneled through the Florida Keys. There were numerous sightings of Bachman's warblers in Key West, and a record of 21 of the birds being killed in 1889, when they struck an offshore light at Sombrero Key, on the Atlantic Ocean side of Marathon, Florida. Others were reportedly killed by shotgun pellets in Key West (W. B. Robertson, Jr., former NPS and USGS/BRD biologist, personal communication 1998). Migration is believed to occur primarily at night (Howell 1932, Curson *et al*. 1994, Stevenson and Anderson 1994, Hamel 1995).

Relationship to Other Species

No information is available on predators of this species. Although suspected, nest parasitism by brown-headed cowbirds was never confirmed. Several observers noted that the Bachman's warbler displayed aggression toward other species of small passerines, although interspecific territoriality was never documented (Stevenson and Anderson 1994, Hamel 1995).

In migration, Bachman's warblers associated with other neotropical migratory birds including: prairie (*Dendroica discolor*) yellow-rumped (*D. coronata*), yellow-throated (*D. dominica*) and palm warblers (*D. palmarum*); northern parula (*Parula americana*); blue-gray gnatcatchers (*Polioptila caerulea*); tufted titmice and Carolina chickadee (*Parus bicolor* and *P. carolinensis*), red-eyed and solitary vireos (*Vireo olivaceus* and *V. solitarius*), ruby-crowned kinglets (*Regulus calendula*), Carolina wrens (*Thryothorus ludovicianus*), catbirds (*Dumetella carolinensis*), brown thrashers (*Toxostoma rufum*), and towhees (*Pipilo erythrophthalmus*)(Brewster 1891, Stevenson and Anderson 1994).

Status and Trends

Although Bachman's warbler was first described in 1833, it remained relatively unnoticed for the next 50 or so years. Population estimates are qualitative in nature and range from rare to abundant. Bachman's warbler was, at one time, the seventh most common migrant along the lower Suwannee River (Brewster 1891, World Wildlife Fund 1990, Ehrlich *et al*. 1992, Hamel 1995). A dramatic decline occurred between the early 1900s and 1940 or 1950. Recognition of this decline resulted in the need to list the species in 1967 with the original listing of threatened and endangered species under the Endangered Species Preservation Act of 1966 (32 FR 4001; 35 FR 8495).

Current population numbers are not known. Between 1975 and 1979, an exhaustive search was conducted in South Carolina, Missouri, and Arkansas. No Bachman's warblers were located (Hamel 1995). The last sighting in Florida was from a single bird observed near Melbourne in 1977. The last confirmed sighting anywhere in the U.S. was in Louisiana in August of 1988 (Curson *et al*. 1994, Stevenson and Anderson 1994, Hamel 1995, Anderson 1996). Based on these records, it is widely believed that Bachman's warbler is either extinct or on the verge of extinction.

Various theories have been postulated to explain the population trends of Bachman's warbler and the causes of decline during the late 19th and early 20th centuries. Bachman's warbler may have historically been rare; however, with the advent of logging in the Mississippi alluvial valley new breeding areas for the species may have been created. This creation of additional breeding habitat may have resulted in an increase in the species' population between the late 19th and early 20th centuries. Subsequent, additional land clearing and development activities in the Mississippi alluvial valley from the 1920s on may have destroyed these breeding areas, resulting in a population decline. Concurrently, land clearing activities in Cuba may have exacerbated the situation by limiting wintering habitat for this species. It is also theorized that severe hurricanes may have killed many Bachman's warblers, rendering it difficult for the remaining breeding birds to locate one another (Hamel 1995).

Another theory on the decline of Bachman's warbler involves destruction of wintering habitat in Cuba. Loss or alteration of wintering habitat apparently increased winter mortality, resulting in lower numbers of breeding birds (Anderson 1996). Others theorize that Bachman's warbler requires specific cane habitat for nesting, and the loss of this vegetative community led to a severe decline (Stevenson and Anderson 1994, Hamel 1995, Anderson 1996). It is doubtful that the factors causing the decline of this diminutive migratory species will ever be clearly identified.

With little information available on the life history and ecology of this species, and no recent occurrence records, it is difficult to identify management actions. Urbanization has not slowed significantly since the Bachman's warbler was first noted to be in decline. Alteration or loss of breeding and wintering habitats undoubtedly have had adverse effects, although these are difficult to quantify. The lack of known migratory habitat or vegetation associations also hampers potential management and protection efforts. Threats reported from the late 1800s included collisions with lighthouses. Although no collisions have been reported in this century (Stevenson and Anderson 1994, Hamel 1995), it is possible that some mortality from collisions with microwave towers or similar structures could occur.

Perhaps the greatest threat to the species is its large historic breeding range and low population size. With population numbers presumed to be abysmally low, it will be difficult, if not impossible for breeding birds to find mates. This alone could lead to its eventual extinction.

Management

No recovery plan exists for this species. The lack of information on the ecology of the species, or on any recent records of occurrence, have resulted in limited recovery efforts. A habitat enhancement project was undertaken on the Francis Marion National Forest in South Carolina, but no birds were found in the enhanced or surrounding areas. No management of wintering habitat has been undertaken.

Researchers believe that the habitat near this bird's last known nesting sites may have improved after Hurricane Hugo since the forest canopy was removed from many areas. However, no confirmed breeding records have been reported from this area of South Carolina or other historically used areas since the mid-1960s. Several sightings were made on Cuban wintering grounds during the late 1980s (Curson *et al*. 1994).

Since Florida is outside the breeding area, and only affords migrants stopover opportunities, identification of important stopover sites would be the most valuable conservation measure to employ. To undertake this, however, more information on the types of habitat preferred during migration stops is needed.

Literature Cited

American Ornithologists' Union. 1983. Checklist of North American birds. Sixth Edition. Allen Press; Lawrence, Kansas.

Anderson, B.H. 1996. Bachman's warbler. Pages 124-127 *in* J.A. Rodgers, H.W. Kale, and H.T. Smith, eds. Rare and endangered biota of Florida, volume V: Birds. University Press of Florida; Gainesville, Florida.

Brewster, W. 1891. Notes on Bachman's warbler (*Helminthophila bachmani*). Auk 8:149-157.

Curson, J., D. Quinn, and D. Beadle. 1994. Warblers of the Americas, an identification guide. Houghton Mifflin Company; New York, New York.

Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1992. Birds in jeopardy. Stanford University Press; Stanford, California.

Hamel, P.B. 1995. Bachman's warbler (*Vermivora bachmanii*). No. 150. *in* A. Poole and F. Gill, eds., The birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and the American Ornithologists' Union; Washington, D.C.

Hamel, P.B. and S.A. Gauthreaux, Jr.. 1982. The field identification of Bachman's warbler (*Vermivora bachmanii* Audubon). American Birds 36(3):235-240.

Hooper, Robert, and Paul B. Hamel. 1976. Nesting habitat of Bachman's warbler--A review. Unpublished report for the United States Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; Clemson, South Carolina.

Howell, A.H. 1932. Florida bird life. Coward-McCann, Inc.; New York, New York.

Robertson, W.B., Jr. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. August, 1998.

Stevenson, H.M. and B.H. Anderson. 1994. Birdlife of Florida. Pages 539-540. University Press of Florida; Gainesville, Florida.

Terres, J.K. 1980. The Audubon Society encyclopedia of North American birds. Alfred A. Knopf; New York, New York.

World Wildlife Fund 1990. Pages 712-713 *in* Mathews, J.R. ed., The official guide to endangered species of North America. Beacham Publishing, Inc.; Washington, D.C.

Recovery for the Bachman's Warbler

Vermivora bachmanii

Recovery Objective: **NOT AVAILABLE** (no recovery plan for this species)

South Florida Contribution: **CONDUCT SURVEYS** during the migration

Recovery Criteria

The best scientific information available raises questions about whether the Bachman's warbler still exists in South Florida or elsewhere. Unless new information demonstrates that the Bachman's warbler still exists and continues to migrate in South Florida or that they could be re-introduced into South Florida, no recovery criteria will be developed or proposed.

Species-level Recovery Actions

S1. Determine the distribution and status of the Bachman's warbler in South Florida.

- **S1.1. Conduct surveys** for the Bachman's warbler after identifying potentially suitable migratory habitat for this species.

Kirtland's Warbler

Dendroica kirtlandii

Federal Status:	**Endangered (March 11, 1967)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Kirtland's warbler is one of our rarest warblers. This species has an extremely limited nesting range in a relatively small area of central Michigan. It nests in young jack-pine (*Pinus banksiana*) forests exclusively. It is also the first bird species to have a monument (Terres 1980). Its migratory pattern brings it to the east coast of Florida in the fall and spring.

This account represents South Florida's contribution to the range-wide recovery plan for the Kirtland's warbler (FWS 1985).

Description

Kirtland's warbler is a large insectivorous warbler (149-153 mm in length) with a finely pointed bill. It is blue-gray above with black streaks on the back. The male has a black mask and is yellow below with distinct dark spots on the sides and possibly the breast. The bird has a broken white eye-ring and black lores with black legs, feet, and bill. White spots may be found on the outer tail feathers or retrices. Bluish-grey and white markings on the wing coverts form obscure wing bars. The female is duller and lacks the black lores and mask. In non-breeding plumage, the face, sides, and upper parts of the male are duller and similar to the female's coloration. Immatures have plumage similar to non-breeding adults. Fledglings are identified in the field by their shorter tail length up to 16 days post-fledging. Kirtland's warbler also has a habit of constantly bobbing its tail (Mayfield 1992, Curson *et al*. 1994, Sykes 1996).

The Kirtland's warbler's song is a clear *chip-chip-che-way-o* and resembles the northern waterthrush (*Seiurus novebracensis*). Females and immature males do not normally sing (Mayfield 1992).

Taxonomy

Kirtland's warbler is in the Order Passeriformes, Family Emberizidae. This species was originally described in 1852 by Spencer Baird and named *Sylvicola kirtlandii*. It was named for Jared Kirtland, a naturalist from Cleveland, Ohio (Terres 1980). Taxonomists place Kirtland's warbler between the pine warbler (*D. pinus*) and the prairie warbler (*D. discolor*). It may be related to the yellow-throated warbler (*D. dominica*) although there is some uncertainty of this taxonomic link (Mayfield 1992).

Distribution

Kirtland's warbler breeds in upper and lower Michigan in 13 counties from Lake Huron west to Kalkaska County, and from Presque Isle County south to Ogemaw County. This area is principally in the watershed of the AuSable River. Male Kirtland's warblers have been sighted in Wisconsin, Ontario, and Quebec, although no breeding in these areas has been noted or confirmed (Miller and Conroy 1990, Mayfield 1992, Craves 1994).

This species is migratory, and winters throughout the Bahama Islands, although there have been additional sightings in the Turks and Caicos Islands. Although the known wintering islands in the Bahamas are relatively close, Kirtland's warblers have never been reported wintering in Florida, Cuba or Hispaniola. Additional records for Mexico and the Dominican Republic have not been confirmed (Miller and Conroy 1990, Mayfield 1988, 1992).

Habitat

Kirtland's warbler is a habitat specialist on its breeding grounds, preferring young jack-pine (*Pinus banksiana*) forests on flat or gently rolling landscapes. The age of the pine stand can vary from 6 to 22 years of age, and should be at least 34 ha in size (Mayfield 1960; Walkinshaw 1983; Probst 1986, 1988; Mayfield 1992). Larger areas of 200 ha or more are preferred. Other plant species associated with Kirtland's habitat are northern pin oaks (*Quercus ellipsoidalis*), blueberry (*Vaccinium augustifolium*, *V. myrtilloides*), bearberry (*Arctostaphylos uva-ursi*), sweet-fern (*Comptonia peregrina*), sedge (*Carex pennsylvanica*), grasses, and bracken fern (*Pteridium aquilinum*). The soils are sandy and well-drained (Mayfield 1960, Smith 1979, Walkinshaw 1983, Zou *et al*. 1992).

Jack pine stands 6 years post-burn with tree heights of 1.5 to 2.0 m are preferred for nesting, and these stands will continue to be used for approximately 15 years. When these trees become 3 to 5 m in height and the lower branches, which shade and conceal the nests, die the warblers begin to abandon the site. As an area becomes less suitable, all birds except unmated males leave the area (Mayfield 1992, Craves 1994, Sykes 1996).

Migrating Kirtland's have been observed in a variety of habitats including woodlands, scrub, fencerows, and vegetated yards but prefer dense vegetation less than 1.5 m in height (Stevenson and Anderson 1994). A migrating juvenile Kirtland's warbler was banded and recaptured twice in an 11-day period during fall migration in 1971 in a dense hawthorn (*Crataegus* spp.) crabapple (*Pyrus coronaria*) thicket (Clench 1973).

The Bahamian winter habitat has been described as pine woods, broad-leafed scrub, and Australian pine (*Casuarina* spp.). Although specific winter habitat requirements are not known, this species seems to prefer dense scrub vegetation. They have also been sighted in the dense understory of tall pines as well as in early successional habitat dominated by lantana (*Lantana* spp.) (Mayfield 1972, 1992; Miller and Conroy 1990).

Behavior

Reproduction

Kirtland's warblers are loosely colonial and breed in their second year. Adult males return to their breeding colonies although first year birds disperse widely. These birds are normally monogamous, however, some polygyny has been noted. Approximately half of all returning birds mate with the same individual in subsequent years (Mayfield 1992, Craves 1994, Sykes 1996).

Males are the first to arrive on the breeding grounds, and pair bonding begins within a week of the females' arrival. Nests are constructed between mid-May and early June. Female Kirtland's warblers construct a shallow cup nest directly on the ground over a 4 to 8 day period. Nests are usually well concealed by ground cover or low hanging branches. Nests are only used once (Sykes 1996, Mayfield 1992).

Egg laying occurs from late-May to mid-July with a clutch size of three to five eggs. Incubation is undertaken by the female, begins the day before the clutch is complete, and takes 13 to 16 days. The male feeds the female during incubation (Terres 1980). Hatching is fairly synchronous, with all chicks emerging within 24 hours. Females mainly brood the chicks, and the male brings food to both the female and the young. Fledging occurs 9 days after hatching, with the entire clutch fledging almost simultaneously. Parents care for the young up to 44 days after fledging, however the young appear to be capable of survival at 23 days post-fledging. This species may occasionally double brood, however, survival rate of the second brood is low (Mayfield 1992, Curson *et al.* 1994, Sykes 1996).

The number of fledglings produced per pair, per year, varies, but is usually 2.2 in good years. The probability of survival from egg to fledging is 0.32 under ideal conditions (e.g. without cowbird parasitism). Adult survivorship from year to year has been estimated at 65 percent. The average lifespan for adult birds is 2 years; the oldest recorded ages are 8 and 9 years for a female and male, respectively (Mayfield 1992).

Both the parents and the young apparently leave the jack pine habitat after July, as few of the birds have ever been observed there in August (Sykes 1996).

Foraging

Kirtland's warbler is a gleaner that forages primarily on the ground and at midlevels in vegetation. Probing and hover-gleaning are other methods employed by this species for foraging (Sykes 1989, Mayfield 1992).

While on the breeding grounds, the Kirtland's warbler has been observed feeding on moths, caterpillars, adult ant lions, sawfly adults and larvae, grasshopper nymphs, spanworms, horseflies, deerflies, crickets, centipedes, and numerous other insects and larvae (Terres 1980, Mayfield 1992). It feeds on the ground or in the tops of pines or scrub oaks. Later in the breeding season, ripe blueberries are consumed by adults and fed to young birds (Mayfield 1992, Sykes 1996). During the winter months, the diet consists mainly of small fruits with some arthropods (Sykes 1989, 1996; Mayfield 1992).

Migration

The entire Kirtland's warbler population migrates between Michigan and the Bahamas, possibly without any stops. Other authors as well as museum records indicate at least some birds make stopovers during migration. Departure from the Bahamas in spring probably occurs in late April or early May. The route taken, most likely, follows a narrow band that crosses South and North Carolina, Virginia, West Virginia, and Ohio before reaching Michigan. It is extremely rare in Florida during migration, with records between mid-April and early May from Palm Beach, Alachua, and Duval Counties although Clench (1973) discounts many of these sightings since there are no photos or specimens to corroborate the record (Mayfield 1988, 1992; Sykes 1996).

Fall migration takes the same route, with birds departing the breeding grounds between August and October. The first arrival of Kirtland's warblers to the Bahamas was recorded in August. Those birds which occasionally reach Florida have probably been blown off course (Robertson and Woolfenden 1992). Birds observed in Florida have been seen between early September and late November in Miami-Dade, Escambia, Collier, Martin, Palm Beach, St. Lucie, St. John's, and Wakulla Counties (Sykes 1996).

Relationship to Other Species

Kirtland's warbler appears to have little threat from mammalian predators and appears quite tame on the breeding grounds. Avian predators may include sharp-shinned hawks (*Accipiter striatus*), northern harrier (*Circus cyaneus*), great-horned owl (*Bubo virginianus*), and domestic cats (*Felis domesticus*). Egg predators include blue jays (*Cyanocitta cristata*), garter snakes (*Thamnophis* spp.), possibly American crows (*Corvus brachyrhynchos*), thirteen-lined ground squirrels (*Citellus tridecemlineatus*), and red squirrels (*Tamiasciurus hudsonicus*) (Mayfield 1992).

Perhaps the most important relationship to the survival and recovery of this species is its relationship to the brown-headed cowbird (*Molothrus ater*). This nest parasite expanded its nesting range into northern Michigan in the late 1800's. Cowbird presence is correlated with the desertion of approximately one-third of all nests during incubation when left uncontrolled. Fledgling production in parasitized nests decreases by 40 to 55 percent in nests with one cowbird egg, and to zero percent in nests with two cowbird eggs (Mayfield 1992, Sykes 1996). Although many bird species have adapted to cowbird nest parasitism by learning to eject cowbird eggs from the nest, Kirtland's warbler has learned no such defense. With such a small population, it is unlikely the Kirtland's warbler will ever adapt to such predation (Craves 1994).

Status and Trends

Evolution of the Kirtland's warbler most likely began with the end of the Wisconsin glaciation 6,000 to 8,000 years ago, when it began to develop traits which allowed the species to exploit jack pine habitat and avoid competition with other warbler species. This narrow ecological niche increases the warbler's vulnerability to extinction (Craves 1994).

Prior to 1951, no attempt was made to estimate the Kirtland's warbler population. However, it is generally believed that large fires in the late 1800s converted white pine (*P. strobus*) forests to suitable jack pine forest. This event resulted in an increase in this species' numbers. Collectors were able to take birds in areas where they were rarely seen in the winter range prior to the fire event. The first complete population census, performed in 1951, resulted in an estimate of 1,000 individuals. A census in 1961 again yielded a population estimate of 1,000, but the population dwindled to an estimated 300 pairs in 1967. This decline, as well as the 60 percent decline in the number of singing males documented in the 1971 census, led to its listing as an endangered species (32 FR 4001; 35 FR 8495).

Since the population lows between 167 and 242 males from 1971 to 1989, Kirtland's warbler populations have increased to a maximum of 766 males in the 1995 10-day breeding season census. A wildfire in 1980 may have enabled this population increase by creating large tracts of suitable habitat (Sykes 1996).

This species is vulnerable to many threats due to its small numbers, limited distribution in breeding and wintering areas, exacting breeding habitat requirements, and nest parasitism by brown-headed cowbirds. The level of nest parasitism in Kirtland's warblers was over 50 percent until recently (Curson *et al*. 1994).

Although minimal human disturbance does not appear to be detrimental to nesting Kirtland's warblers, human residential development usually results in the loss of habitat and the introduction of domestic predators. From the information available, it would seem that residential and commercial development of breeding sites is not an issue. However, proposed recreational and commercial uses of Kirtland's nesting habitat during the breeding season, as well as efforts to suppress natural fire threaten this species (FWS 1985, Sykes 1996).

Habitat available to wintering Kirtland's warblers appears to be stable and abundant. Agricultural endeavors in the Bahamas that fail and become fallow provide suitable habitat for this species. However, loss of coastal, forested communities in the continental U.S. could affect this species during migration by eliminating important stopover areas (FWS 1985, Sykes 1996).

Management

Kirtland's warbler is a low-ranging species, preferring stands of young jack pine (*P. banksiana*) (Stevenson and Anderson 1994). The nesting habitat is restricted to these young jack pine stands, ideally 81 ha or larger, with thick ground cover. Management efforts for this species began in 1957 when three areas encompassing 1,036 ha were set aside and managed for different age stands of jack pine. An additional 1,600 ha tract was set aside by the U.S. Forest Service in 1962. After passage of the Endangered Species Act of 1973, recovery actions were increased and management for Kirtland's warblers was proposed for 21,646 ha of the Huron-Manistee National Forest and an additional 30,005 ha of the AuSable, Mackinac, and Pere Marquette State Forests (FWS 1985, Mayfield 1992, Curson *et al*. 1994).

In addition to habitat preservation and management, cowbird trapping programs have been initiated. These programs have been successful in minimizing parasitism and reestablishing normal fledging success rates for the species (FWS 1985, Sykes 1996). The current cowbird control program must continue in order to reduce this threat further. Despite the success of trapping efforts, the Kirtland's warbler population has not significantly increased (Curson *et al*. 1994).

A technique for transferring Kirtland's warbler chicks or eggs into other species' nests may be a useful tool to establish breeding colonies in suitable, unoccupied sites away from the breeding center, possibly in Wisconsin or Ontario. When attempted with surrogate species, a single, returning bird settled in characteristic habitat, and behaved territorially toward others of its species (Brewer and Morris 1984).

Sykes (1996) recommends that a prescribed burning program be implemented. He also states that research on post-breeding activities such as movements, dispersal, and over-winter survival should be undertaken. Satellite imagery analysis of preferred winter habitat may be helpful in this endeavor (Miller and Conroy 1990). Such information would allow us to determine what threats, if any, originate during migration or on the winter range of this species and how we may ameliorate those threats.

The recovery plan provides the following basic recommendations: (1) maintain and develop suitable nesting habitat for the warbler throughout its former known range; (2) protect this bird on its wintering grounds and along the migration route; (3) reduce key factors adversely affecting reproduction and survival; (4) monitor breeding populations of the warbler to evaluate responses to management practices and environmental changes; and, (5) reintroduce the birds into areas in the upper peninsula of Michigan or in other states in an attempt to establish independent self-sufficient populations. The ultimate recovery plan objective is to develop a stable wild population of 1,000 pairs, which is approximately the same number estimated to exist at the time of the 1951 and 1961 population censuses.

Since Kirtland's warblers do not frequent, and are not dependent upon, reserves in South Florida, management actions specific to this species are not needed. However, management actions that benefit neotropical migratory birds should benefit any Kirtland's warblers that reach Florida.

Literature Cited

Brewer, R. and K.R. Morris. Cross-fostering as a management tool for the Kirtland's warbler. Journal of Wildlife Management 48(3):1041-1045.

Clench, M.H. 1973. The fall migration route of Kirtland's warbler. Wilson Bulletin. 85(4):417-428.

Craves, J.A. 1994. The natural history of Kirtland's warbler. Jack-Pine Warbler 71(3):13-14.

Curson, J., D. Quinn, and D. Beadle. 1994. Warblers of the Americas. Houghton Mifflin Company Publishers; New York, New York.

Mayfield, H.F. 1960. The Kirtland's warbler. Cranbrook Institute of Science; Bloomfield Hills, Michigan.

Mayfield, H.F. 1972. Winter habitat of Kirtland's warbler. Wilson Bulletin 84(3):347-349.

Mayfield, H.F. 1988. Do Kirtland's warblers migrate in one hop? Auk 105(1):204-205.

Mayfield, H.F. 1992. Kirtland's warbler. No. 19 *in* A. Poole, P. Stettenheim, and F. Gill, eds., The birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and the American Ornithologists' Union; Washington, DC.

Miller, K.V. and M.J. Conroy. 1990. SPOT satellite imagery for mapping Kirtland's warbler wintering habitat in the Bahamas. Wildlife Society Bulletin 18(3)252-257.

Probst, J.R. 1986. A review of factors limiting the Kirtland's warbler on its breeding grounds. American Midland Naturalist 116:87-100.

Probst, J.R. 1988. Kirtland's warbler breeding biology and habitat management. Pages 23-35 *in* Integrating forest management for wildlife and fish. W. Hoekstra and J. Capp, comp. U.S. Department of Agriculture General Technical Report NC-122.

Robertson, W.B. and G.E. Woolfenden. 1992. Florida bird species. Florida Ornithological Society. Gainesville, Florida.

Smith, E. 1979. Analysis of Kirtland's warbler breeding habitat in Ogemaw and Roscommon counties, Michigan. M.S. thesis, Michigan State University. East Lansing, Michigan.

Stevenson, H.M. and B.H. Anderson. 1994. The birdlife of Florida. University Press of Florida; Gainesville, Florida.

Sykes, P.W., Jr. 1989. Kirtland's warblers on their wintering grounds in the Bahamas Archipelago--a preliminary report. 9-11 February 1989 Proceedings of Kirtland's warbler symposium for the U.S. Forest Service; Lansing, Michigan.

Sykes, P.W., Jr. 1996. Kirtland's warbler. Pages 113-123 *in* J.A. Rodgers, Jr., H.W. Kale II, and H.T. Smith, eds., Rare and endangered biota of Florida, volume V: Birds. University Press of Florida, Gainesville, Florida.

Terres, J.K. 1980. The Audubon Society encyclopedia of North American birds. Alfred A. Knopf; New York, New York.

U.S. Fish and Wildlife Service [FWS]. 1985. Kirtland's warbler recovery plan, revised. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

Walkinshaw, L.H. 1983. Kirtland's warbler: the natural history of an endangered species. Cranbrook Institute of Science, Bloomfield Hills, Michigan.

Zou, X., C. Theiss, and B.V. Barnes. 1992. Pattern of Kirtland's warbler occurrence in relation to landscape structure in its summer habitat northern lower Michigan. Landscape Ecology 6:221-231.

Recovery for the Kirtland's Warbler

Dendroica kirtlandii

Recovery Objective: **RECLASSIFY** to threatened

South Florida Contribution: **CONDUCT SURVEYS** during migration

Recovery Criteria

The best scientific information available raises questions about whether the Kirtland's warbler still migrates through South Florida. Unless new information demonstrates that the Kirtland's warbler continues to migrate in South Florida, no recovery criteria will be developed or proposed as part of this recovery plan.

Species-level Recovery Actions

S1. Determine the distribution and status of the Kirtland's warbler in South Florida.

S1.1. Conduct surveys for the Kirtland's warbler after identifying potentially suitable migratory habitat for this species.

Ivory-billed Woodpecker

Campephilus principalis

Federal Status:	**Endangered (March 11, 1967)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status :	**Not Applicable**
Geographic Coverage:	**South Florida**

Ivory-billed woodpeckers once inhabited the old-growth forests of southeastern North America and Cuba. As these forests were cleared late in the 19th century, the ivory-billed woodpecker began its decline toward extinction, a decline that was helped by hunters who relished the flavor of this bird's meat. For years, ornithologists and other conservationists have hoped to discover ivory-billed woodpeckers in remote swamps and pine forests in South Florida, South Carolina, Louisiana, or Cuba. After several surveys in North America and Cuba failed to locate ivory-billed woodpeckers, this hope has diminished.

Description

The ivory-billed woodpecker is the largest woodpecker in North America. Its body-length averages about 50.8 cm. The wing length averages 237 to 264 mm (Short 1982). Jackson (1996) identified the only recorded weight as 453g. The ivory-billed woodpecker has glossy, black plumage with a purplish cast. A white stripe started on each cheek and continues down each side of their necks to their back, where the two stripes curved to meet in the middle of their backs. The outer halves of their secondaries are white, along with the ends of their inner, primary feathers. The white feathers on the trailing edge of their wings are visible even when their wings are folded. This white wing bar is the best characteristic for identifying the ivory-billed woodpecker in the field and distinguishing it from species like pileated woodpeckers.

Male ivory-billed woodpeckers has a prominent, scarlet crest; the crest of female ivory-billed woodpeckers is completely black. Their bills are large and ivory-white.

Taxonomy

The ivory-billed woodpecker (*Campephilus principalis*) is the northernmost of 11 species contained in the neotropical genus *Campephilus.* It is most closely related to the imperial woodpecker (*C. imperialis*), another endangered woodpecker that occurs in the mountains of western Mexico. Two races of ivory-billed woodpeckers have been recognized: *C. p. principalis* of the U.S. and *C. p. bairdi* of Cuba (AOU 1983).

Distribution

In the United States, the ivory-billed woodpecker occur in old-growth, lowland, deciduous forests and pinelands in eastern Texas, Oklahoma, Arkansas, Missouri, Illinois, Indiana, Kentucky, North Carolina, South Carolina, Louisiana, Mississippi, Alabama, Georgia, and Florida. In Cuba, the ivory-billed woodpecker occurred in lowland deciduous forests and montane pine forests.

In Florida, the ivory-billed woodpecker occurred throughout the Florida peninsula and the Florida panhandle east of the Appalachicola River. In peninsular Florida, the ivory-billed woodpecker occurred in portions of the Upper St. John's River, Kissimmee River, Peace River, Caloosahatchee River, and Big Cypress drainages. Highlands Hammock State Park is identified several times in the literature as having ivory-billed woodpeckers present in the 1960s and 1970s (Robertson and Woolfenden 1992, Jackson 1996).

Habitat

The habitat of ivory-billed woodpeckers has been described as mature (old-growth), forested wetlands (Tanner 1942). However, Jackson (1996) argued that the ivory-billed woodpecker may have retreated to the swamps as mature, upland forests were destroyed. As evidence, he noted that in Cuba, ivory-billed woodpeckers retreated to montane pine forests as mature, low-elevation forests were destroyed.

Nevertheless, Tanner's (1942) studies provide the most extensive information on the habitats used by the remnant populations of ivory-billed woodpecker in the U.S. In Florida, the ivory-billed woodpecker occurred in or adjacent to swamps and hardwood hammocks. In Florida, bald cypress (*Taxodium distichum*) dominated all of these habitats, but black gum (*Nyssa sylvatica*), red maple (*Acer rubrum*), red bay (*Persea borbonia*), sweet bay (*Magnolia virginiana*), laurel oak (*Quercus laurifolia*), American elm (*Ulmus americana*), and palmetto (*Sabal palmetto*) were associated species. Jackson (1996) and Tanner (1942) included longleaf (*Pinus palustris*) and slash pines (*P. elliottii*) to the list of ivory-billed woodpecker habitat. In addition to ivory-billed woodpeckers nesting in the pines, information indicates that the woodpeckers regularly fed on beetles from recently-dead pines (Jackson 1996).

Ivory-billed woodpeckers require large tracts of undisturbed, mature forest. They need mature trees to excavate their cavities and a continuous supply of large, dead trees to provide the wood-boring beetles that form their primary food source.

Behavior

The most comprehensive information on the distribution, biology, ecology, and behavior of the ivory-billed woodpecker is derived from the 1937-1939 study conducted by Tanner (1942). Additional, anecdotal information is presented in

Howell (1932) and Sprunt (1954). Most of the information in the following treatment comes from Tanner's study.

Foraging

Ivory-billed woodpeckers feed mostly on wood-boring larvae burrowed between the bark and sapwood of dead trees; but fruits, nuts, and seeds were occasionally eaten. Most of these foraging trees were recently dead, so recently that the bark is still tight against the tree and light branches have not fallen. They feed on those portions of the trees that supported shallow-wood borers and moved from tree branches to tree trunks as borers attacked the dead tree. They feed primarily on the larger trees of a forest; 87 percent of the trees they forage have diameters greater than 30 centimeters (Tanner 1942).

Ivory-billed woodpeckers scaled the bark of these trees loose with blows from their bills. When they dig into a tree, they chisel into the sap wood and heartwood like other woodpeckers. Most of the preferred larvae are larval Coleoptera—Scolytids, Buprestids, and Cerambycids—which are the first species to attack a tree or tree-limb after the tree dies (Tanner 1942).

Reproduction

Ivory-billed woodpeckers are not social birds. They do not travel in flocks, although they remain as a family group between breeding seasons. The basic social organization of the ivory-billed woodpecker is the breeding pair, which is a strong, apparently monogamous, life-long pair-bond. The mated pair probably requires extensive stands of mature, lowland hardwood forest without disturbance from forestry practices. An area of 6.5 to 8 km^2 has been estimated to be the minimum size for a home range for these birds. Ivory-billed woodpecker pairs travel together, following each other through the forest. If they are separated, they will call to one another; if the separation continues both birds will become nervous until they reunite.

Ivory-billed woodpeckers usually nest at a distance from one another, although Tanner (1942) did not find them defending particular territories. Nevertheless, Tanner found several pairs of ivory-billed woodpeckers that used the same nesting area repeatedly; one pair used the same nesting area for 5 consecutive years, another pair used the same nesting area for 4 consecutive years.

Ivory-billed woodpeckers initiate courtship at different times throughout their range. In Florida, they begin courtship in December and nest-building in late January. Generally, the breeding season extends from January to May. In Florida, ivory-billed woodpeckers built their nest cavities in living or dead bald cypresses. Elsewhere in their range, in the Mississippi River Delta for example, ivory-billed woodpeckers nest exclusively in hardwood trees. Occasionally, they nest in dead pines, bay, and cabbage palms. In Florida, ivory-billed woodpeckers excavate their nest cavities about 15 m from the ground; the lowest was 8 m, the highest was 20 m. The cavities ivory-billed woodpeckers excavate range between 50 and 70 cm in depth in dead or partially dead trees.

Ivory-billed woodpeckers lay between one and four eggs, with an average of 2.9 eggs. The incubation period is uncertain, although Tanner (1942) believed they required about 20 days. Incubation, brooding, and feeding requirements are handled by both parents, with the males incubating or brooding at night.

Fledgling birds probably stay in the nest for five weeks, during which they are fed regularly by both parents. Male ivory-billed woodpeckers brood the young overnight and do most of the brooding during the daytime. Male ivory-billed woodpeckers also clean the nest. After they fledge, young birds are fed by their parents for 2 months or more. Sometimes, these birds will stay with their parents through their first summer and may remain with them until the following nesting season.

Relationship to Other Species

The mature forests that provide habitat for the ivory-billed woodpecker support a large variety of other species. Many of those species, like their forests habitats, have become extinct; these include the Carolina parakeet (*Conuropsis carolinensis*, extinct in 1918) and Passenger pigeon (*Ectopistes migratorius,* extinct in 1914). Others, like the Florida panther (*Puma* (*=Felis) concolor coryi*) survive as endangered species on the federal list of threatened and endangered species.

Status and Trends

Although they were once common in some geographic areas, ivory-billed woodpeckers began their decline toward extinction by the late 1800s (Jackson 1996, Tanner 1942). Ivory-billed woodpeckers were hunted for food and overhunting was responsible for the initial declines of this endangered bird. By the late 1880s, ornithologists raised concerns about the status and trends of the ivory-billed woodpecker (Howell 1932). The other major threat to this species was the destruction of mature (old growth) forests throughout the southeastern U.S. which continued until the 1920s.

Chapman (1907) wrote that the range of the ivory-billed woodpecker had contracted to encompass the states bordering the Gulf of Mexico and the lower Mississippi River valley; even within this range, he wrote that it was only locally distributed. By 1913, the ivory-billed woodpecker had been extirpated from Indiana, Missouri, North Carolina, South Carolina, and Texas (Hornaday 1913). The same report concluded that the ivory-billed woodpecker was threatened with extinction in Florida and Louisiana. By 1926, many thought the ivory-billed woodpecker was already extinct.

Tanner's studies between 1937 and 1939 demonstrated that the ivory-billed woodpecker still existed, but in only a fraction of its original range. By the time of Tanner's study, the ivory-billed woodpecker only survived in the Madison Parish region of Louisiana, the Santee Swamp of South Carolina, and the Suwanee River and Big Cypress regions of Florida. The last verified observation of an ivory-billed woodpecker in the United States was in 1969. Jackson (1996) conducted an extensive survey of potential refugia for the ivory-billed woodpecker between 1987 and 1992. He discounted most reports as pileated or red-headed woodpeckers (*Dryocopus pileatus* and *Melanerpes erythrocephalus*, respectively); however, a sighting in Jonathan Dickinson State Park in 1985 seemed authentic. Overall, though, his surveys found no evidence of ivory-billed woodpeckers in the U.S. If ivory-billed woopeckers continue to exist in the U.S., Jackson believes Florida is one of the most likely areas they may be found.

The ivory-billed woodpecker may have survived in the lowland forests of Cuba (Jackson 1996). Most of the lowland, old-growth, deciduous forests in Cuba had been cleared by the beginning of the twentieth century, restricting the ivory-billed woodpecker to the pine forests in eastern Cuba. In 1948 and 1956, a population of ivory-billed woodpeckers remained in the Cuchillas de Moa mountain range.

A proposal to protect the most threatened area of Cuba, Bandolero, near the lumber and mining town of Moa was made. However, after the Cuban revolution in 1959, most foreign contacts were broken off and the status of *C. principalis* in Cuba became unclear, as well as the status of the Bandolero area.

The area was re-surveyed in 1985 (Lammertink 1995). The investigators did not observe woodpeckers, but they found fresh marks of a foraging ivory-billed woodpecker. Most of the forest that was surveyed in 1956 had been logged, except for portions of the Ojito de Agua region; a single ivory-billed woodpecker was seen in 1986 (Lammertink 1995). Three other ivory-billed woodpeckers were seen during the same year. The last, verified observation of an ivory-billed woodpecker in the region was in 1987. The region was re-surveyed in 1988 and 1991, but researchers did not observe ivory-billed woodpeckers or signs of them; worse, these surveys did not locate suitable habitat that could support ivory-billed woodpeckers.

All evidence leads to the conclusion that the ivory-billed woodpecker has been extirpated in the U.S. The failure of recent surveys in Cuba to locate either ivory-billed woodpeckers or suitable habitat strongly suggests that the ivory-billed woodpeckers has been extirpated there as well.

Management

For many years, surveys have been the only management action that has been taken for the ivory-billed woodpecker. These surveys have focused on determining if the ivory-billed woodpecker still exists. Between 1987 and 1989, Jackson (1996) surveyed potential habitats in the southeastern U.S. in the hope of locating ivory-billed woodpeckers, to no avail. Similarly, surveys in Cuba between 1985 and 1991 failed to locate ivory-billed woodpeckers or suitable habitat for them. Although large tracts of land in areas formerly occupied by ivory-billed woodpeckers have been placed in public ownership, Jackson (1996) feels the efforts to conserve this species may be “too little, too late.” All of the available evidence suggests that the ivory-billed woodpecker has been extirpated from North America and probably has been extirpated in Cuba. If the latter is true, the ivory-billed woodpecker is extinct.

Literature Cited

Agey, H.N. and G.M. Heinzmann. 1971. The ivory-billed woodpecker found in central Florida. Florida Naturalist 44: 46-47, 64.

American Ornithologists' Union. 1983. Checklist of North American birds. Sixth Edition. Allen Press; Lawrence, Kansas.

Chapman, F.M. 1907. Birds of eastern North America. D. Appleton and Company; New York, New York.

Ehrlich, P.R., D.S. Dobkin, and D. Wheye. 1992. Birds in jeopardy. Stanford University Press; Stanford, California.

Hornaday, W.T. 1913. Our vanishing wildlife. The New York Zoological Society; New York, New York.

Howell, A.H. 1932. Florida bird life. Coward-McCann, Inc.; New York, New York.

Jackson, J.A. 1996. Ivory-billed woodpecker. Pages 103-112 *in* J.A. Rodgers, H.W. Kale, and H.T. Smith, eds. Rare and endangered biota of Florida, Volume V: Birds. University Press of Florida; Gainesville, Florida.

Lammertink, M. 1995. No more hope for the ivory-billed woodpecker. Cotinga 3, February.

Robertson, W.B. Jr. and G.E. Woolfenden. 1992. Florida bird species: an annotated list. Florida Ornithological Society Special Publication No. 6. Florida Ornithological Society; Gainesville, Florida.

Short, L.L. 1982. Woodpeckers of the world. Delaware Museum of Natural History. Monogram series no. 4.

Sprunt, A. Jr. 1954. Florida bird life. Coward-McCann, Inc. and the National Audubon Society; New York, New York.

Stevenson, H.M. and B.H. Anderson. 1994. The birdlife of Florida. University Press of Florida; Gainesville, Florida.

Tanner, J.T. 1942. The ivory-billed woodpecker. National Audubon Society Research Report No. 1. National Audubon Society; New York, New York.

Recovery for the Ivory-billed Woodpecker

Campephilus principalis

Recovery Objective: **NOT AVAILABLE** (no recovery plan for this species)

South Florida Contribution: **CONDUCT SURVEYS**

Recovery Criteria

The best scientific information available argues that the ivory-billed woodpecker no longer exists in South Florida. Unless new information demonstrates that ivory-billed woodpeckers persist in South Florida or that they could be re-introduced into South Florida, no recovery criteria will be developed or proposed.

Species-level Recovery Actions

S1. Determine the distribution and status of the ivory-billed woodpecker in South Florida.

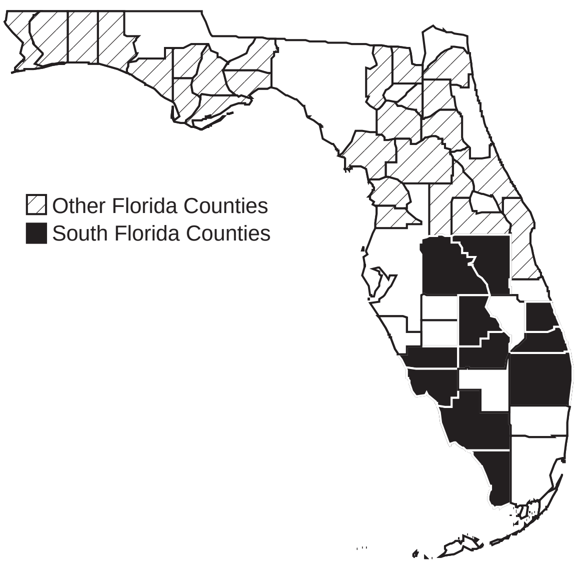
- **S1.1. Conduct surveys** for the ivory-billed woodpecker after identifying potentially suitable habitat. Surveys should focus on the Big Cypress Drainage in Collier and Monroe counties to determine if sufficient area with large enough trees exists in the region.

Red-cockaded Woodpecker

Picoides borealis

Federal Status:	**Endangered (October 13, 1970)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. Florida distribution of the red-cockaded woodpecker.



The red-cockaded woodpecker is one of 22 species of woodpeckers native to North America. Its historic range encompassed the southeastern U.S. from eastern Texas and Oklahoma to New Jersey, and it was characterized as "abundant" in 19th century literature. Throughout the 20th century, however, the species' distribution within its historic range has become fragmented, and its total population numbers have decreased drastically due to the destruction of it's habitat. The red-cockaded woodpecker was federally listed as endangered in 1970, and currently is classified as threatened by the State of Florida. The primary threat to the species continues to be destruction or degradation of its habitat as a result of timbering and other land-clearing activities. Although South Florida is not a designated recovery population for red-cockaded woodpeckers, the area contains significant support populations for recovery of the species in the southeast. Additional surveys are needed to assess the current status of the birds in South Florida so that conservation measures used elsewhere can be implemented here.

This account represents South Florida's contribution to the range-wide recovery plan for the red-cockaded woodpecker (FWS 1985).

Description

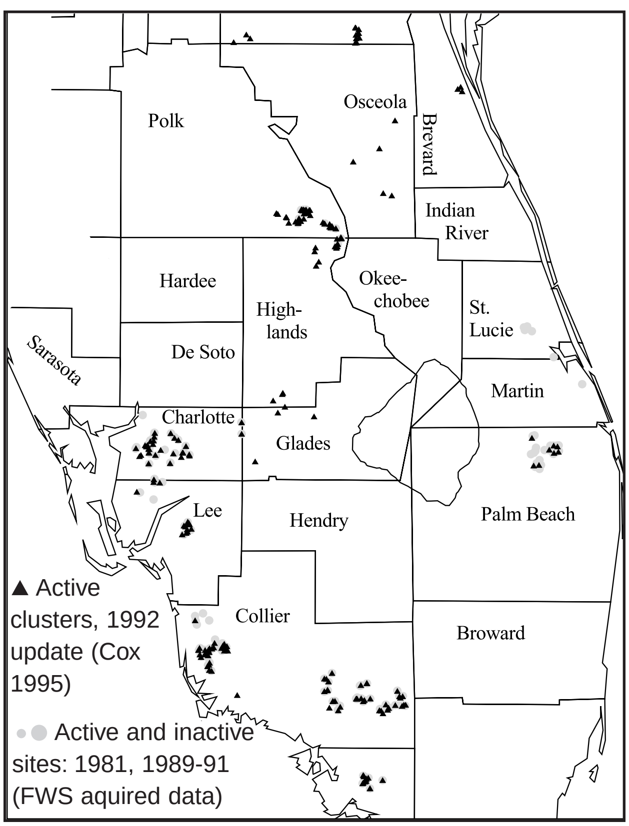
Adult red-cockaded woodpeckers (*Picoides borealis*) are approximately 18 to 20 cm in length and have a wingspan that ranges between 35 to 38 cm. The weight of the adult red-cockaded woodpecker is approximately 45 g; males are slightly larger than the females (Porter 1984). The woodpecker nearest in size to the red-cockaded in Florida is the hairy woodpecker, which is slightly larger. The red-cockaded woodpecker is easily distinguished from the hairy woodpecker, however, by its large, conspicuous white cheek patches, black cap and neck, and black-and-white barred back and wings (Jackson 1994). The only other woodpecker in Florida with a black-and-white barred back is the red-bellied woodpecker (*Melanerpes carolinus*), but that species is substantially larger than the red-cockaded, and a considerable amount of red is visible on its head and nape; no red is readily visible on adult red-cockaded woodpeckers.

Male red-cockaded woodpeckers have a few red feathers slightly above and behind each eye (the "cockades"), but that red spot is essentially covered by black feathers and rarely visible in the field, usually only when the male is displaying; otherwise, adult males and females are black and white in coloration and essentially indistinguishable from each other. The sex of nestlings and fledglings can be distinguished because males have scarlet crown patches until their first molt in the fall, whereas females lack any red coloration throughout their lives (Hovis and Labisky 1996).

Taxonomy

The red-cockaded woodpecker (Order Piciformes; Family Picidae) is one of nine *Picoides* congeners. Jackson (1971) provides a thorough discussion of the taxonomic history of *Picoides*. The red-cockaded woodpecker was formerly recognized in the genera *Picus* by Vieillot in 1807, and in the genera *Dendrocopos* by Peters in 1948. Interestingly, in 1941, Wetmore divided the red-cockaded woodpecker into two races, and described a separate subspecies from southern Florida with the subspecific name *hylonomus*. He described this race as similar to *borealis*, but with much shorter wings. These two subspecies were included as northern and southern races in the 1957 AOU checklist. The three-toed woodpeckers were later grouped with typical *Dendrocopos* woodpeckers, and the red-cockaded woodpecker's name was eventually changed to *Picoides borealis*.

Figure 2. Active and inactive clusters for red-cockaded woodpeckers in South Florida.



Distribution

The red-cockaded woodpecker probably once occurred in all 67 Florida counties, with exception of the Florida Keys in Monroe County (Hovis and Labisky 1996). The southernmost historic record is from the Florida City area in Miami-Dade County (Howell 1921). This species is still widely distributed in the state, but substantial populations now occur only in the Panhandle; elsewhere, populations are relatively small and disjunct. The estimated breeding population of the red-cockaded woodpecker in Florida is 1,500 pairs, with about 75 percent of that total occurring in the Panhandle (Cox *et al*. 1995). The population centered in the Apalachicola National Forest (680 active clusters as of 1996) is the most substantial population in the species' entire remaining range in Florida (R. Costa, FWS, personal communication 1997).

Red-cockaded woodpecker.
Original photograph courtesy of U.S. Forest Service.

In South Florida, the status and distribution of the red-cockaded woodpecker is uncertain, particularly in Highlands, Glades, Hendry, St. Lucie, Martin, and Sarasota counties, because of the inability to access and survey private lands that may support suitable habitat. The current range and distribution of red-cockaded woodpeckers in South Florida is shown in Figures 1 and 2. The most current information on the numbers of active clusters in South Florida was obtained from Cox *et al.* (1995), and updated during the FWS South Florida Multi-Species Recovery Team meeting in 1996 (Table 1).

Habitat

Pine stands, or pine-dominated pine/hardwood stands, with a low or sparse understory and ample old-growth pines, constitute primary red-cockaded woodpecker nesting and roosting habitat. The low or sparse understory affords unimpeded access to cavities. Red-cockaded woodpeckers will abandon otherwise suitable nesting/roosting areas when the understory approaches cavity height (Wood 1996).

Nest and roost cavities are almost always excavated in old-age living pines; the average nest tree typically ranges between 63 and 130 years in age for longleaf pine (*Pinus palustris*) and between 62 and 149 years in age for other pine species (Hopkins and Lynn 1971, Wood 1983, Rudolph and Conner 1991). Longleaf pine is preferred where available (Hopkins and Lynn 1971, Lennartz *et al*. 1983, Hovis and Labisky 1985), however cavities are also constructed in all other pine trees in Florida with the exception of sand pine (*P. clausa*) and spruce pine (*P. glabra*). The old-age living pines selected for cavity excavation characteristically have thinner sapwood and greater heartwood diameter than other mature pines (Conner

Table 1. Known active clusters of red-cockaded woodpeckers in South Florida.

County	Location	Number of Clusters
Polk	KICCO WMA	1 active cluster
Osceola	Three Lakes WMA	34 clusters
Highlands	Avon Park Air Force Range	20 active clusters
	River Ranch	12 active clusters
	Venus Flatwood	1 cluster
St. Lucie	Campbell property	12 clusters
	The Reserves	1 cluster of 1 bird
Martin	Babcock Ranch	unknown number
Palm Beach	Corbett WMA	14 clusters
Glades	Walter Johnson Tract	estimate 4 clusters
Charlotte	Cecil M. Webb WMA	estimate 27 clusters
	Charlotte Harbor Flatwoods	5 to 6 clusters
	Fairway Woodlands	2 clusters
Collier/Monroe	Naples	estimate12 clusters
	Big Cypress National Preserve	33 active clusters
	Golden Gate Estates, north and south blocks	unknown number

et al. 1994). Many cavity trees are also typically infected with a fungus (*Phellinus pini*) that decays the heartwood, thus facilitating cavity excavation (Jackson 1977, Conner and Locke 1982, Conner *et al.* 1994).

In south central Florida, at Avon Park AFR, cavities are excavated only in longleaf pine, even though active red-cockaded woodpecker clusters occur in mixed longleaf/slash pine stands (Bowman and Fitzpatrick 1993). South of the longleaf pine range, red-cockaded woodpeckers can only excavate cavities in slash pine. In this region, cavity trees selected by red-cockaded woodpeckers are typically shorter and smaller in dbh, on average, than cavity trees elsewhere in the Southeast (Shapiro 1983, Bowman and Huh 1995).

In her survey of five wildlife management areas in South Florida, Shapiro (1983) compared the characteristics of cavity trees and vegetation used by red-cockaded woodpeckers in South Florida with that reported elsewhere in the literature; her results are reproduced in Table 2. The overstory vegetation surrounding cavity trees in South Florida is also very sparse. Red-cockaded woodpecker clusters are typically found in the older or oldest, sparsely stocked pine stands, where cavity trees are more widely spaced than trees found further north. Shapiro (1983) attributed the differences in cavity trees and vegetation to the poor site quality and growth conditions of South Florida flatwoods, and historic timber management practices.

Bowman and Huh (1995) also found that hydric slash pines greater than 60 years old were significantly smaller in dbh and height and tended to have smaller crown to bole ratios than either mesic slash or longleaf pines of the same age. They also found that hydric slash pine had more heartwood rot than the other pines.

Older growth pine or pine-dominated stands are also needed for foraging, but not to the extent needed for nesting or roosting. Red-cockaded woodpeckers will forage to some degree on hardwood trees and even in bayheads and cypress domes, but in general, mature pines constitute the primary foraging substrate. This habitat, in association with or proximal to nesting/roosting habitat, is necessary for population survival. In South Florida, red-cockaded woodpeckers need more habitat for foraging than in areas farther north because of the poor habitat quality (less than 7 m^2/ha pine basal area) (Hovis and Labisky 1996).

In southwest Florida (Charlotte, Collier, and Lee counties), the hydric slash pine (*P. elliotii* var. *densa*) flatwoods provide the preferred critical nesting and

Table 2. Characteristics of red-cockaded woodpecker cavity trees in south-central and South Florida and elsewhere in the literature [Adapted from Shapiro (1983)].

	South Florida			Literature		
Parameter	Longleaf	Slash	Mixed	Longleaf	Slash	Mixed
dbh (cm)						
x	32.1	33.8	27.9	39.4	40.6	43.7
N	133	168	42	770	15	729
Range	20.8-48.3	22.3-51.4	20.3-33.8	---	––	---
Source[1]	---	---	---	4,5,7	7	2,5
Height (m)						
x	13.5	15.3	15.9	21.7	25	20.5
N	139	169	42	764	15	723
Range	6.7-24.1	2.7-30.2	8.8-28.0	---	––	---
Source	---	---	---	4,5,7	7	2,5
Age (years)						
x	103.5	102.7	109.5	86	70	84
N	105 (+8 heartrot)[2]	91 (+20 heartrot)	39 (+3 heartrot)	610	15	627
Range	55-142	57-182	80-137	---	––	---
Source	---	---	---	3	3	3
Cavity Height (m)						
x	4.9	7.8	6.4	7.4	No Data	7.9
N	156	191	45	70	––	1,164
Range	1.4-9.1	1.8-21.7	2.7-12.2	---	––	---
Source	---	---	---	1,5,6	––	2,5
Cavities/Tree						
x	1.1	1.2	1.3	1.01	1.0	1.6
N	145	165	42	560	15	815
Source	---	---	---	7	7	2

2] = Baker, 1971; 2 = Carter, 1974; 3 = Wood, 1975; 4 = Hopkins and Lynn, 1971; 5 = Lay and Swepston, 1973; 6 = Ligon, 1970; 7=Thompson and Baker, 1971.
2Trees with heartrot could not be aged.

foraging habitat for red-cockaded woodpeckers (Beever and Dryden 1992). This community has been maintained by fire and hydroperiod, and therefore does not have the dense midstory more typical of xeric and mesic flatwoods in southwest Florida. Also, hydric pine flatwoods were not as accessible to historic forestry, agriculture, and land clearing practices as the xeric and mesic communities.

A common cavity tree is 20.5 to 30.8 cm dbh (Beever and Dryden 1992); the smallest cavity tree observed in southwest Florida was 15.4 cm dbh, the largest was 35.9 cm dbh (153 years old). Good quality hydric pine habitat in southwest Florida has approximately 133 trees/ha, 5 to 8 pine stems of 25.8 cm or larger in dbh, and a basal area of approximately 4.6 m^2/ha (Beever and Dryden 1992). Given this, foraging habitat per group would be estimated at

46.8 ha based on total pine stems, 183.6 ha based on pine stems greater than or equal to 25.8 cm, and 171.9 ha based on basal area.

The spatial extent needed to sustain red-cockaded woodpeckers depends primarily on habitat quality. Home ranges in optimal habitat in the Carolinas average 70 to 90 ha. In most of Florida, however, habitat quality is considerably lower than the optimal conditions in the Carolinas, as well as other areas within the species' range. Home ranges for red-cockaded woodpeckers in northern Florida average 120 to 140 ha (Porter and Labisky 1986). Habitat quality in southern and central Florida is particularly marginal in that respect; home ranges average 140 to 160 ha, but can exceed 200 ha (Patterson and Robertson 1981, Nesbitt *et al.* 1983, DeLotelle *et al.* 1987, Wood 1996). Territory sizes for red-cockaded woodpeckers in South Florida have been reported as large as 300 to 400 ha in Big Cypress National Preserve, because the pinelands are not contiguous (D. Jansen, Big Cypress National Preserve, personal communication 1996). At Avon Park AFR, the largest home range size reported was 360 ha, with an average of 160 ha. In constrained territories, home range is limited to 70 ha (Paul Ebersbach, Avon Park AFR, personal communication 1996).

Behavior

Social Structure

Red-cockaded woodpeckers are non-migratory, territorial, and live in cooperative breeding social units called groups. Such groups are typically comprised of a breeding pair and up to three "helpers," which are usually males (juvenile females disperse or are expulsed from the breeding groups) and most often offspring of the mated pair from previous years (Jackson 1994). In central Florida, however, the frequency of female helpers is higher than what is reported for populations elsewhere (DeLotelle and Epting 1992). Helpers assist in defending territories (territorial disputes between neighboring groups are common) and in feeding and otherwise caring for the young. Mated pairs usually remain together until one dies, but some inter-group movement of breeding adults occurs (Walters *et al*. 1988). Breeding groups average 2 to 4 birds prior to breeding and 4 to 6 afterward, but groups numbering up to 8 to 10 birds have been observed.

The cooperative breeding social structure of the red-cockaded woodpecker is comparable to the social structure of the Florida scrub-jay (*Aphelocoma coerulescens*), whose breeding groups likewise typically consist of a breeding pair and helpers. The red-cockaded woodpecker and the acorn woodpecker (*Melanerpes formicivorus*), which occur in western North America, are the only cooperatively breeding woodpeckers in North America, but breeding units of the acorn woodpecker commonly have more than one breeding male and/or female.

Cavity Excavation

The red-cockaded woodpecker is the only North American woodpecker which excavates its roost and nest cavities in living trees. Cavities are typically excavated on the west to southwest side of a mature pine tree. They are typically located 10 to 13 m above the ground and are found just below the lowest branches, although cavity height can range from less than 1 m up to almost 100 m (Jackson 1994). Once a cavity is completed, small, conical "resin wells" are excavated above, alongside, and below the cavity, as well as on the opposite side of the tree (Jackson and Thompson 1971). Resin wells are continuously maintained to sustain exudation of sap for the life of the tree. The resulting resin flow gives the tree a glazed, "candle-like" appearance, which makes it unmistakable as a red-cockaded woodpecker cavity. The resin flow is an effective deterrent to rat snakes (*Elaphe guttata*) and perhaps other predators of cavity-nesting birds (Jackson 1974, Rudolph *et al*. 1990).

In south-central Florida, in both hydric and mesic habitats, red-cockaded woodpeckers excavate cavities in trees with the crown-bole ratios associated with the maximum resin flow (Bowman and Huh 1995). Red-cockaded woodpeckers also chip away the bark from the immediate vicinity of cavities, creating a smooth "plate." Red-cockaded woodpeckers can excavate cavities within a few months, but more typically take 1 to 3 years. It is also possible for a "start hole" to be created that remains unattended for several months or even years before excavation is resumed; the heartwood may be initially too hard for successful cavity completion, but will soften over time.

Cavity trees tend to be aggregated into geographic areas known as "clusters" (Walters 1990) which support a breeding group. The number of cavity trees in these clusters usually exceeds the size of the breeding group, which allows the breeding group to grow in size and shift its nest locations. Within an active cluster, cavities under construction are called "starts," while those that have been completed and are in use are called "active" (FWS 1985). It is also typical for a cluster to have a number of trees with start holes and several abandoned cavity trees. Abandoned or inactive trees are often trees that have died (red-cockaded woodpeckers typically abandon cavity trees soon after they die) and/or trees with cavities that have been enlarged or taken over by other species.

Reproduction and Demography

Red-cockaded woodpeckers attain breeding age at 1 year; however, reproductive success improves with increased age (Walters 1990). The nesting season in Florida is late April through early June. The nest cavity is usually the roost cavity of the breeding male (Ligon 1970, Lennartz *et al.* 1987). The red-cockaded woodpecker is monogamous, and essentially single-brooded, although rare instances of double-brooding in a given year have been documented (Jackson 1994, Schillaci and Smith 1994). Clutch size is normally two to four eggs (Ligon 1970), and incubation is 10 to 11 days; this is one of the shortest incubation periods among birds (Ligon 1970, Crosby 1971). Both parents and helpers incubate the eggs (Jackson 1994). Usually one to three young fledge at 26 to 29 days of age (Ligon 1970), but they are dependent to some degree upon their parents and any helpers for 2 to 5 months thereafter (Jackson 1994). Although not all groups produce young, in South Florida, 81 percent of groups were found to be successful.

The red-cockaded woodpecker is long-lived for a bird its size; banded birds in the wild have reached 15 years of age, and a captive-reared bird was documented at 13 years (Jackson 1994).

Dispersal

Most female red-cockaded woodpeckers disperse within 1 year after fledging. They may attain breeding status in another territory or become "floaters" that are not definitively associated with a particular group of birds or cluster of cavity trees (Hovis and Labisky 1996). Some fledgling males also disperse to become breeders or floaters, or to establish and defend a territory, while others remain on their natal territory as helpers until a breeding opportunity arises (Walters *et al.* 1988). There is little information on dispersal distances for birds in South Florida; however, a dispersal distance of 17 km was reported from Avon Park AFR (P. Ebersbach, Avon Park AFR, personal communication 1996).

Foraging

Red-cockaded woodpeckers forage primarily on arthropods, taken by chipping away the outer layer of tree bark and gleaning what they find underneath. They will occasionally feed on vegetative matter such as pine mast and fruits (Jackson 1994). They have also been observed taking flying insects on the wing. Red-cockaded woodpeckers typically forage in larger pines in pine-dominated habitat (90 percent), rather than in hardwoods (Ramey 1980, Bradshaw 1990). Male red-cockaded woodpeckers tend to forage primarily on the branches and upper trunk of pines, whereas females forage primarily on the trunk below the lowest branches (Ligon 1968, Ramey 1980, Jackson and Parris 1995). As stated previously, because of the poor habitat quality in South Florida, more habitat is needed for foraging than in areas farther north (Beever and Dryden 1992).

Relationship to Other Species

The hairy woodpecker (*P. villosus*) and downy woodpecker (*P. pubescens*) are two closely related species that coexist with the red-cockaded woodpecker throughout Florida. Other species compete with the red-cockaded woodpecker for cavity use, including the flying squirrel (*Glaucomys volans*), red-bellied woodpecker, red-headed woodpecker (*M. erythrocephalus*) and pileated woodpecker (*Dryocopus pileatus*) (Jackson 1994, Kappes and Harris 1995). Those species will usurp red-cockaded woodpecker cavities, either temporarily or permanently, particularly if the invading species enlarges the cavity. Competition for foraging areas may also occur between red-cockaded woodpeckers and red-bellied woodpeckers, although the effects on reproductive success of red-cockadeds have not been documented.

The Florida grasshopper sparrow (*Ammodramus savannarum floridanus*) occurs with the red-cockaded woodpecker at Three-Lakes WMA and Avon Park AFR in transitional flatwoods/dry prairie habitat. In scrubby flatwoods/high pine habitat, the red-cockaded woodpecker may occur with the Florida scrub-jay.

Status and Trends

The red-cockaded woodpecker was federally listed as endangered in 1970 due to documented declines in local populations, presumed reductions in available nesting habitat, and because of its perceived rarity (35 FR 8495). As a result of its listing, research efforts were initiated on the biology, status, and distribution of the species.

Jackson (1978) estimated the total population of red-cockaded woodpeckers to be between 1,500 to 3,000 clusters and 4,500 to 10,500 birds, based upon extensive literature reviews and questionnaire surveys. This was revised from his earlier estimate of 2,939 birds-a conservative estimate based upon limited data.

The most extensive, rangewide population surveys for red-cockaded woodpeckers have been conducted on federal lands. In 1979, the FWS southeast region and the USFS initiated a rangewide survey of clusters on federal lands in the Southeast. The results of this effort estimated 2,677 (+/- 456) active red-cockaded woodpecker clusters on the lands censused (Lennartz *et al.* 1983). With the addition of a few federal properties not included in the census, the population was subsequently estimated to exceed 3,000 active clusters (FWS 1985). Among the federal lands censused (national forests, military bases, national wildlife refuges), the largest number of active clusters (2,121) was found on national forests. More recent surveys estimate the rangewide population at 4,694 active clusters (Costa and Walker 1995).

In Florida, the largest population of red-cockaded woodpeckers (~590 active clusters) is on the Apalachicola National Forest, and the second largest population (~208 active clusters) is on Eglin Air Force Base; both populations are in the northwestern part of the state (Cox *et al.* 1995). The population on the Apalachicola NF is also the largest for the red-cockaded woodpecker throughout its range. Statewide, the population size has been estimated as 2,646 birds (943 active and inactive clusters) between 1969-1978 (Baker *et al.* 1980); 2,262 to 3,431 birds (1,139 active clusters) in 1983 (Wood and Wenner 1983); and, 1,146 active clusters in 1992 (Cox *et al.* 1995). The apparent increase in population size between the first and latter estimates reflects improved survey techniques (Wood and Wenner 1983; Cox *et al.* 1995).

In South Florida, the status of the red-cockaded woodpecker is still uncertain, particularly on private lands in Highlands, Glades, St. Lucie, Martin, and Sarasota counties. Populations on private lands in the Naples area (Collier County), however, are declining (K. Dryden, GFC, personal communication 1996). Populations on public lands at Avon Park AFR, River Ranch, Three Lakes Wildlife Management Area, and Big Cypress National Preserve are presently stable (J. Pederson, Three Lakes WMA, personal communication 1996; D. Jansen, Big Cypress National Preserve, personal communication 1996).

Throughout its range, the red-cockaded woodpecker is threatened by habitat loss and fragmentation and lack of fire or infrequent fire that maintains habitat quality; in Florida, invasion by exotic vegetation is also a problem. In South Florida, destruction and fragmentation of pine flatwoods habitat on private lands due to urbanization is a major threat, particularly in southwest Florida. In addition, trees in foraging habitat, as well as cavity trees, have been illegally removed, and landowners are using a variety of tactics to discourage use by red-cockaded woodpeckers.

The loss of habitat on private lands has demographically isolated red-cockaded woodpeckers remaining on public lands, which could affect the genetic viability of these birds. Historically, and even as recently as 30 years ago, there was probably genetic interchange among red-cockaded woodpeckers in South Florida. Increasing isolation from current rates of habitat loss could lead to inbreeding and genetic depression.

Changes in hydrology in South Florida have resulted in the loss of pineland habitat. Hydrologic changes have caused a major loss of pines in the Lostman's Pines area of Big Cypress National Preserve (D. Jansen, Big Cypress National Preserve, personal communication 1996). Alteration of the hydroperiod for residential housing construction has killed a large area of pines on Cecil M. Webb WMA. The restoration of Golden Gate Estates, Collier County, may help red-cockaded woodpeckers in Belle Meade through draining, and all of the south blocks area of Golden Gate Estates through an increase in hydroperiod or surface water.

Management

Management for the red-cockaded woodpecker should include efforts to ensure the long-term survival and viability of the species. The carrying capacity of red-cockaded woodpecker habitat is directly correlated with habitat quality — the availability and abundance of old-age, living pines for nesting and roosting in combination with the availability and abundance of pines for foraging. The most critical factor is the abundance and availability of old-age, living pines. Not only do such trees constitute ideal foraging substrates, they are required for nesting and roosting. Red-cockaded woodpeckers abandon cavity trees soon after the trees die, therefore suitable potential replacement trees must be available. Red-cockaded woodpeckers will not persist where the abundance of mature pines is insufficient to offset the loss of cavity trees that die, regardless of the amount of otherwise suitable foraging habitat that may be available.

Effective management strategies for the long-term survival and viability of red-cockaded woodpecker populations, as adapted from (Wood 1996), are discussed below. They are presented in descending order of importance based on efficacy and logistical implications.

Understory Control: Red-cockaded woodpeckers will abandon cavity tree clusters when the height of the understory/midstory approaches cavity heights. The most effective method for controlling understory growth is to burn nesting/roosting habitat every 3 to 5 years (Komarek 1974). Cavity trees, including abandoned trees and trees with start holes, should be afforded some degree of protection during such burns, by manually removing fuel from their vicinity, creating fire lanes (but not so near cavity trees as to damage root systems), and/or executing burns when climatic conditions would minimize their vulnerability. Existing snags should likewise be afforded the same protection so as to provide nest/roost substrates for other cavity-nesting species that would otherwise compete with red-cockaded woodpeckers. Such precautions may be logistically prohibitive in areas supporting large numbers of cavity tree clusters, but in such instances the loss of a few cavity trees would be offset by the benefits of burning. Manual removal of understory and midstory vegetation may be needed in cavity tree clusters or in the immediate vicinity of individual cavity trees when such vegetation is approaching cavity heights and burning has been ineffective in killing it. Foraging habitat should be similarly burned, to reduce fuel that could eventually result in a devastating crown fire, and to promote potential nesting/roosting habitat conditions.

While burning and thinning are recommended to maintain proper spacing and species composition, such treatments should be scheduled outside the nesting season-which occurs from April through June-to avoid possible disruption of reproductive activities. Considerable caution and skill is required when using fire to control hardwoods in clusters. Beckett (1971) noted that when the resin or pitch flow on cavity trees ignites, cavity trees can be damaged and cavities burnt out and enlarged. Hopkins and Lynn (1971) suggested that combustible materials be raked away from the base of cavity trees to reduce the probability of damage. Connor and Locke (1979) and Stamps *et al.* (1983) have documented, however, that even raking out cavity trees will not protect against fire damage where the fuel load around trees is heavy or when fires become too hot due to wind and other weather conditions. A direct effect of raking is that resins may build up on the base of the tree and eventully lead to a very hot fire directly on the tree trunk. Raking too deeply can also remove wiregrass so the areas will not burn as well. The best solution for preventing fire damage to cavity trees is to burn frequently enough that fuel loads do not become excessive. Where hardwoods have become well developed in a stand, and a hotter than normal burn is required to control them (*i.e.*, a spring or summer fire), or where understory fuel loads are especially heavy (*e.g.*, dense palmetto), the protective measures suggested by Connor and Locke (1979) and Stamps *et al.* (1979) are recommended. These intensive protective measures are probably also warranted on areas supporting just a few active clusters, where the loss of just a few trees could have a significant impact on the local population.

Tree Thinning: Dense stands of young pines (10 to 30 years old) should be thinned to create better foraging habitat. This opens up the habitat and also ensures long-term foraging value by increasing the growth rate of the remaining trees.

Artificial Start Hole Creation: Suitable, sufficient substrate for cavity excavation can be a limiting factor in localized situations. To increase the number of cavities, artificial start holes can be excavated in selected trees both in clusters and in suitable but unoccupied nesting/roosting habitat. Selected trees should be >50 years old and/or >23 cm dbh, and the hole should be situated on the southwesterly side of trees 1 to 3 m below the lower crown branches. Individual holes should be 5.7 cm in diameter and deep enough to penetrate the heartwood. In active clusters, selected trees should be near active cavity trees, and in unoccupied areas selected trees should be grouped into a simulated cluster. In South Florida, artificial start holes are being used at Big Cypress National Preserve (D. Jansen, Big Cypress National Preserve, personal communication 1996) and at Three Lakes WMA (M. Salyer, GFC, personal communication 1996).

Artificial Cavity Creation: When the availability of trees suitable for cavity excavation in a cluster is severely restricted, or when a management objective is to induce occupation of an unoccupied but suitable area within a short period of time, artificial cavities can be drilled in available trees (Copeyon 1990, Taylor and Hooper 1991) and/or artificial "cavity inserts" can be installed (Allen 1991). Both techniques have been demonstrated to be effective in terms of red-cockaded woodpeckers adopting them (Copeyon *et al.* 1991, Richardson and Stockie 1995, Watson *et al.* 1995). However, the cavity insert technique requires relatively large trees, at least 38 cm in diameter at the height of the planned insert, and the cavity excavation technique requires trees at least 75 years old with 25 cm of heartwood. In South Florida, cavity inserts are being used at Big Cypress National Preserve, in trees in Islesworth and Naples, and they are being considered at Avon Park AFR.

Installing Cavity Restrictors: Where competition for cavities from other species is a significant problem, or when rehabilitation of cavities in living trees that have been enlarged by competitors is needed, cavity restrictor devices can be installed on cavities. This technique can significantly reduce cavity competition and/or render previously unsuitable *(i.e.,* enlarged) cavities suitable for occupancy by red-cockaded woodpeckers (see Carter *et al.* 1989 for methodology).

Augmentation: Small, isolated populations are prone to eventual extinction due to stochastic events, demographic problems and/or a lack of genetic vigor. When the management objective is to maintain such populations, translocations of individual birds can be employed. The most effective technique for translocating red-cockaded woodpeckers is capturing and relocating juvenile females to groups comprised of bachelor males. This technique is only effective, however, when it also has been shown that relocating juvenile males to single female groups, and simultaneously translocating unrelated juvenile males and females to recruitment clusters, is effective in establishing new potential breeding groups (Rudolph *et al.* 1992, Costa and Kennedy 1994). When isolated populations are extremely small and destined to extirpation, it may be best to translocate the juveniles in those populations, as long as they persist, and introduce them into other, more secure populations.

Survey/Monitoring Techniques

Red-cockaded woodpecker cavity trees are so conspicuous and unmistakable that determining whether or not a particular area is being used for breeding is relatively simple. Habitats that warrant surveying include old growth (>50 years old) pinelands or pine-dominated pine/hardwood stands, or younger stands with scattered mature pines. Walking linear transects, spaced according to the visibility afforded by the vegetation present, usually 30 to 80 m apart, is the most effective technique for locating cavity trees. Helicopter transects can also be effective in some situations.

Cavities can be treated as active if the tree is living and the resin is flowing. Cavities in living trees that have not been enlarged by other species but with dry, caked and discolored (usually grayish or greenish) resin can be treated as inactive. Such cavities, however, may be reactivated by red-cockaded woodpeckers even after several years of inactivity. Cavities in dead trees and enlarged cavities usually have little direct benefit to red-cockaded woodpeckers, and for most purposes can be considered permanently abandoned. Inactive/abandoned cavities have indirect benefits, however, in that they provide nest/roost sites for species that might otherwise compete with red-cockaded woodpeckers, and thereby should be considered in management strategies.

The number of birds comprising a given group can be determined by positioning observers at cavity trees during morning departure times and/or evening return times. Several observers would normally be needed in that regard to ensure all occupied trees in a given cluster are under observation.

It is more complex to determine whether or not an area is being used as foraging habitat by red-cockaded woodpeckers. More specific guidelines for determining foraging areas in South Florida need to be developed. In general, any area dominated by mature pines which are proximal to nesting/roosting habitat is potentially suitable for foraging. There are subtle indications of red-cockaded woodpeckers foraging in an area, particularly if the area is heavily used. For example, observation of trees with smoother bark and a more reddish appearance (caused by the birds chipping away bark during foraging) can be a good indication of foraging habitat. A more definitive technique, although not altogether effective, is to play a tape recording of red-cockaded woodpeckers calls at stations throughout potential nesting/roosting or foraging habitat. Tape-recorded calls will often elicit a territorial response by any red-cockaded woodpeckers within hearing distance. However, this technique is only effective in the morning hours during the breeding season, and requires daily repetition for several consecutive days. Otherwise a group foraging out of hearing distance may not be detected.

Demographic monitoring typically requires banding red-cockaded woodpeckers. In banding operations, adults can be captured most effectively by deploying a mist net or mosquito net hoop connected to a pole over an occupied cavity either prior to the resident bird's morning departure, shortly after dawn, or just after its evening return near dusk. Hitting the tree trunk with a solid object will usually induce the bird to exit the cavity into the netting. Adults can also be captured, although much less effectively, by deploying a standard mist net in a cavity tree cluster and playing a tape recording of red-cockaded woodpecker calls under or very near the net. Resident birds will attempt to seek out and expel the "intruders," and in so doing may fly into the net. When color-banding red-cockaded woodpeckers (or any other species of woodpecker), red bands should not be used. The color red is a behavioral trigger for most woodpecker species, and red bands could disrupt social behavior patterns. State and Federal permits must be obtained prior to banding any birds.

Banding nestlings or inspecting nest contents requires climbing cavity trees with Swedish climbing ladders to reach cavities. A flashlight and mirror are needed to view the contents, and nestlings can be extracted with monofilament line snares (see Jackson 1982 for methodology).

Conservation

The conservation and management of red-cockaded woodpeckers in South Florida has not been seriously addressed. These efforts should focus on managing and restoring habitat. Additional surveys are needed to update our information on the status of active and inactive clusters, as well as the availability of suitable unoccupied habitat throughout South Florida. We also need to evaluate the potential carrying capacity for red-cockaded woodpeckers on existing public lands where suitable or restorable habitat exists.

Involvement and cooperation of private landowners is essential for the conservation of red-cockaded woodpeckers on private lands. Private lands can provide corridors of habitat or island populations between or in close proximity to other support populations, and can support juveniles to maintain demographic and genetic health, and increase population size (Costa and

Edwards 1997). Prior to 1991-1992, there was no comprehensive plan to address the management of private lands for red-cockaded woodpeckers. In 1992, the FWS developed a conservation strategy to address red-cockaded woodpecker losses on private lands, economic impacts to private landowners of providing habitat, and cooperative conservation efforts between the public and private sectors. This strategy contains a draft red-cockaded woodpecker procedures manual for private lands (Costa 1992) and discusses statewide Habitat Conservation Plans and Memorandums of Agreement (MOA) between private landowners and the FWS for habitat management and monitoring (Costa 1995). A number of incentives have been proposed to compensate private landowners willing to manage for red-cockaded woodpeckers.

One such mechanism that involves cooperation with landowners is the FWS Safe harbor Policy. This policy encourages private landowners to manage their properties for red-cockaded woodpeckers by providing assurances that the establishment of additional groups on their property will not result in further land use restrictions. Upon enrollment for Safe Harbor, private lands are surveyed for red-cockaded woodpeckers and the numbers of groups using the property at the time of enrollment are determined to be the “baseline.” If better land management subsequently results in the establishment of additional groups above the baseline, the landowner has no responsibility, under the Safe harbor agreement, to maintain them. The Safe Harbor approach provides assurances to land owners about land uses, reduces uncertainty about the ESA requirements, and benefits red-cockaded woodpeckers by increasing available habitat. The Safe Harbor concept could work in South Florida for the large tracts of private pine flatwoods, such as in the southwestern part of the state. This program could be a key to maintaining population exchange of red-cockaded woodpeckers in South Florida and lend more demographic stability to population centers. It also may help curtail illegal activities that have harmed the woodpecker by removing the “fear” of the ESA.

In addition, land acquisition programs for suitable habitat in South Florida are being implemented through state efforts such as the Conservation and Recreation Lands (CARL) and Save Our Rivers programs. Lands identified for acquisition should be located adjacent to or be contiguous with publicly owned conservation lands or other lands proposed for acquisition that contain red-cockaded woodpecker clusters (Beever and Dryden 1992). Two properties in South Florida identified through the CARL program to benefit red-cockaded woodpeckers are the Belle Meade and Charlotte Harbor Flatwoods parcels in Collier and Charlotte counties, respectively (DEP 1995). The GFC also identified numerous other parcels that may benefit red-cockaded woodpeckers if they are acquired and managed properly (Cox *et al*. 1994).

As the human population continues to increase in South Florida, there will be an increasing demand for residential, commercial, and agricultural uses of South Florida’s pinelands. It is likely that many of these uses will be incompatible with red-cockaded woodpecker habitat needs; therefore, unavoidable adverse effects to the species are likely. Where adverse effects cannot be avoided, measures must be taken to minimize on-site disturbance, and compensate or mitigate for the impacts that remain. On-site minimization measures can include relocating certain portions of projects to conserve the most suitable areas for red-cockaded woodpeckers, connecting portions of project areas to preserves, and establishing preserves similar in size to the amount of suitable habitat affected by a particular project.

Habitat compensation results in the protection and management of suitable red-cockaded woodpecker habitat in another area. The FWS generally recommends that areas used as habitat compensation be located in the vicinity of the affected habitat, where appropriate, to avoid further fragmentation and isolation of existing habitat. Mitigation must at least replace each red-cockaded woodpecker group in-kind (*i.e.,* potential breeding pair or solitary bird) from the affected property onto another property, either by creating artificial recruitment clusters and/or by the translocation of an adequate number of juveniles to existing recruitment clusters. Other examples of mitigation include purchase of portions of areas identified for acquisition as key conservation lands, or contributions toward the perpetual management of existing conservation lands. For off-site mitigation, the FWS is recommending requiring a management endowment to accompany the mitigation package to be used by the entity receiving the birds or cluster(s), in addition to the approximate average figure of $4,400 for each new cluster created.

In areas where habitat is so threatened that red-cockaded woodpeckers would not be able to survive, translocation of birds to protected areas of suitable habitat is an option under a number of conservation strategies through the FWS. Translocation of red-cockaded woodpeckers has been successful elsewhere in their range (Rudolph *et al.* 1992, Costa and Kennedy 1994, Reinman 1995). The translocation of red-cockaded woodpeckers from threatened private lands is intended to result in a net gain of red-cockaded woodpeckers on public lands or in establishment of larger, more secure private populations (Costa 1995).

Habitat restoration is also an important component of red-cockaded woodpecker conservation. Management activities in South Florida should promote regeneration and encourage establishment of the more densely stocked pine stands that occurred historically (Shapiro 1983). It is important to remember, however, that these areas are less than what is reported as optimal or acceptable habitat in other areas. The Federal guidelines for evaluating red-cockaded woodpecker habitat to prepare biological assessments (Henry 1989) are inadequate for South Florida, particularly the hydric slash pine flatwoods in southwest Florida. At least half of the areas in southwest Florida would fail to meet the 23.1 cm dbh criteria for determining suitable habitat, and more than half of the cluster sites would fail to meet the standard for identifying suitable cavity trees (Beever and Dryden 1992). As mentioned previously, good quality hydric slash pine habitat in southwest Florida has approximately 133 trees/ha, 5 to 8 pine stems of 25.8 cm or larger dbh, and a basal area of approximately 4.6 m^2/ha (Beever and Dryden 1992). Given this, foraging habitat per group would be estimated at 46.8 ha based on total pine stems, 183.6 ha based on pine stems greater than or equal to 25.8 cm, and 171.9 ha based on basal area. The FWS, in cooperation with the GFC and others, needs to work toward revising these guidelines to be beneficial for red-cockaded woodpeckers in South Florida.

Although South Florida is not a designated recovery population for red-cockaded woodpeckers (250 breeding pairs or groups based on the need for ~400 potential breeding pairs), it contains significant support-populations. A goal for this area should be to establish additional populations of red-cockaded woodpeckers on public and private lands, where feasible, and create as much habitat connectivity as possible, to maximize dispersal opportunities. Efforts should focus on protecting habitat for the birds on private lands where medium-sized populations (10 to 30 groups) are known to exist (*e.g.* Belle Meade, River Ranch, *etc.*), and expanding populations on key public lands. To achieve this, the FWS is undertaking a landscape approach, using GIS and spatially-explicit models, to identify important conservation areas for red-cockaded woodpeckers, including corridors to allow for interchange among populations, and conservation areas necessary for the long-term survival of red-cockaded woodpecker populations.

Literature Cited

Allen, D. H. 1991. An insert technique for constructing artificial red-cockaded woodpecker cavities. General Technical Report SE-73. U.S. Department of Agriculture, Forest Service, Southeastern Forest Experimental Station; Asheville, North Carolina.

Baker, W.W., R.L. Thompson, and R.T. Engstrom. 1980. The distribution and status of red-cockaded woodpecker colonies in Florida: 1969-1978. Florida Field Naturalist 8:41-45.

Beckett, T.A., III. 1971. A summary of red-cockaded woodpecker observations in South Carolina. Pages 87-95 *in* R.L. Thomson, ed. Ecology and management of the red-cockaded woodpecker. U.S. Bureau of Sport Fisheries and Wildlife and Tall Timbers Research Station, Tallahassee, Florida.

Beever, J.W. III and K.A. Dryden. 1992. Red-cockaded woodpeckers and hydric slash pine flatwoods. Transactions of the North American wildlife and natural resources conference. 57:693-700.

Bowman, R., and J.W. Fitzpatrick. 1993. Florida scrub jay and red-cockaded populations at the Avon Park Air Force Range. Final report. Department of Defense, Avon Park, Florida.

Bowman, R. and C. Huh. 1995. Tree characteristics, resin flow, and heartwood rot in pines (*Pinus palustris, Pinus elliotii*), with respect to red-cockaded woodpecker cavity excavation, in two hydologically-distinct Florida flatwood communities. Pages 415-426 *in* D.L. Kulhavey, R.G. Hooper, and R. Costa, eds. Red-cockaded woodpecker: recovery, ecology, and management. Center for Applied Studies in Forests, College of Forestry, Stephen F. Austin State University; Nacogdoches, Texas.

Bradshaw, D.S. 1990. Habitat quality and seasonal foraging patterns of the red-cockaded woodpecker (*Picoides borealis*) in southeastern Virginia. M.A. thesis, College of William and Mary; Williamsburg, Virginia.

Carter, J.H. III, J.R. Walters, S.H. Everhart and P.D. Doerr. 1989. Restrictors for red-cockaded woodpecker cavities. Wildlife Society Bulletin 17:68-72.

Conner, R.N., and B.A. Locke. 1979. Effects of a prescribed burn on cavity trees of red-cockaded woodpeckers. Wildlife Society Bulletin. 7:291-293.

Conner, R.N., and B.A. Locke. 1982. Fungi and red-cockaded woodpecker cavity trees. Wilson Bulletin 94:64-70.

Conner, R.N., D.C. Rudolph, D. Saenz, and R.R. Schaefer. 1994. Heartwood, sapwood, and fungal decay associated with red-cockaded woodpecker cavity trees. Journal of Wildlife Management 58:728-734.

Copeyon, C.K. 1990. A technique for constructing cavities for the red-cockaded woodpecker. Wildlife Society Bulletin 18:303-311.

Copeyon, C.K., J.R. Walters, and J.H. Carter, III. 1991. Induction of red-cockaded woodpecker group formation by artificial cavity construction. Journal of Wildlife Management 55:549-556.

Costa, R. 1992. Draft red-cockaded woodpecker procedures manual for private lands. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Costa, R. 1995. Red-cockaded woodpecker recovery and private lands: a conservation strategy responsive to the issues. Page 67-74 *in* D.L. Kulhavey, R.G. Hooper, and R. Costa, eds. Red-cockaded woodpecker: recovery, ecology, and management. Center for Applied Studies in Forests, College of Forestry, Stephen F. Austin State University; Nacogdoches, Texas.

Costa, R., and E. Kennedy. 1994. Red-cockaded woodpecker translocations 1989-1994: state-of-our-knowledge. Pages 74-81 *in* American zoo and aquarium association annual conference proceedings. American Zoo and Aquarium Association; Wheeling, West Virginia.

Costa, R., and J.L. Walker. 1995. Red-cockaded woodpecker. Pages 86-89 *in* E. T. LaRoe, G.S. Farris, C.E. Puckett, and others, eds. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. National Biological Services, Washington, D.C.

Costa, R. and J.W. Edwards. 1997. Cooperative conservation agreements for managing red-cockaded woodpeckers on industrial forest lands: what are the motivations? Proceedings of the symposium on the economics of wildlife resources on private lands, 5-6 August 1996. Auburn University; Auburn, Alabama.

Cox, J., R. Kautz, M. MacLaughlin, and T. Gilbert. 1994. Closing the gaps in Florida's wildlife habitat conservation system. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Cox, J., W.W. Baker, and D. Wood. 1995. Status, distribution, and conservation of the red-cockaded woodpecker in Florida: a 1992 update. Pages 457-464 *in* D.L. Kulhavey, R.G. Hooper, and R. Costa, eds. Red-cockaded woodpecker: recovery, ecology, and management. Center for Applied Studies in Forests, College of Forestry, Stephen F. Austin State University; Nacogdoches, Texas.

Crosby, G.T. 1971. Ecology of the red-cockaded woodpecker in the nesting season. M.S. thesis; University of Florida; Gainesville, Florida.

DeLotelle, R. S. and R. J. Epting. 1992 .Reproduction of the red-cockaded woodpecker in central Florida. Wilson Bulletin 104:285-294.

DeLotelle, R.S., R.J. Epting and J.R. Newman. 1987. Habitat use and territory characteristics of red-cockaded woodpeckers in central Florida. Wilson Bulletin 99:202-217.

Dryden, K. 1996. FWS Multi-Species Recovery Team meeting, 25 May 1996.

Florida Department of Environmental Protection {DEP} 1995. Conservation and recreation lands 1995 anual report. Florida Department of Environmental Protection, Office of Environmental Services, Division of State Lands; Tallahassee, Florida.

Ebersbach, P. 1996. FWS Multi-Species Recovery Team meeting, 25 May 1996.

Henry, V.G. 1989. Guidelines for preparation of biological assessments and evaluations for the red-cockaded woodpecker. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Hopkins, M.L. and T.E. Lynn, Jr. 1971. Some characteristics of red-cockaded woodpecker cavity trees and management implications in South Carolina. Pages 140-169 *in* R.L. Thompson, ed. The ecology and management of the red-cockaded woodpecker. Proceedings of a symposium. Bureau of Sport Fisheries and Wildlife, U.S. Department of the Interior and Tall Timbers Research Station; Tallahassee, Florida.

Hovis, J.A. and R.F. Labisky. 1985. Vegetative associations of red-cockaded woodpecker colonies in Florida. Wildlife Society Bulletin 13:307-314.

Hovis, J.A. and R.F. Labisky. 1996. Red-cockaded woodpecker. Pages 81-102 *in* J.A. Rodgers, Jr., H.W. Kale II, H.T. Smith, eds. Rare and endangered biota of Florida. Volume v: Birds, University Press of Florida; Gainesville, Florida.

Howell, A.H. 1921. A list of the birds of Royal Palm Hammock, Florida. Auk 38:250-263.

Jackson, J.A. 1971. The evolution, taxonomy, distribution, past populations and current status of the red-cockaded woodpecker. Pages 4-29 *in* R.L. Thompson, ed. The ecology and management of the red-cockaded woodpecker. Proceedings of a symposium. U.S. Bureau of Sport Fisheries and Wildlife and Tall Timbers Research Station; Tallahassee, Florida.

Jackson, J.A. 1974. Gray rat snakes versus red-cockaded woodpeckers: predator-prey adaptations. Auk 91: 342-347.

Jackson, J. A. 1977. Red-cockaded woodpeckers and pine red heart disease. Auk 94:160-163.

Jackson, J.A. 1978. Analysis of the distribution and population status of the red-cockaded woodpecker. Pages 101-111 *in* R.R. Odom and L. Landers, eds. Proceedings of the rare and endangered wildlife symposium. Georgia Department of Natural Resources, Game and Fish Division, Technical Bulletin WL4; Atlanta, Georgia.

Jackson, J. A. 1982. Capturing woodpecker nestlings with a noose-a technique and its limitations. North American Bird Bander 7(3):90-92.

Jackson, J.A. 1994. Red-cockaded woodpecker (*Picoides borealis*). *in* A. Poole and F. Gill, eds. The birds of North America, No. 85. The Academy of Natural Sciences; Washington, D.C., The American Ornithologists' Union; Philadelphia, Pennsylvania.

Jackson, J.A. and R.L. Thompson. 1971. A glossary of terms used in association with the red-cockaded woodpecker. Pages 187-188 *in* R.L. Thompson ed. The ecology and management of the red-cockaded woodpecker. Proceedings of a symposium. U.S. Department of the Interior, Tall Timbers Research Station; Tallahassee, Florida.

Jackson, J.A. and S.D. Parris. 1995. The ecology of red-cockaded woodpeckers associated with construction and use of a multi-purpose range complex at Fort Polk, Louisiana. Pages 277-282 *in* D.L. Kulhavey, R.G. Hooper, and R. Costa, eds. Red-cockaded woodpecker: recovery, ecology, and management. Center for Applied Studies in Forests, College of Forestry, Stephen F. Austin State University; Nacogdoches, Texas.

Jansen, D. 1996. FWS Multi-Species Recovery Team meeting, May 25, 1996.

Kappes, J.J., Jr, and L. D. Harris. 1995. Interspecific competition for red-cockaded woodpecker cavities in the Apalachicola National Forest. Pages 389-393 *in* D.L. Kulhavy, R.G. Hooper, and R. Costa, eds. Red-cockaded woodpecker: recovery, ecology and management. Center for Applied Studies in Forestry, College of Forestry Stephen F. Austin State University, Nacogdoches, Texas.

Komarek, E.V. 1974. Effects of fire temperature forests and related ecosystems: southeastern United States. Pages 251-277 *in* T.T. Kozlowski and C.E. Ahlgren, eds. Fire and ecosystems; Academic Press, New York.

Lennartz, M.R., P.H. Geissler, R.F. Harlow, R.C. Long, K.M. Chitwood, and J.A. Jackson. 1983. Status of the red-cockaded woodpecker on federal lands in the South. Pages 7-12 *in* D.A. Wood, ed. Red-cockaded woodpecker symposium II proceedings. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Lennartz, M.R., R.G. Hooper and R.F. Harlow. 1987. Sociality and cooperative breeding of red-cockaded woodpeckers. Behavior Ecology and Sociobiology 20:77-88.

Ligon, J.D. 1968. Sexual differences in foraging behavior in two species of Dendrocopos woodpeckers. Auk 85:203-215.

Ligon, J.D. 1970. Behavior and breeding biology of the red-cockaded woodpecker. Auk 87: 255-278.

Nesbitt, S.A., A.E. Jerauld, and B.A. Harris. 1983. Red-cockaded woodpecker summer range sizes in southwest Florida. Pages 68-71 *in* D.A. Wood, ed. Proceedings of the red-cockaded woodpecker symposium II; Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Patterson, G.A. and W.B. Robertson, Jr. 1981. Distribution and habitat of the red-cockaded woodpecker in Big Cypress National Preserve. National Park Service, South Florida Research Center. Report T-613; Homestead, Florida.

Pederson, J. 1996. FWS Multi-Species Recovery Team meeting, May 25, 1996.

Porter, M. L. 1984. Home range size and foraging habitat requirements of the red-cockaded woodpecker (*Picoides borealis*) in pine habitats of north Florida. M.S. thesis, University of Florida, Gainesville, Florida.

Porter, M.L. and R.F. Labisky. 1986. Home range and foraging habitat of red-cockaded woodpeckers in northern Florida. Journal of Wildlife Management. 50:239-247.

Ramey, P. 1980. Seasonal, sexual, and geographic variation in the foraging ecology of red-cockaded woodpeckers (*Picoides borealis*). M.S. thesis, Mississippi State University; Mississippi.

Reinman, J.P. 1995. Population status and management of red-cockaded woodpeckers on St. Marks National Wildlife Refuge 1980-1992. Pages 106-111 *in* D.L. Kulhavey, R.G. Hooper, and R. Costa, eds. Red-cockaded woodpecker: recovery, ecology, and management. Center for Applied Studies in Forests, College of Forestry, Stephen F. Austin State University; Nacogdoches, Texas.

Richardson, D.M, and J. Stockie. 1995. Response of a small red-cockaded woodpecker population to intensive management at Noxubee National Wildlife Refuge. Pages 98-105 *in* D.L. Kulhavy, R.G. Hooper, and R. Costa, eds. Red-cockaded woodpecker: recovery, ecology and management. Center for Applied Studies in Forestry, College of Forestry, Stephen F. Austin State University, Nacogdoches, Texas.

Rudolph, D.C., H. Kyle, and R.N. Conner. 1990. Red-cockaded woodpeckers vs. rat snakes: the effectiveness of the resin barrier. Wilson Bulletin 102:14-22.

Rudolph, D.C., R.N. Conner, D.K. Carrie, and R. Shaefer. 1992. Experimental reintroduction of red-cockaded woodpecker. Auk 109: 914-916.

Rudolph, D.C. and R.N. Conner. 1991. Cavity tree selection by red-cockaded woodpeckers in relation to tree age. Wilson Bulletin 103:458-467.

Salyer, M. 1996. FWS Multi-Species Recovery Team meeting, May 25, 1996.

Schillaci, J.M. and R.J. Smith. 1994. Red-cockaded woodpeckers in northwestern Florida produce a second clutch. Florida Field Naturalist 22:112-113.

Shapiro, A.E. 1983. Characteristics of red-cockaded woodpecker cavity trees and colony areas in southern Florida. Florida Scientist 46:84-95.

Stamps, R.T., J.H. Carter, III, T.L. Sharpe, P.D. Doerr, and N.J. Lantz. 1983. Effects of prescribed burning on red-cockaded woodpecker colonies during the breeding season in North Carolina. Pages 78-80 *in* D.A. Wood, ed. Red-cockaded woodpecker symposium II proceedings. Florida Game and Fresh Water Fish Commission. Tallahassee, Florida.

Taylor, W.E., and R.G. Hooper. 1991. A modification of Copeyon's drilling technique for making artificial red-cockaded woodpecker cavities. General Technical Report SE-72. U.S. Department of Agriculture, Forest Service, Southeastern Forest Experimental Station; Asheville, North Carolina.

U.S. Fish and Wildlife Service [FWS]. 1985. Red-cockaded woodpecker recovery plan. On file at U.S. Fish and Wildlife Service; Atlanta, Georgia.

Walters, J.R. 1990. Red-cockaded woodpeckers: a "primitive" cooperative breeder. Pages 69-101 *in* P.B. Stacey and W.D. Koenig, eds. Cooperative breeding in birds, Cambridge University Press; Cambridge, England.

Walters, J.R., P.D. Doerr and J.N. Carter III. 1988. The cooperative breeding system of the red-cockaded woodpecker. Ethology 78:275-305.

Watson, J.C., R.G. Hooper, D.L. Carlson, W.E. Taylor, and T.E. Milling. 1995. Restoration of the red-cockaded woodpecker population on the Francis Marion National Forest: three years post Hugo. Pages 172-182 *in* D.L. Kulhavy, R.G. Hooper, and R. Costa, eds. Red-cockaded woodpecker: recovery, ecology and management. Center for Applied Studies in Forestry, College of Forestry, Stephen F. Austin State Univ., Nacogdoches, Texas.

Wood, D.A. 1983. Observations on the behavior and breeding biology of the red-cockaded woodpecker in Oklahoma. Pages 92-94 *in* D.A. Wood, ed. Red-cockaded woodpecker symposium II proceedings. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Wood, D.A. 1996. Promoting red-cockaded woodpecker welfare in Florida. Nongame Wildlife Management Bulletin Number 1. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Wood, D. A., and A. S. Wenner. 1983. Status of the red-cockaded woodpecker in Florida: 1983 update. Pages 89-91 *in* D. A. Wood, ed. Red-cockaded woodpecker symposium II proceedings. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Recovery for the Red-cockaded Woodpecker

Picoides borealis

Recovery Objective: PERPETUATE VIABLE POPULATIONS where species currently exists.

South Florida Contribution: ESTABLISH SUPPORT POPULATIONS to facilitate range-wide recovery.

Recovery Criteria

South Florida can contribute the establishment of one or more viable populations of red-cockaded woodpeckers toward the overall recovery goal for the species throughout its range. In particular, we should focus on increasing numbers of birds in the hydric pine flatwoods community of southwest Florida; South Florida is the only place where red-cockaded woodpeckers inhabit this community type throughout their range.

This objective will be achieved when: a reserve design for South Florida is developed that identifies patches of suitable-size nesting and foraging habitat (stands of old-age, mature pines of adequate size) essential for preventing further declines in the population; when any further loss and fragmentation of habitat within these reserves has been prevented; when suitable, occupied habitat within the reserves is protected through appropriate management on public and private lands, land acquisition, and cooperative agreements with private landowners; when additional nesting and foraging habitats are created or restored adjacent to existing clusters; when augmentation or artificial cavities are successfully implemented where needed to establish new groups; and when groups of red-cockaded woodpeckers within the reserves sustain

Species-level Recovery Actions

S1. **Determine the distribution and status of red-cockaded woodpeckers in South Florida.** The status of the red-cockaded woodpecker in South Florida will remain uncertain and controversial until reliable census data are acquired. A range-wide survey was completed for most Federal lands in 1982. Additional surveys are needed on public and private lands to update our information on the status of active and inactive clusters, as well as the availability of suitable unoccupied habitat throughout South Florida.

S1.1 **Conduct surveys on Federal and other public lands.** Current surveys should be expanded to include Federal properties not included in the original survey as well as other public lands such as state forests, parks, wildlife management areas, and conservation lands.

S1.2. **Conduct surveys on private lands.** Develop non-invasive techniques (*i.e.* use of aerial photography) to identify potentially suitable habitat on private lands that could be occupied by red-cockaded woodpeckers. Work with landowners to obtain access to survey those lands and other private properties where red-cockaded woodpeckers are known to occur.

S1.3. **Repeat surveys at 5 to 10 year intervals.** Surveys should be repeated at 5 to 10 year intervals to determine local trends and to maintain consistency with region-wide surveys.

S1.4. **Use survey techniques that are consistent with region-wide surveys.** Use of standardized procedures in censusing local populations will facilitate communication among investigators, managers, and policy makers, and permit the integration of South Florida data into regional and range-wide estimates. Use these data to determine population status and trends.

S1.5. **Maintain red-cockaded woodpecker distribution data in a GIS database.** Update the existing GIS database by including information on the distribution of known clusters of red-cockaded woodpeckers and the current status of pine flatwoods communities throughout South Florida.

S2. Protect red-cockaded woodpeckers in South Florida.

S2.1. **Develop a reserve design for red-cockaded woodpeckers in South Florida using landscape maps, GIS and spatially explicit models.** Design reserves to consist of areas identified as critical to the survival of the red-cockaded woodpecker in South Florida. Large, contiguous patches of pineland habitat are ideal. Non-contiguous patches must be large enough to support at least short-term viable populations of at least 10 clusters, or must have corridors to link to additional suitable habitat.

S2.1.1. **Identify all public lands, other conservation lands, and private lands where red-cockaded woodpeckers currently exist.** Determine the current status and distribution of red-cockaded woodpeckers on protected and private lands from S1.5.

S2.1.2. **Identify all unoccupied, potentially restorable pineland areas on public and other conservation lands.** Work with Federal, State, and county agencies and NGOs to identify areas where management is needed, and where such management would benefit red-cockaded woodpeckers.

S2.1.3. **Identify additional key privately owned lands that could enhance existing red-cockaded woodpecker preserves on conservation lands,** that would serve as source sites for red-cockaded woodpeckers, or that would provide corridors to facilitate dispersal between occupied conservation lands.

S2.1.4. **Use spatially explicit models** with the existing information on suitable and restorable pineland habitat remaining in South Florida, and data on red-cockaded woodpecker biology, to identify the most suitable and feasible alternative for development of a reserve design to conserve red-cockaded woodpeckers in South Florida.

S2.2. **Protect, manage, and enhance red-cockaded woodpecker populations on public lands.** In South Florida, red-cockaded woodpeckers are Federally protected on Avon Park AFR and Big Cypress National Preserve, and also occur on state-administered lands. The survival of the red-cockaded woodpecker depends to a large extent on maintaining and enhancing clusters on these public lands.

S2.2.1. **Develop management plans for red-cockaded woodpeckers where they occur on public lands.** With assistance from the FWS, each public property manager should develop a long-term management plan designed to protect and enhance red-cockaded woodpecker clusters on their property. The plans should include fire and/or mechanical management to maintain the habitat in a suitable condition, as well as the use of starts or artificial cavities where feasible. Monitoring should be incorporated in the plan as feedback for adaptive management.

S2.2.2. **Implement management plans for red-cockaded woodpeckers on public lands.** Public land managers should coordinate efforts to ensure that the implementation and timing of management actions on adjacent properties are not in conflict, and that equipment and personnel are used effectively and efficiently.

S2.3. **Encourage protection and management of red-cockaded woodpeckers on private lands**. In 1992, the FWS began developing a conservation strategy to address red-cockaded woodpecker losses on private lands, economic impacts to private landowners of providing habitat, and cooperative conservation efforts between the public and private sectors (Costa 1995). A number of incentives have been proposed to compensate private landowners willing to manage for red-cockaded woodpeckers.

S2.3.1. **Develop Memorandums of Agreement between the FWS, private landowners, and other cooperators.** Agreements should specify management actions needed to protect the species and identify the party responsible (landowner or Federal agency) for implementing the various actions. Agreements should set forth the total commitments of the two parties including land base, funds, equipment, manpower, and time period, and provide a means and time frame for terminating the agreement.

S2.3.2. **Implement Safe Harbor Policy for red-cockaded woodpeckers where it would benefit recovery.** The Safe Harbor concept could work in South Florida for the large tracts of privately held pine flatwoods, such as in the southwestern part of the state. This program could be a key to maintaining population exchange of red-cockaded woodpeckers in South Florida and lend more demographic stability to population centers.

S2.3.3. **Recognize or reward protection and management efforts.** Management efforts on private lands should be recognized and rewarded in any way possible in light of the limited legal responsibilities involved.

S2.3.4. **Develop and implement other conservation programs.** The opportunities for a model tax incentive program at State and Federal levels should be explored and implemented if feasible.

S2.3.5. **Provide information on management and legal requirements to private landowners and managers.**

S2.3.5.1. **Continue development of information articles and management guidelines oriented to private lands.** These articles and guidelines should include information and visual aids to identify habitat of the species, detailed information for managing the species by an array of options depending on the total land management objectives of the owner or manager, and specific information on the legal responsibilities of private landowners through section 9 of the ESA. Legal responsibilities under section 7 of the ESA should also be detailed to explain the different obligations when there is Federal involvement of any kind.

S2.3.5.2. Distribute information to private landowners and managers through professional and industrial associations. The information developed in **S2.3.5.1.** should be distributed through a variety of professional and trade associations and agencies, such as the State and Private Forestry branch of the USDA Forest Service, county agricultural extension agents, and state forestry associations.

S2.4. Enforce available protective measures. Employ local, State and Federal regulations and guidelines to protect red-cockaded woodpeckers and their habitat.

S2.4.1. Initiate section 7 consultation when applicable. All Federal agencies must consult with the FWS on any of their activities (authorized, funded, or carried out) that might adversely affect resident red-cockaded woodpecker populations. Such activities include (among others) pesticide use, road construction, military training exercises, and clearing of land for new buildings and runways. Implement on-site minimization through section 7 when needed.

S2.4.2. Implement on-site minimization, habitat compensation, and mitigation on private lands through section 10 when needed. Where adverse effects cannot be avoided, measures must be taken to minimize on-site disturbance, and compensate or mitigate for the impacts that remain. The FWS generally recommends that areas used as habitat compensation be located in the vicinity of the affected habitat, where appropriate, to enhance existing clusters, and avoid further fragmentation and isolation of existing habitat.

S2.5. Revise the Federal guidelines for evaluating red-cockaded woodpecker habitat in South Florida. The FWS needs to work toward revising the Federal guidelines (Henry 1989) to be beneficial for red-cockaded woodpeckers in South Florida. These guidelines are inadequate for South Florida, particularly for the hydric slash pine flatwoods in southwest Florida. At least half of the areas there would fail to meet the 23.1 cm dbh criteria for determining suitable habitat, and more than half of the clusters would fail to meet the standard for determining suitable cavity trees (Beever and Dryden 1992).

S3. Conduct research on the life history and population dynamics of red-cockaded woodpeckers in South Florida. Although red-cockaded woodpeckers have been well studied, very little is known about the life history and subsequent management needs of birds in South Florida.

S3.1. **Gather basic life history and demographic data,** such as reproductive success, juvenile and adult survival and mortality, juvenile recruitment into the breeding population, the role of helpers, home range size requirements, and dispersal of birds within the various subpopulations in South Florida.

S3.2. **Conduct risk assessment analysis to determine the probability of persistence of red-cockaded woodpeckers in South Florida,** given the current amount of available, suitable pineland habitat. Include pineland areas that could be restored or enhanced to become suitable habitat.

S3.2.1. **Identify which subpopulations of red-cockaded woodpeckers are considered "viable"** according to our recovery criteria, and which subpopulations or groups of birds are most vulnerable to extinction.

S3.2.2. **Incorporate results of this effort into the reserve design** for red-cockaded woodpeckers to assist with project review and consultation purposes.

S3.3. **Study the effects of habitat fragmentation due to urbanization.** On a landscape level, determine how residential development affects the metapopulation dynamics of red-cockaded woodpeckers. On a population level, identify the conditions that red-cockaded woodpeckers can tolerate and adapt to in a suburban setting, in addition to the conditions that significantly alter their vital rates, such as reproductive success, growth, and survival.

S3.4. **Determine the biological and ecological conditions necessary to ensure natural colonization following habitat restoration.** Describe the conditions that are conducive to natural immigration of red-cockaded woodpeckers after restoration of unoccupied pineland communities. Collect life history information on red-cockaded woodpeckers that naturally immigrate to restored habitat, including immigration, habitat use, territoriality, reproduction, adult and juvenile survival, dispersal, and recruitment.

S3.5. **Research feasibility of translocation of red-cockaded woodpeckers in South Florida.** Translocation of red-cockaded woodpeckers has been shown to be successful in areas outside of South Florida, and has not yet been attempted here. Explore opportunities for translocating red-cockadeds to establish new populations, to enhance gene flow, or to salvage groups permitted for incidental take.

S3.5.1. **Identify areas in South Florida where red-cockaded woodpeckers occur in small, isolated populations that are subject to eventual extinction,** or where habitat is so threatened that birds would not be able to survive due to stochastic events, demographic problems and/or a lack of genetic vigor.

S3.5.2. **Conduct an experimental translocation of birds from one of the areas identified in 3.5.1. to an area with suitable habitat that can support additional birds.** Follow the protocols established for red-cockaded woodpeckers that have been successful elsewhere (Costa and Kennedy 1994).

S4. Monitor red-cockaded woodpecker subpopulations.

S4.1. Monitor representative groups within each subpopulation in South Florida to collect data on habitat use, reproduction, survival, mortality, dispersal, and recruitment. Use these data to determine the status and trends of birds throughout South Florida.

S4.2. Monitor birds in urban areas for changes in their vital rates, such as reproductive success, growth, and survival, as urbanization affects territory size.

S4.3. Monitor natural immigrants and translocated birds. Collect data as in **S4.1** to determine the success of birds that inhabit newly restored habitat as well as birds that have been translocated to new areas.

S5. Inform and involve the public. This is an ongoing task. Particular emphasis should be placed on explaining the status, importance and biological needs of red-cockaded woodpeckers and the legal responsibilities for the species' protection.

S5.1. Prepare informative articles for the news media and popular publications. Information articles for the news media and popular publications should be prepared. The news media should be contacted and encouraged to utilize the information articles as prepared or incorporate all or part of the information in articles prepared by news media staff.

S5.2. Distribute information to the public via mailings to conservation groups and individuals and through public meetings. The popular publications should be distributed to the public via mailings to conservation groups and individuals, and through public meetings. Availability of the publications should be publicized and the public encouraged to request copies.

Habitat-level Recovery Actions

H1. Prevent degradation of existing red-cockaded woodpecker habitat in South Florida. The long-term survival of the red-cockaded woodpecker is dependent upon the immediate protection of as much of the remaining occupied and suitable, unoccupied pineland communities as possible, given biological, social, economic, and legal constraints.

H1.1. Prioritize areas identified in reserve design for management and acquisition. Large, contiguous habitat patches are the most ideal for conserving red-cockaded woodpeckers. High priority should be given to areas contiguous with, or within short dispersal distance of, existing conservation lands where red-cockaded woodpeckers occur. High priority should also be given to areas adjacent to suburban sites where red-cockaded woodpeckers occur, allowing natural dispersal of birds from suburban areas to protected habitat.

H1.2. Protect red-cockaded woodpecker habitat on private lands through easements, acquisitions, and donations. Lands identified for acquisition should be located adjacent to, or be contiguous with, publicly owned conservation lands or other lands proposed for acquisition that contain red-cockaded woodpecker clusters. Lands containing red-cockaded woodpeckers should receive special consideration where these lands would consolidate Federal ownership or control and contribute to overall resource management objectives of the agencies.

H1.2.1. Support State acquisition efforts. The Florida Conservation and

Recreation Lands (CARL) program has a number of ongoing projects and proposals for the acquisition of threatened vegetative communities in Florida. Florida's Save Our Rivers (SOR) acquisition program administered by the water management districts targets wetlands for protection but some sites also contain xeric uplands, and potentially red-cockaded woodpecker habitat that could benefit from the SOR program.

H1.2.2. Encourage acquisition by Non-Governmental Organizations. Occupied and suitable, unoccupied areas not targeted in Federal and State acquisition programs may become available for private purchase and management.

H1.2.3. Pursue acquisition of lands identified as necessary for developing red-cockaded woodpecker reserves that are not covered under H1.2.1 or H1.2.2 .

H1.2. Maintain adequate nesting habitat in addition to currently active clusters, to replace clusters abandoned or lost through mortality, and to provide for population expansion. Cavity trees can be provided by lengthened rotations, by leaving old-growth remnant trees well distributed throughout younger stands, by perpetuating small remnant stands or patches of old-growth throughout the forest area, or by a combination of these methods. Manage clusters as stands rather than as individual trees and avoid isolating clusters from adjacent forest cover and foraging habitat. Burn or otherwise treat clusters to control hardwood stocking. Potential nesting habitat should be burned and thinned similarly to clusters.

H1.3. Maintain adequate foraging habitat to support existing groups and to facilitate establishment of new territories. Although the loss of nesting habitat is the most serious threat to red-cockaded woodpeckers, groups cannot survive without adequate foraging habitat as well. In South Florida, because of the difference in habitat structure and composition, more habitat is needed for foraging than in areas in the northern portion of the species' range (Hovis and Labisky 1996; Beever and Dryden 1992).

H1.4. Prevent loss or fragmentation of pine flatwoods within reserves identified in S2.1. Ensure that no habitat gaps are created within reserves that might preclude dispersal by red-cockaded woodpeckers.

H2. Restore and enhance red-cockaded woodpecker habitat.

H2.1. Use artificial starts in suitable areas. Suitable substrate for cavity excavation is a limiting factor in localized situations, so artificial starts should be excavated in selected trees both in clusters and in suitable but unoccupied nesting/roosting habitat.

H2.2. Create artificial cavities in suitable areas. When the availability of trees suitable for cavity excavation in a cluster is severely restricted, or when the management objective is to induce colonization of an unoccupied but suitable area, artificial cavities can be created in suitable trees (Copayon 1990; Allen 1991; Taylor and Hooper 1991).

H3. Conduct research on habitat needs and management for red-cockaded woodpeckers in South Florida.

H3.1. Determine the amount of foraging habitat needed to sustain a group of woodpeckers in South Florida in both mesic and hydric pine flatwood habitats. The current Federal foraging guidelines for red-cockaded woodpeckers are unsuitable for use in South Florida because of the significant differences in habitat quality. These data are needed to produce guidelines specific to South Florida.

H3.2. Investigate the best method(s) to provide and manage nesting habitat. Determine whether successful ongoing management activities for red-cockaded woodpeckers elsewhere are suitable for use in South Florida, or how they may be modified for use here.

H3.3. Determine the potential carrying capacity for clusters of red-cockaded woodpeckers on existing public and private lands where suitable or restorable habitat exists.

H3.4. Assess the biological processes associated with cluster abandonment (*e.g.,* interspecific competition, predation, *etc.*), and methods for preventing abandonment.

H3.5. Determine whether retention of snags and dead and abandoned cavity trees within clusters increases or decreases competitive pressure on red-cockaded woodpeckers.

H4. Monitor xeric communities that provide red-cockaded woodpecker habitat.

H4.1. Monitor pineland habitat that is occupied by red-cockaded woodpeckers to ensure public lands are managed to maintain habitat in suitable condition for red-cockaded woodpeckers, and to assess when unmanaged areas become unsuitable. Also monitor to ensure the site is not becoming a population “sink”.

H4.2. Monitor unoccupied pine flatwood communities following restoration to collect data on habitat characteristics upon immigration and establishment of red-cockaded woodpeckers. This will provide information on the habitat conditions that are suitable for red-cockaded woodpeckers following restoration.

H4.3. Maintain red-cockaded woodpecker habitat data in a GIS database. Update the existing GIS database by including information obtained from surveys in **S1.1** on the current status of pineland habitat in South Florida. Record the condition of the habitat, and the type and timing of all pertinent management actions.

H5. Increase public awareness of pine flatwoods communities. Efforts should highlight habitat acquisition initiatives, importance of biodiversity, and biology of pineland-dependent species. Federal, State, and county governments, as well as private organizations, should support the development and dissemination of educational materials pertaining to the conservation of the remaining pine flatwoods in South Florida. Materials such as brochures, posters, postcards, slide programs and videotapes can improve public understanding of and increase appreciation for protection of this community. Environmental education programs throughout South Florida should be encouraged to distribute materials or develop lesson plans on the pine flatwoods community, highlight species such as the red-cockaded woodpecker, and discuss the importance of maintaining biological diversity.

The Reptiles

Ten threatened or endangered reptiles occur in South Florida. Of these, only the blue-tailed mole skink is endemic to this region. The sand skink is predominantly found in South Florida, but also occurs just north of this Ecosystem boundary. South Florida represents the northernmost range for the American crocodile, and may represent the southern-most range for the Atlantic salt-marsh snake. The Eastern indigo snake occurs throughout South Florida but is also more widely distributed throughout the southeastern United States. Four of the five species of sea turtles are globally-distributed, but at least three of them nest regularly in South Florida.

This section of the Multi-Species Recovery Plan contains accounts of the threatened and endangered reptile species of South Florida. These accounts detail the biology, ecology, status and trends, and management for each of these species. Each account is followed by the recovery needs of the species which outline the recovery objective, criteria that will be used to determine when the objective has been achieved (called recovery criteria), and the tasks that will be necessary to achieve the objective (called recovery actions). The recovery tasks are divided into species-level recovery actions that address species-specific conservation and biology, and habitat-level recovery actions that address habitat management, conservation, and restoration needs for the species. The habitat-level recovery actions form the basis for the multi-species/community-level restoration actions that are provided in the community accounts. For species that have distributions outside of South Florida, there are two sections to the recovery objective; the first is the recovery objective for the species throughout its range; the second section identifies how South Florida will contribute to the species' recovery throughout its range.

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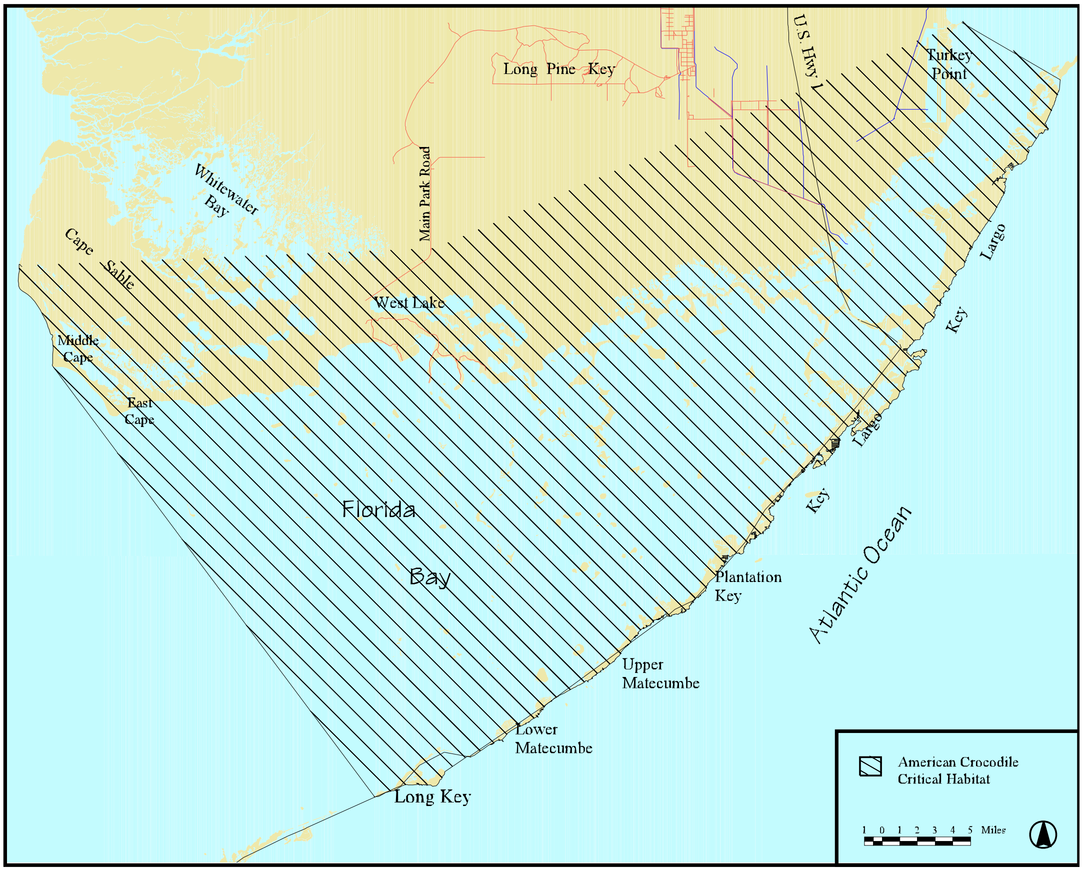
Figure 2. American crocodile critical habitat.



As with most crocodilians, courtship and mating are stimulated by increasing ambient water and air temperatures. Reproductive behaviors peak when body temperatures reach levels necessary to sustain hormonal activity and gametogenesis. In South Florida, temperatures sufficient to allow initiation of courtship behavior are reached by late February through March. Like all other crocodilians, the mating system of the American crocodile is polygynous; each breeding male may mate with a number of females (Magnusson *et al.* 1989). Males typically establish and defend a breeding territory from late February through March (Moore 1953a, Garrick and Lang 1977). Vocalizations, body posturing, and outright aggression are used to maintain and defend territories and to secure mating privileges with females that roam freely between territories. Male and female American crocodiles go through a ritualistic mating sequence prior to copulation. Courtship in this species is considered to be one of the most structured of all crocodilians, with copulation predictably following precopulatory behaviors (Lang 1989, Thorbjarnarson 1991).

Following courtship and mating, females search for and eventually select a nest site in which they deposit an average of about 38 elongated oval eggs. Reported clutch size ranges from 8 to 56 eggs (Kushlan and Mazzotti 1989; P. Moler, GFC, personal communication 1998). Although American crocodile nesting is generally considered a non-social event, communal nesting is the norm in parts of the Caribbean, southeast Cuba, and Haiti. In the U.S., several incidents of 2-clutch nests have been reported (Kushlan and Mazzotti 1989; P.

indentation of the upper jaw leaves the fourth tooth of the lower jaw exposed when the mouth is closed. Compared to the alligator, the American crocodile may be distinguished by its longer, narrower, more tapered snout and the exposed fourth tooth of the lower jaw.

Taxonomy

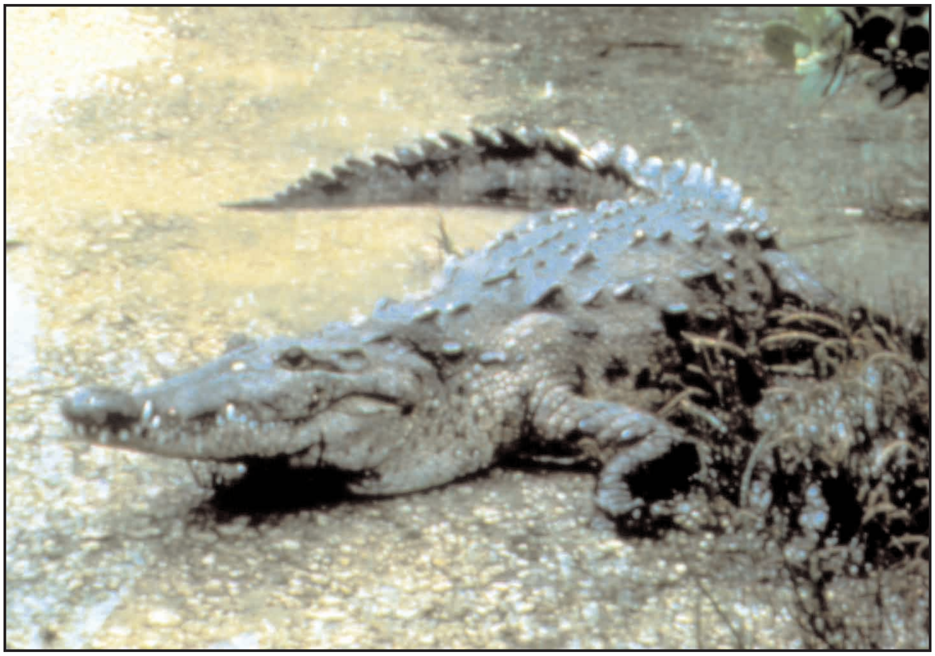
The American crocodile is one of 22 species of crocodilians (*Crocodylidae*) found throughout the world, and one of 13 species of crocodiles (*Crocodylinae*). Four species of crocodilians are found in North America; only the American crocodile and American alligator (*Alligator mississippiensis*) occur in the United States. In addition to the present treatment as American crocodile (*Crocodylus acutus*, Cuvier), Florida populations have also been reported as *Crocodylus floridanus* (Hornaday) and *Crocodylus americanus* (Boulenger).

Distribution

The historic distribution of American crocodiles in southern Florida has been debated for many years. Kushlan and Mazzotti (1989) provided the most comprehensive review of information regarding crocodile distribution, and suggested that the overall range of American crocodiles has not changed substantially over the past 200 years. Historically, American crocodiles occurred at least as far north on the Florida east coast as Lake Worth, Palm Beach County (DeSola 1935, Hornaday 1914, FWS 1984), to Tampa Bay on the west coast (Kushlan and Mazzotti 1989), and as far south as Key West (Allen and Neill 1952, Neill 1971).

The current distribution of the American crocodile is limited to extreme South Florida, including coastal areas of Miami-Dade, Monroe, Collier, and Lee counties (Figure 1). In Biscayne Bay, crocodiles have been observed as far north as Crandon Park, Bill Baggs Cape Florida SRA, and Snapper Creek (J. Maguire, Miami-Dade County Park and Recreation Department, personal communication 1998). Occasional sightings are still reported farther north on the east coast, and there are also records from Broward County, along the entire length of Biscayne Bay (Barbour 1923, 1944, DeSola 1935, Dimock 1915, FWS 1984); a few isolated crocodiles still survive in remnant mangrove habitats there. Along Florida’s southwest coast, several small groups and individual crocodiles have been documented from Sanibel Island, Lee County, south to Collier Seminole SP, Collier County. Very few reliable reports are available for the Ten Thousand Islands area. Crocodiles are regularly seen in Everglades NP along the mainland shoreline of Florida Bay from the Cape Sable peninsula east to U.S. Highway 1, in mangrove habitats on North Key Largo from Blackwater Sound north to Ocean Reef Club, and at Florida Power and Light’s Turkey Point Nuclear Electrical Generating Facility. These areas include Federal or State owned/managed lands in Everglades NP and Biscayne NP; Crocodile Lake NWR and J. N. “Ding” Darling NWR; Collier Seminole SP; and Key Largo Hammocks State Botanical Preserve. Crocodiles possibly occur on Homestead AFB and John Pennekamp Coral Reef SP. There are also records further south in the Florida Keys to the Matecumbe Keys, Stock Island, and Bahia Honda (Carr 1940, FWS 1984, P. Moler, GFC,

American crocodile. *Original photograph by Paul Moler.*



personal communication 1998).

The distribution of crocodiles during the non-nesting season may vary considerably among years since adult crocodiles can disperse great distances (Kushlan and Mazzotti 1989). However, the majority of crocodiles are present in the vicinity of core nesting areas, located near Biscayne and Florida bays (Kushlan and Mazzotti 1989).

The American crocodile also occurs in Cuba, Hispaniola, Jamaica, Trinidad, Margarita; the Atlantic Coast of Mexico from the Bay of Campeche south through the offshore islands of Belize to Venezuela and Colombia. On the Pacific Coast it is found from Sinaloa, Mexico, and the Tres Marias Islands south to coastal Ecuador and the Rio Chira in Peru (King *et al*. 1982, Ross and Magnusson 1989). Throughout their range, American crocodiles are sympatric with other crocodilians, although they tend to inhabit more saline waters than most other species. In Cuba they overlap with the Cuban crocodile (*Crocodylus rhombifer*) and in Central America and southern Mexico with the common caiman (*Caiman crocodylus*) and Morelet's crocodile (*Crocodylus moreletti*). The American crocodile and alligator are sympatric in brackish-water portions of their range in South Florida, but, due to evolutionary divergence, no hybridization would be expected.

Habitat

The American crocodile is found primarily in mangrove swamps and along low-energy mangrove-lined bays, creeks, and inland swamps (Kushlan and Mazzotti 1989). In Florida, patterns of crocodile habitat use shift seasonally. During the breeding and nesting seasons, adults outside of Key Largo and Turkey Point use the exposed shoreline of Florida Bay. Males tend to stay more inland than the females at this time (L. Brandt and F. Mazzotti, University of Florida, personal communication 1998; P. Moler, GFC, personal communication 1998). During the non-nesting season, they are found primarily in the fresh and brackish-water inland swamps, creeks, and bays, retreating further into the back country in fall and winter (Kushlan and Mazzotti 1989). In a study by Kushlan and Mazzotti (1989) along northeastern Florida Bay, crocodiles were found in inland ponds and creeks (50 percent of observations), protected coves (25 percent of observations), exposed shorelines (6 percent of observations) and a small number were observed on mud flats. The high use of inland waters suggests crocodiles prefer less saline waters, using sheltered areas such as undercut banks and mangrove snags and roots that are protected from wind and wave action. Access to deep water (>1.0 m) is also an important component of preferred habitats (Mazzoti 1983).

Natural nesting habitat includes sites with sandy shorelines or raised marl creek banks adjacent to deep water. Crocodiles also nest on elevated man-made structures such as canal berms and other places where fill has been introduced. In natural nesting situations, creek bank nests are generally considered optimal since these sites provide a good incubation medium and are generally protected from wind and wave action. These nest sites also provide deep water refuge for adult females. Nests adjacent to open water provide little protection from wave action for the nest, hatchlings, or adults. Shore nests are typically not located near good nursery habitat, and mortality of hatchlings is generally higher than in inland nests (Kushlan and Mazzotti 1989). Both nesting sites are desirable as there are tradeoffs associated with each, and hatching success at each type of location will vary among years depending on climatic conditions (L. Brandt and F. Mazzotti, University of Florida, personal communication 1998).

Critical Habitat

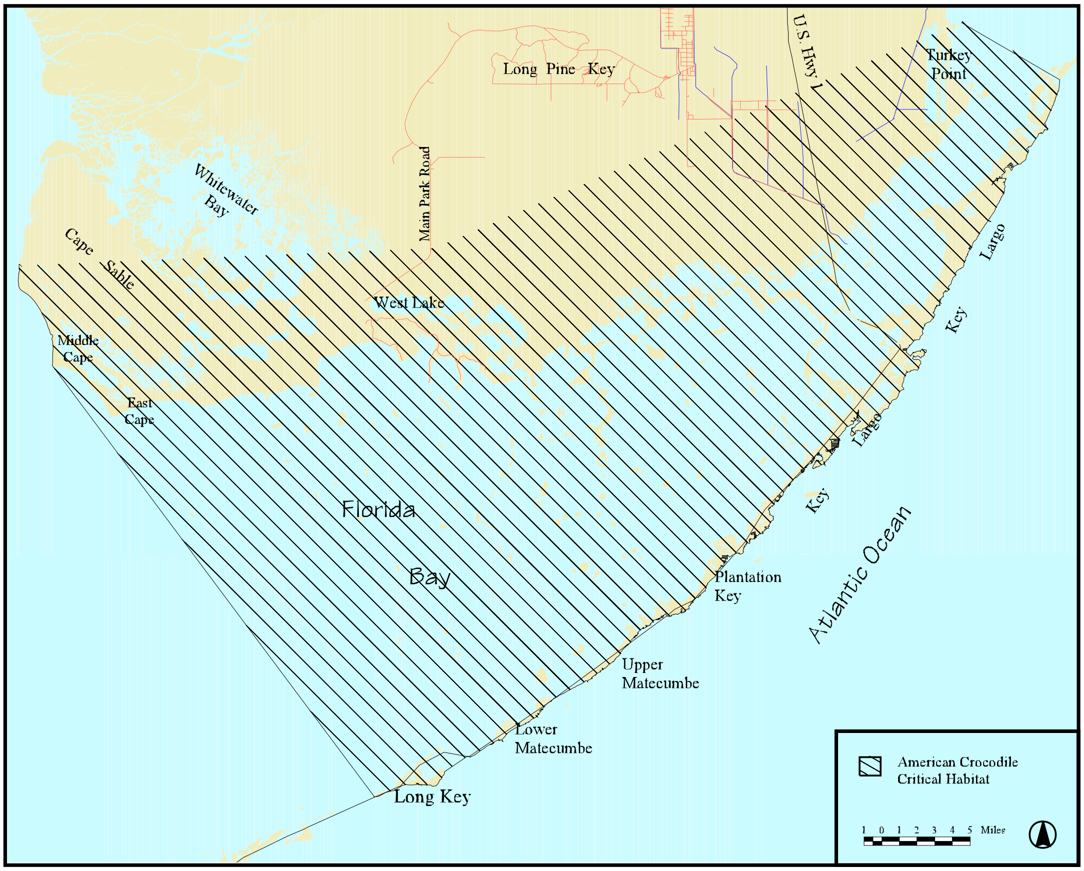
Critical habitat for the American crocodile (Figure 2) includes all land and water within an area encompassed by a line beginning at the easternmost tip of Turkey Point, Miami-Dade County, on the coast of Biscayne Bay; southeast along a straight line to Christmas Point at the southernmost tip of Elliott Key; southwest along a line following the shores of the Atlantic Ocean side of Old Rhodes Key, Palo Alto Key, Angelfish Key, Key Largo, Plantation Key, Lower Matecumbe Key, and Long Key, to the westernmost tip of Long Key; northwest along a straight line to the westernmost tip of Middle Cape; north along the shore of the Gulf of Mexico to the north side of the mouth of Little Sable Creek; east along a straight line to the northernmost point of Nine-Mile Pond; northeast along a straight line to the point of beginning (50 CFR 17.95).

Behavior

Reproduction

Females reach sexual maturity at about 2.25 m (Mazzotti 1983), a size reached at an age of about 10 to 13 years (LeBuff 1957). It is not known at what age and size females mature (Ogden 1978a). Similarly, the maximum

Figure 2. American crocodile critical



reproductive age for either sex is not known, although it is known that captively reared crocodilians eventually fail to reproduce.

As with most crocodilians, courtship and mating are stimulated by increasing ambient water and air temperatures. Reproductive behaviors peak when body temperatures reach levels necessary to sustain hormonal activity and gametogenesis. In South Florida, temperatures sufficient to allow initiation of courtship behavior are reached by late February through March. Like all other crocodilians, the mating system of the American crocodile is polygynous; each breeding male may mate with a number of females (Magnusson *et al.* 1989). Males typically establish and defend a breeding territory from late February through March (Moore 1953a, Garrick and Lang 1977). Vocalizations, body posturing, and outright aggression are used to maintain and defend territories and to secure mating privileges with females that roam freely between territories. Male and female American crocodiles go through a ritualistic mating sequence prior to copulation. Courtship in this species is considered to be one of the most structured of all crocodilians, with copulation predictably following precopulatory behaviors (Lang 1989, Thorbjarnarson 1991).

Following courtship and mating, females search for and eventually select a nest site in which they deposit an average of about 38 elongated oval eggs. Reported clutch size ranges from 8 to 56 eggs (Kushlan and Mazzotti 1989; P. Moler, GFC, personal communication 1998). Although American crocodile nesting is generally considered a non-social event, communal nesting is the norm in parts of the Caribbean, southeast Cuba, and Haiti. In the U.S., several incidents of 2-clutch nests have been reported (Kushlan and Mazzotti 1989; P. Moler, GFC, personal communication 1998). Nest sites are typically selected where a sandy substrate exists above the normal high water level. Nesting sites include areas of well drained sands, marl, peat, and rocky spoil and may include areas such as sand/shell beaches, stream banks, and canal spoil banks that are adjacent to relatively deep water (Ogden 1978a, Kushlan and Mazzotti 1989). In some instances, where sand or river banks are not available for nesting sites, a hole will be dug in a pile of vegetation or marl the female has gathered. The use of mounds or holes for nesting is independent of the substrate type and may vary among years by the same female (Kushlan and Mazzotti 1989).

The success of American crocodile nesting in South Florida is dependent primarily on the maintenance of suitable egg cavity moisture throughout incubation. Predation and flooding also affect nest success. On Key Largo and other islands, failure of crocodile nests is typically attributed to desiccation due to low rainfall (Moler 1991a). On Key Largo, about 52 percent of nests were successful in hatching at least one young (Moler 1991a). Nest failures on the mainland may be associated with flooding, desiccation, or predation (Mazzotti *et al*. 1988, Mazzotti 1989). On the mainland, about 13 percent of nests monitored were affected by flooding or desiccation, whereas 13 percent of nests were partially or entirely depredated (Mazzotti *et al.* 1988, Mazzotti 1989). More recently, Mazzotti (1994) found that predation rates on the mainland increased to 27 percent, and only 9 percent of nests failed because of infertility or embryonic mortality. Most examined eggs have been fertile (90 percent, range 84 to 100 percent) (Kushlan and Mazzotti 1989, Mazzotti 1989).

Incubation of the clutch takes about 86 days (Lang 1975), during which time the female periodically visits the nest (Moore 1953a, Neill 1971, Ogden 1978a). Some females may also attend and defend their nest during incubation (Alvarez del Toro 1974, Ross and Magnusson 1989), but this behavior is highly variable among individuals and nest defense has not been observed in the U.S or Cuba (P. Moler, GFC, personal communication 1998). In Florida, American crocodiles are not known to regularly defend their nest against humans (Kushlan and Mazzotti 1989). However, all females must return to the nest to excavate hatchlings since the young are unable to liberate themselves from the nest cavity (Moore 1953b, Neill 1971, Ogden and Singletary 1973, FWS 1984). Parental care after hatching has not been reported for this species in Florida, even though this behavior has been documented in other American crocodile populations (Kushlan and Mazzotti 1989).

The young may remain together loosely for several days to several weeks following hatching, but they are rarely seen with adults (Lang 1975, Moler 1991b, Mazzotti 1983, Kushlan and Mazzotti 1989). Hatchling survival appears to be low in Everglades NP (< 5 percent) (Mazzotti 1983, Kushlan and Mazzotti 1989), higher at Turkey Point (8.5 percent) (L. Brandt and F. Mazzotti, University of Florida, personal communication 1998), and even higher in the more sheltered habitats of North Key Largo (20.4 percent) (Moler 1991b). Higher survival on Key Largo has been attributed to the close proximity of nest sites to suitable nursery habitat. On the mainland, nest sites on exposed beaches are often far from nursery habitat, requiring recently hatched young to disperse long distances in unsheltered water. Hatchlings seek shelter during the day in beach wrack or among mangrove roots when available (Mazzotti 1983). Predation during these dispersals is probably high, although little information is available to support this conclusion (Kushlan and Mazzotti 1989).

Foraging

The American crocodile is typically active from shortly before sunset to shortly after sunrise (Lang 1975, Mazzotti 1983). During these times, crocodiles forage opportunistically, eating whatever animals they can catch. Juveniles typically eat fish, crabs, snakes, and other small invertebrates, whereas adults are known to eat fish, crabs, snakes, turtles, birds, and small mammals (Ogden 1978b, Ross and Magnusson 1989). American crocodiles probably feed only rarely during periods of low ambient air temperatures, since metabolic and digestive systems are slowed at lower body temperatures.

Relationship to Other Species

As mentioned above, American crocodiles live sympatrically with American alligators where salinities are low. Most crocodilians tolerate others of the same species and of different ages provided food and other essential habitat requirements are not limiting. Where two or more species coexist, tolerance among species is also common and is usually ensured by species-specific differences in habitat utilization. In Florida, the American crocodile and alligator have probably coexisted for thousands of years and relied on changing salinity gradients of surface waters to dictate which species predominated in certain areas. Though these species probably intermingle frequently throughout the year, we are aware of only one location where both species may nest side-by-side. If substantiated, the nesting sites along a canal berm in the vicinity of Marco Island, Collier County, would indicate use of a common nesting area by these species. However, the species' breeding seasons may be sufficiently asynchronous in this area to allow crocodiles to breed and nest before alligators become reproductively active.

The depredation rate of American crocodile nests by raccoons (*Procyon lotor*) in South Florida is low compared to depredation rates other crocodilians suffer from terrestrial nest predators. Therefore, although the raccoon may locally be an important predator, their overall effect on the crocodile population is not considered limiting in areas where their populations are not unnaturally high. Once hatched, crocodilians may be eaten by several species of wading birds and gulls, blue crabs, sharks, and other crocodiles. Though limited, survival information from Key Largo suggests that predation does not limit recruitment of juveniles in that area.

Status and Trends

Crocodiles were listed as endangered throughout their range in 1975, (40 CFR 44151) and critical habitat was established for this species in 1979 (44 CFR 75076). The listing of the species and protection of habitat were required because of documented population declines most likely associated with habitat alterations and direct human disturbances to crocodiles and their nests (FWS 1984).

Historic estimates of the American crocodile population in South Florida are difficult to substantiate because many records are anecdotal and early observations may have been confused with sympatric alligators. In addition, estuarine habitats, preferred by crocodiles, were remote and inaccessible to early settlers, thereby precluding reliable and consistent observations. Ogden (1978a) estimated that between 1,000 to 2,000 American crocodiles existed in South Florida in the early 20th century, but he thought this probably underestimated the population because extensive settlement and associated hunting had already occurred by this time. During the late 19th century and the first half of the 20th century, many Florida crocodiles were collected for museums and live exhibits (Cory 1896, Hornaday 1914, Dimock 1915, DeSola 1935, Dickinson 1953, Behler 1978). The species was also legally hunted in Florida until about 1962. By the mid-1970s, crocodile numbers had been reduced to between 100 to 400 non-hatchling individuals (Ogden 1978a).

In addition to the taking of individual crocodiles, habitat modification and destruction has been occurring since the human settlement of South Florida. Formerly occupied habitats from Lake Worth, Palm Beach County, south to central Biscayne Bay, Miami-Dade County, have been largely destroyed by urbanization. In some of these areas, crocodiles have been essentially extirpated. (DeSola 1935, FWS 1984). Recent trends, however, indicate that they may be expanding back into central Biscayne Bay, and that they have successfully nested at Chapman Field Park (J. Maguire, Miami-Dade County Parks and Recreation Department, personal communication 1998). In the Middle and Lower Florida Keys urbanization has led to habitat degradation and loss. Though crocodiles were never abundant in these areas, further habitat loss limits opportunities for dispersing crocodiles to persist there. Crocodiles were also probably never common along Florida's west coast. Urbanization there has also substantially altered much of the habitat once occupied.

Human encroachment into estuarine habitats can disturb crocodiles to such an extent that normal behavior patterns are altered. As recreational demands increase on public lands, indirect disturbance by apparently innocuous human activities such as camping, fishing, and boating are expected to increasingly affect crocodiles. Observations suggest that repeated close human presence may cause female crocodiles to abandon nests or relocate nest sites (Kushlan and Mazzotti 1989). Recreational boating, including use of jet skis, has been limited in portions of the American crocodile's habitat within Everglades NP, but public demands for additional recreational opportunities will likely threaten these sanctuaries in the future.

Crocodiles are frequently killed on U.S. Highway 1 and Card Sound Road. On average, 3 to 4 crocodiles are killed annually while crossing these roads (Mazzotti 1983, Moler 1991b). Unfortunately, subadults and adults make up the majority of road mortalities. Efforts to preclude crocodile movement across portions of Card Sound Road by fencing sections of the road have been largely unsuccessful, due primarily to improper installation of the fence.

Natural, catastrophic, stochastic events such as hurricanes also are known to adversely affect American crocodiles and may be one of the most important factors limiting the number and distribution of this species in South Florida. Crocodiles are long-lived and suffer high juvenile mortality and must, therefore, produce many young over their lifetime to ensure sufficient recruitment and population persistence. Natural events that add substantial adult mortality can result in long periods of little or no recruitment. Failure to successfully recruit age classes in consecutive years can, if repeated periodically, depress small populations.

Crocodiles undoubtedly perish during tropical storms and hurricanes that make landfall in extreme South Florida. The tidal surges, rough seas, and high winds probably result in direct mortality, but may also erode important nesting beaches, destroy nests, and alter other important habitat features. The adverse effects of tropical weather have not been quantified or reported extensively in the literature. Ogden (1978a) suggested that the occurrence of major hurricanes at regular intervals may be a factor that serves to hold the Florida crocodile population at some depressed level.

Even though extreme South Florida is considered sub-tropical, it is occasionally exposed to sub-freezing temperatures. The effect of freezing temperatures on American crocodile populations is not well known, principally because crocodiles which may be killed during freezes are rarely found (Dimock 1915, Barbour 1923, Mazzotti 1983). Critical minimum water temperatures are not known, but water temperatures of 13 to 14° C in sheltered canals did not result in crocodile mortality during an extremely hard freeze in southern Florida during 1989. Unconfirmed reports identified four dead crocodiles in exposed areas after this freeze; mortality was likely much higher since dead crocodiles were difficult to find (Moler 1991b). Moler (1991b) documented a substantial decline in nesting effort during the following spring, and suggested that adult mortality during the freeze may have been responsible for the observed decline in nesting.

Water salinity affects habitat use and may be locally important, especially during periods of low rainfall. Although American crocodiles have salt glands that excrete excess salt and physiological mechanisms to reduce water loss (Dunson 1970, 1980, 1982; Evans and Ellis 1977; Dunson and Mazzotti 1989; Mazzotti 1989), maintenance of an osmotic balance requires access to low salinity water for juveniles. Hatchling crocodiles are particularly susceptible to osmoregulatory stress and may need to have brackish to fresh water (4 ppt) available at least once per week to increase growth (Mazotti *et al.* 1986). Crocodiles larger than 200 g have sufficient mass to withstand osmoregulatory stress and are not typically believed to be affected by drought (Mazzotti and Dunson 1984). Freshwater needs of the crocodile are usually met with frequent rainfall, which results in a “lens” of fresh water on the surface that may persist for several days after rainfall (Mazzotti and Dunson 1984). Hatchling crocodiles are probably stressed and occasionally die during periods of low rainfall. Anthropogenic changes in the amount and timing of freshwater flow to South Florida may have resulted in shifts in the distribution of American crocodiles. Unfortunately, detailed data on crocodile distribution is only available since the early 1970s, and any changes that may have occurred due to hydrological perturbations over the past century cannot be identified with available information.

Combined, many of the natural and anthropogenic factors described above have resulted in adverse effects to the American crocodile. Compared to the historical estimates of 1,000 to 2,000 animals (Ogden 1978a), populations have declined, and shifts in the nesting distribution have likely occurred. The lowest estimated population levels apparently occurred sometime during the 1960s or 70s, when Ogden (1978b) estimated the Florida population of the American crocodile to be between 100 and 400 non-hatchlings.

The American crocodile population in South Florida has increased substantially over the last 20 years. P. Moler (GFC, personal communication 1996) believes between 500 and 1,000 individuals (including hatchlings) persist there currently. The recent increase is best represented by changes in nesting effort. Survey data gathered with consistent effort indicate that nesting has increased from about 20 nests in the late 1970s to about 50 nests in 1997. Since female crocodiles produce only one clutch per year, it follows that the population of reproductively active females has more than doubled in the last 20 years. In addition, since at least a portion of the population's sex ratio approaches 1:1 (Moler 1991b), it is likely that the male portion of the population has also increased substantially.

Throughout the remainder of its range, the American crocodile has suffered from threats similar to those that have adversely affected the species in South Florida. Unfortunately, only Costa Rica and Venezuela have adequately protected the American crocodile and its habitat, although Cuba protects a number of areas with large crocodile populations (King 1989, P. Moler, GFC, personal communication 1998). Other countries have no or few laws to protect them or are unable to enforce conservation laws that do exist. Current threats to the continued survival of the American crocodile outside of the United States include changes in agricultural, ranching, and forestry practices that affect coastal habitats; developing tourism industries that seek to benefit from tropical, beachfront properties (Alcala and Dy-Lyiacco 1989); and legal and illegal hunting. As natural habitats are destroyed and replaced with landscapes that benefit humans, American crocodiles will become increasingly susceptible to the public's intolerance of human/crocodile conflicts.

Management

Protection of the American crocodile outside of the United States was enhanced when most countries throughout the range of the species became signatories to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). CITES signatories agreed that, as an Appendix I species, the American crocodile would be afforded protection from international commerce. This protective measure has greatly reduced, and in some cases eliminated illegal harvests of the crocodile for its hide. Other protective measures include prohibitions against hunting all crocodilians in Mexico, and establishment of no-hunting areas in certain portions of Cuba (National Resolution No. 21-79).

In 1984 the FWS prepared a recovery plan for the American crocodile. Numerous conservation measures were identified in the recovery plan that were needed to ensure persistence and recovery of the crocodile in South Florida, including securing habitat for all life stages and establishment of self-sustaining populations at natural carrying capacity in appropriate habitats. In addition, the recovery plan for the American crocodile called for research to determine habitat needs, habitat distribution, ownership, and habitat availability to crocodiles. Management options include controlling of human-related mortality, informing the public, reducing natural mortality, and protecting nest sites.

Recovery efforts for the American crocodile are underway and are likely responsible for increases in the number of crocodiles in South Florida. About 2,640 ha have been acquired for protection of crocodiles and other imperiled species at Crocodile Lake NWR. This area consists of 262 ha of wetlands and open water habitats that directly support crocodile conservation. Crocodile habitat is also protected in Everglades NP Biscayne NP, J. N. “Ding” Darling NWR, Ten Thousand Islands NWR, Collier Seminole SP, Key Largo Hammocks State Botanical Preserve, and several Miami-Dade County parks: Matheson, Snapper Creek, Black Point, Chapman Field and Crandon. The Biscayne Wetlands and Cutler Wetlands acquisition projects in Miami-Dade County seek to place over 810 additional ha of coastal habitat into public ownership; these areas border Biscayne National Park (J. Maguire, Miami-Dade County Park and Recreation Department, 1998). The only area extensively used by crocodiles that is not under public ownership is the habitat created by construction of Florida Power and Light’s Turkey Point electrical generating facility.

Crocodile nesting continues to be monitored by the GFC and FWS on Key Largo, Florida Power and Light at Turkey Point, NPS on the mainland, and by Miami-Dade County at Chapman Field. In 1984, crocodile crossing signs were erected along U.S. Highway 1 to provide public awareness and reduce automobile/crocodile collisions. During future road widening of U.S. Highway 1, box culverts will replace existing small diameter culverts to allow crocodiles to pass under the highway. Fencing also may be erected along portions of U.S. Highway 1 to discourage crocodile movement over the road (P. Moler, GFC, personal communication 1996).

The timing and frequency of the freshwater hydroperiod substantially influences the health of the estuarine environment in South Florida and may be one of the most important large scale factors influencing crocodile populations on the mainland. It is well known that historic alterations to the natural flow have directly affected plant and animal communities. Although there is no direct causal relationship between freshwater flow alterations and American crocodile numbers, some of the population decline witnessed through the 1970s probably was attributable to changes in the amount and timing of surface water flow to South Florida. Future changes in hydrology that mimic natural flow conditions are likely to benefit crocodiles in the long-term, but care should be taken to ensure that changes in the delivery of water do not result in catastrophic, short-term, adverse effects. When added to all other natural and anthropogenic sources of mortality, such habitat changes could have substantial impacts on crocodile nesting and hatchling survival. As advances in water management are made in South Florida, research is expected to continue to assess the effects on the American crocodile of changes in the amount and timing of water delivery (Mazzotti 1996).

As discussed above, availability of fresh water is essential to hatchling crocodile survival. Instream freshwater flow and rainfall provide this water to hatchlings emerging from mainland nests, but hatchlings from islands (including Key Largo) depend solely on rainfall. During periods of low rainfall, island hatchlings do not gain mass and are less likely to survive during winter months (Moler 1991b). To increase hatchling survival and recruitment, Moler (1991b) suggested that supplemental sources of fresh water be provided during the 3 to 4 month period following hatching. Supplemental sources of fresh water may be particularly important since recent efforts to restore functioning mangrove wetlands in Crocodile Lake NWR have increased salinities in an important crocodile nursery area. Restoration of suitable salinities in this area should be considered if future monitoring indicates low hatchling growth and survival.

The numerous hydrologic projects associated with the restoration of the South Florida Ecosystem are in various stages of planning and implementation. The FWS has determined that the Central and South Florida Restudy should provide a benefit to the American crocodile. These efforts propose to improve habitat conditions through decreased salinities in Florida Bay and Shark River Slough estuarine areas by increasing volume and improved timing of freshwater flows to those areas.

Encroachment of exotic vegetation has degraded thousands of hectares of wildlife habitat in South Florida. In coastal areas, and on Key Largo, Australian pine (*Casuarina equisetifolia*), cajeput (*Melaleuca quinquenervia*), and Brazilian pepper (*Schinus terebinthifolius*) aggressively invade levees and berms. Moler (1991a) found widespread invasion of *C. equisetifolia* and to a lesser extent *M. quinquenervia* and *S. terebinthifolius* at crocodile nesting sites on Key Largo. Many of the exotics were removed during habitat restoration efforts in 1994, but vigorous regrowth and reinvasion is inevitable, and periodic efforts to control exotic vegetation will likely be required to maintain suitability of crocodile nesting sites. F. Mazzotti (University of Florida, personal communication 1996) indicated that invasive exotics were also encroaching on crocodile nest sites at Turkey Point. However, he noted that if measures outlined in Florida Power and Light's crocodile management plan were followed, exotic vegetation would be controlled before it threatened crocodile nesting sites. Renewed efforts may be needed to control exotic plants at Turkey Point. Exotic plant control in Everglades NP should continue. Australian pine has been found, and destroyed by Park staff, on nesting beaches and keys (Brandt *et al.* 1995; L. Brandt and F. Mazzotti, University of Florida, personal communication 1998).

Management programs or land-use restrictions are used on some public lands to protect and conserve natural resources. In Everglades NP, closure of water bodies has reduced boat traffic and minimized human-crocodile encounters. Unfortunately, restrictions on land and water use are now being challenged, and increasing demands for recreational opportunities may threaten crocodiles in some areas. Although human exclusion may be the best management technique for protecting crocodiles and their habitat, it is clear that an increasing number of the general public do not support this management alternative.

Though management of the physical components of crocodile habitat is essential to the continued survival of this species, emphasis must be placed on mimimizing the potential for human-crocodile encounters. Human tolerance for and acceptance of increasing crocodile numbers is one of the primary reasons for the increase in population numbers over the last 20 years. However, as the crocodile population continues to increase, we anticipate an increasing number of human-crocodile conflicts. Unfortunately, dredging of shallow waters and creation of exposed shorelines have resulted in artificial habitats that attract crocodiles to areas adjacent to human habitation. Although American crocodiles are generally considered to be non-aggressive, the public's perception of them is that of a large, dangerous, carnivore. If crocodile numbers continue to increase, we believe that more encounters will result in an increasing intolerance of crocodiles and more demands for action to reduce human-crocodile conflicts.

The GFC, through a cooperative agreement with the FWS, currently addresses human-crocodile conflicts on a case-by-case basis (GFC 1988). We believe that the GFC's guidelines for managing human-crocodile conflicts are a reasonable and flexible management alternative that can be used well into the future. These guidelines, however, are reactionary and do not attempt to address the factors leading to human-crocodile conflicts. As mentioned above, part of the reason for increasing conflicts is that humans have altered the landscape for residential, commercial, or recreational purposes without rendering this formerly potential crocodile habitat completely unsuitable. The expanding crocodile population will continue to move into these habitats and will occasionally come into conflict with humans. The guidelines should be updated to include guidance to land managers who are dealing with an increased presence of crocodilians near populated areas. The guidelines should then be incorporated into management plans.

It is unlikely that the expanding crocodile population can be prevented from using artificial habitats. These areas provide important components of crocodile habitat including basking, nesting, nursery, and deep water refugia. It is less likely that human use of already altered land can be substantially modified. For example, homeowners are not likely to abandon their houses because crocodiles bask or nest in their yards. Similarly, filling of deep water channels is improbable since these provide watercraft access to waterfront homesites. Seasonal restrictions for disruptive recreational uses such as powerboating, jet skis, camping, etc. may be appropriate near crocodile nesting locations. In other areas, new or increased recreational access may not be appropriate, since recreational use could result in greater human-crocodile conflict. Implementing recreational restrictions will be difficult, as demands for access continue to increase. Public education must provide the foundation for developing positive, proactive, attitudes about crocodile conservation. Aggressive public education

Literature Cited

is probably the most effective tool available to ensure the continued growth and recovery of South Florida's American crocodile population.

Alcala, A.C., and M.T.S. Dy-Lyiacco. 1989. Habitats. Pages 136-153 *in* C.A. Ross, ed. Crocodiles and alligators. Facts On File, Inc.; New York, New York.

Allen, E.R., and W.T. Neill. 1952. The Florida crocodile. Florida Wildlife Magazine, July 1952.

Alvarez del Toro, M. 1974. Los crocodylia de Mexico D.F.: Instituto Mexicano de Recursas Naturales, A.C.

Barbour, T. 1923. The crocodile in Florida. Occasional Papers of the University of Michigan, Museum of Zoology. 131:1-6.

Barbour, T. 1944. That vanishing Eden. A naturalist's Florida. Little, Brown and Company.

Behler, J.L. 1978. Feasibility of the establishment of a captive-breeding population of the American crocodile. South Florida Research Center T-509 Report to the NP Service; Homestead, Florida.

Brandt, L.A., F.J. Mazzotti, J.R. Wilcox, P.D. Barker, G.L. Hasty, and J. Wasilewski. 1995. Status of the American crocodile (*Crocodylus acutus*) at a power plant site in Florida, USA. Herpetological Natural History. 3(1):29-36.

Brandt, L., and F. Mazzotti. 1998. Comments on draft species account, January 26.

Carr, A.F., Jr. 1940. A contribution to the herpetology of Florida. University of Florida Publication Biological Science Series 3:1-118.

Cory, C.B. 1896. Hunting and fishing in Florida. Estes and Lauriat; Boston, Massachusetts.

DeSola, C.R. 1935. Herpetological notes from southeastern Florida. Copeia 1935(1):44-45.

Dickinson, W.E. 1953. In quest of an adult crocodile. Everglades Natural History 1(4):151-156.

Dimock, A.W. 1915. Florida enchantments (Revised edition). Outing Publishing Company; Peekamose, New York.

Dunson, W.A. l970. Some aspects of electrolyte and water balance in three estuarine reptiles, the diamondback terrapin, American and "salt water" crocodiles. Comparative Biochemical Physiology 32:161-174.

Dunson, W.A. 1980. Osmoregulation of crocodiles in Everglades National Park. South Florida Research Center Report T-599. Everglades National Park; Homestead, Florida.

Dunson, W.A. 1982. Salinity relations of crocodiles in Florida Bay. Copeia 1982(2):374-385.

Dunson, W.A., and F.J. Mazzotti. 1989. Salinity as a limiting factor in the distribution of reptiles in Florida Bay: a theory for the estuarine origin of marine snakes and turtles. Bulletin of Marine Science 44(1):229-244.

Evans, D.H., and T.M. Ellis. 1977. Sodium balance in the hatchling American crocodile, *Crocodylus acutus*. Comparative Biochemical Physiology 58A:159-162.

Florida Game and Fresh Water Fish Commission [GFC]. 1988. Guidelines for resolving crocodile complaints. Directive by the Executive Director, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Garrick, L.D., and J.W. Lang. 1977. Social signals and behaviors of adult alligators and crocodiles. American Zoologist 17:225-239.

Hornaday, W. T. 1914. The American Natural History. Volume IV Reptiles, amphibians, and fishes. Charles Scribner's Sons; New York, New York.

King. F.W. 1989. Conservation and management. Pages 216-229 *in* C.A. Ross, ed. Crocodiles and alligators, Facts On File, Inc.; New York, New York.

King, F.W., H.W. Campbell, and P.E. Moler. 1982. Review of the status of the American crocodile. Pages 84-98 *in* Proceedings of the 5th working meeting of the Crocodile Specialist Group Species Survival Commission, International Union on Conservation of Nature and Natural Resources, IUCN; Gland, Switzerland.

Kushlan, J.A., and F.J. Mazzotti. 1989. Historic and present distribution of the American crocodile in Florida. Journal of Herpetology 23(1):1-7.

Lang, J.W. 1975. The Florida crocodile: Will it survive? Chicago (Field) Museum of Natural History Bulletin 46(8):4-9.

Lang. J.W. 1989. Social Behavior. Pages 102-117 *in* C.A. Ross, ed. Crocodiles and alligators. Facts On File, Inc.; New York, New York.

LeBuff, D.R., Jr. 1957. Observations on captive and wild North American crocodilians. Herpetologica 13:25-28.

Magnusson, W.E., K.A. Vliet, A.C. Pooley, and R. Whitaker. 1989. Reproduction. Pages 118-135 *in* C.A. Ross, ed. Crocodiles and alligators, Facts On File, Inc.; New York, New York.

Maguire, J. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 28, 1998.

Mazzotti, F.J. 1983. The ecology of *Crocodylus acutus* in Florida. Ph.D. dissertation, Pennsylvania State University.

Mazzotti, F.J. 1989. Structure and function. Pages 42-57 in C.A. Ross ed. Crocodiles and alligators, Facts On File, Inc.; New York, New York.

Mazzotti, F.J. 1994. Status and trends of nesting of the American Crocodile in Everglades National Park, Florida. Final Report to National Park Service, Everglades National Park; Homestead, Florida.

Mazzotti, F.J. 1996. Telephone communication. November 14.

Mazzotti, F.J., and W.A. Dunson. 1984. Adaptations of *Crocodylus acutus* and *Alligator mississippiensis* for life in saline water. Comparative Biochemical Physiology 79(4):641-646.

Mazzotti, F.J., B. Bohnsack, M.P. McHahon, and J.R. Wilcox. 1986. Field and laboratory observations on the effects of high temperature and salinity on hatchling *Crocodylus acutus*. Herpetologica 42(2):191-196.

Mazzotti, F.J., J.A. Kushlan, and A. Dunbar-Cooper. 1988. Desiccation and cryptic nest flooding as probable causes of egg mortality in the American crocodile, *Crocodylus acutus*, in Everglades National Park, Florida. Florida Scientist 51(2):65-72.

Moler, P.E. 1991a. American crocodile nest survey and monitoring. Final Report to

Study No. 7533, Florida Game and Fresh Water Fish Commission, Bureau of Wildlife Research; Tallahassee, Florida.

Moler, P.E. 1991b. American crocodile population dynamics. Final report to study No. 7532, Florida Game and Fresh Water Fish Commission, Bureau of Wildlife Research; Tallahassee, Florida.

Moler, P.E. 1992. American crocodile. Pages 83-89 *in* P.E. Moler ed. Rare and endangered biota of Florida, volume III, amphibians and reptiles. University Press of Florida; Gainesville, Florida.

Moler, P. 1996. Multi-Species Recovery Team meeting. 28 February.

Moler, P. 1998. Comments on the technical agency draft multi-species recovery plan. October 1998.

Moore, J.C. 1953a. The crocodile in the Everglades National Park. Copeia 1953(1):54-59.

Moore, J.C. 1953b. A mound on a key in Florida Bay. Everglades Natural History 1(2):67-75.

Neill, W.T. 1971. The Last of the Ruling Reptiles. Columbia University Press; New York, New York.

Ogden, J. C. 1978a. Status and nesting biology of the American crocodile, *Crocodylus acutus* (Reptilia, Crocodylidae) in Florida. Journal of Herpetology 12(2):183-196.

Ogden, J.C. 1978b. American crocodile. Pages 21-22. *in* R. W. McDiarmid ed. Rare and endangered biota of Florida, volume 3: amphibians and reptiles. University Presses of Florida; Gainesville, Florida.

Ogden, J.C., and C. Singletary. 1973. Night of the crocodile. Audubon 75:32-37.

Ross, C.A., and W.E. Magnusson. 1989. Living crocodilians. Pages 58-75 *in* C.A. Ross, ed. Crocodiles and alligators, Facts On File, Inc.; New York, New York.

Thorbjarnarson, J.B. 1991. *Crocodylus acutus* (American crocodile), social behavior. Herpetological Review 22(4):130.

U.S. Fish and Wildlife Service [FWS]. 1984. American crocodile recovery plan. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Recovery for the American Crocodile

Crocodylus acutus

Recovery Objective: RECLASSIFY to threatened.

Recovery Criteria

The initial recovery plan for this species identified habitat alteration and human disturbances as the primary threats to this species and those that warranted its listing. Although efforts have been undertaken to ameliorate these threats, it is generally believed that these factors continue to act against the American crocodile to some extent. However, despite the ongoing influences of these threats, the crocodile has increased in numbers and is approaching population levels targeted by the initial recovery plan. It is apparent, therefore, that the effects of these threats are not as deleterious as previous assessments may have suggested, and that the reclassification of this species is possible.

Previous recovery efforts identified the need for a minimum of 60 breeding females within the population before reclassification could be considered. Since these criteria were developed, new information, based on consistent surveys, has indicated that the total number of nesting females has increased substantially over the last 20 years, from about 20 animals to about 50, and that nesting has remained stable at the major nesting areas. Based on the fact that the population appears stable, and that all of the threats as described in the original listing have been eliminated or reduced, reclassification of the crocodile will be possible, provided existing levels of protection continue to be afforded to crocodiles and their habitat, and that management efforts continue to maintain or enhance the amount and quality of available habitats necessary for all life stages

Species-level Recovery Actions

S1. Conduct surveys to determine the current distribution and abundance of American crocodiles. Survey all remaining suitable habitats in South Florida for American crocodiles. Most knowledge about the current distribution of crocodiles comes from surveys conducted within Everglades NP, the upper Florida Keys, and areas surrounding Turkey Point in Miami-Dade County. These areas correspond to locations with the highest known crocodile densities, but do not represent the entire range of the American crocodile. Surveys for crocodiles have not been conducted in large portions of South Florida; for example, American crocodiles have been observed in increasing numbers on the southwest coast of Florida, north to the J.N. Ding Darling NWR. These areas should be surveyed in order to determine the size and distribution of the American crocodile population and should include occurrence of individuals and nesting effort.

S1.1. Evaluate coastal wetlands to determine their suitability for crocodiles. Inventory potential habitat for American crocodiles with an emphasis on the southwest coast of Florida from Whitewater Bay north to Marco Island. Most known nesting and nursery sites are now publicly owned, but large areas of mangrove-lined coastline have not been surveyed for crocodiles. Before beginning time-consuming population surveys, coastal habitat in southwestern Florida should be assessed to identify areas that could support

American crocodiles. Continue to survey coastal wetlands of Biscayne Bay because of the increased potential for human/crocodile interactions.

S1.2. **Survey crocodile colonies in suitable habitats in South Florida**. In combination with **S1.1,** survey suitable habitats for all age classes of crocodile, especially in Biscayne Bay where nesting has been documented, and those areas of southwest Florida where information on the distribution and status of crocodiles is lacking. If substantial aggregations are located, they should be included in annual population monitoring programs.

S2. **Protect and enhance existing colonies of American crocodile**s. Although numbers of crocodiles are increasing in South Florida, habitat loss and degradation may limit the extent to which this expansion continues. In order to sustain the growth of the crocodile population, habitat that is suitable to meet the needs of all age classes must be protected. In some cases this habitat must be restored. Even though information is not available on the habitat requirements for each age class of American crocodile, the recovery team has basic information about the biotic and abiotic factors required for survival of this species. Although juvenile and adult crocodiles are less susceptible to fluctuations in their environment than hatchlings, the availability of refugia adjacent to deep water may be the single most important habitat characteristic that ensures the survival of these age classes.

S2.1. **Reduce or eliminate sources of American crocodile mortality**. All activities that affect crocodile habitat should be evaluated and appropriate steps taken to minimize or eliminate adverse affects to crocodiles and their habitat.

S2.1.1. **Control human-induced crocodile mortality and disturbance**. Reduce or eliminate anthropogenic sources of mortality. Human causes of mortality may be additive to an otherwise unknown level of natural mortality. However, many depressed populations can be pushed beyond their capability to recover when sources of additive mortality also affect population levels.

S2.1.2. **Alert motorists on roads where repeated collisions between automobiles and American crocodiles have occurred**. State Road 905, U.S. 1, and Card Sound Road have been posted with crocodile crossing warning signs for some time, but collisions with automobiles still occur periodically. An assessment of the effectiveness of signing should be conducted to determine if additional information would be useful in reducing American crocodile mortalities.

S2.1.3. **Reduce the incidence of American crocodile road mortalities by installing box culverts**. Construct culverts on portions of U.S. 1 to reduce automobile-crocodile collisions. Automobile-crocodile collisions have occurred periodically on portions of U.S. 1 and may be minimized through installation of pass-through culverts. Although there remains uncertainty about the effectiveness of installing culverts for the safe passage of crocodiles under highways, it is likely they will be used to some extent. When U.S. Highway 1 is widened, culverts should be installed at locations where crocodile mortalities have occurred.

S2.1.4. **Control terrestrial predators of crocodile eggs and hatchlings in areas where they may be artifically high**. Human visitation of some areas (such as Cape Sable in Everglades NP) create unnatural conditions for predators such as raccoons. These animals could be adversely affecting survival and recruitment of the crocodile on public lands **.**

S2.2. Continue long-term assessment of pesticide and heavy metal contamination levels in crocodile eggs. Assessments of environmental contaminants in eggs should be conducted every 5 years.

S2.3. Assure coordinated management actions by interagency agreements or other means. Responsibility for the management of the American crocodile is currently divided between the State of Florida (GFC), the NPS, and the FWS. Currently the GFC, in consultation with the FWS, is managing human-crocodile conflicts outside of Everglades NP The NPS retains management authority for crocodiles within Everglades NP. The FWS protects the American crocodile throughout its range through its regulatory programs. Steps should be taken to insure that the actions of these agencies are coordinated and non-conflicting.

S3. Conduct research on the biology and life history of crocodiles. Although basic information on the biology of the American crocodile has been collected, more detailed information is needed to determine the status of the crocodile population in South Florida.

S3.1. Determine the carrying capacity of remaining crocodile habitat in South Florida. The expansion of the American crocodile population in South Florida will be limited by the amount of habitat suitable for one or more life-history stages (*e.g*., nesting, feeding, dispersal, refuge, *etc*.). To estimate the potential for the American crocodile population to continue to grow, it will be necessary to identify limiting habitats. Historical information on the South Florida crocodile population and information on other American crocodile populations may be essential in determining the carrying capacity for South Florida.

S3.2. Conduct research to determine basic biological needs of the American crocodile. Conduct or continue mark-recapture efforts, population and nest surveys, and habitat monitoring in the vicinity of previous research and monitoring work done on Key Largo, Turkey Point, and Everglades NP Where other congregations of crocodiles are found in the future, conduct similar efforts. We know little about the species in southwest Florida or within the recently discovered breeding aggregation on Marco Island. Additional information is needed to determine the demographics of the American crocodile. Information on survival, recruitment, fecundity, and mortality are important in assessing the relative health of this population.

S3.3. Evaluate the effects of human disturbances on crocodile behavior. Conduct research to determine behavioral reactions to human disturbances.

S3.4. Develop identification techniques for American crocodiles. Distinguishing genetic differences between American crocodiles found in South Florida from American crocodiles throughout the remainder of their range will be essential in assessing the extent to which foreign crocodiles have contributed to the present genetic profile of crocodiles in South Florida.

S4. Monitor the South Florida crocodile population. Long-term monitoring is essential to the assessment of the status of the crocodile population.

S4.1. Coordinate monitoring programs and protocols. Data collected, marking system, and database management methods should be standardized among researchers.

S4.2. Conduct surveys for American crocodiles. Ongoing population surveys at Key Largo, Everglades NP, Turkey Point, and Biscayne Bay are important in the long-term assessment of the crocodile population in South Florida. Survey data should provide information on the number, distribution, and size class trends in these areas. As the population expands, survey efforts should be initiated in other areas where congregations of crocodiles occur.

S4.3. Conduct a mark-recapture program for the American crocodile. Mark-recapture data provide important information on growth, survival, and dispersal. These data will be essential in assessing the status of the crocodile in South Florida.

S5. Inform the public about the recovery needs of crocodiles. The public is generally unaware of the biology and status of the American crocodile, and misunderstandings still result in adverse sentiment towards this species. Public education is required to provide accurate biological information and to stimulate interest in the conservation of the American crocodile. Public information should include the general public, public officials, land managers, and policy makers.

S5.1. Continue relocation of problem crocodiles. GFC policy currently provides for the relocation of crocodiles that threaten human safety. Although this program results in the non-lethal removal of problem animals, it reduces the likelihood that habituated or bold crocodiles will be killed by members of the public. This program reduces mortality and provides opportunities for public education.

S5.2. Assess the effectiveness of road signage for reducing the numbers of American crocodiles killed by automobiles. U.S. 1 in the Florida Keys has been posted with crocodile crossing warning signs for some time, but collisions with automobiles still occur periodically. An assessment of the effectiveness of signing should be conducted to determine if different approaches to these signs should be used to reduce crocodile mortalities along these two roads. The signs that have been used for the West Indian manatee should be examined as alternative models.

S5.3. Develop and distribute informational brochures regarding the biology and conservation of American crocodiles. Distribution locations should include facilities that rent boats and personal watercraft, fishing charters, county and State parks, bait and tackle shops, restaurants along Florida Bay, and neighborhoods with resident crocodiles.

Habitat-level Recovery Actions

H1. Protect nesting, basking, and nursery habitat of American crocodiles in South Florida.

H1.1 Acquire or otherwise protect habitat for crocodiles. Large amounts of suitable habitat for American crocodiles have been protected inside Everglades NP, Biscayne NP, and Crocodile Lake NWR. However, extensive areas of suitable, occupied habitat and potentially restorable habitat for American crocodiles are not protected, particularly in southwestern Florida (Collier and Lee counties). Once lands that support suitable, occupied, or potentially restorable habitat for American crocodiles have been identified (see Task **S1**.), those lands should be protected either through additional land acquisition or cooperative management agreements with the land owner or land manager

H1.2. Protect essential crocodile habitat on private lands. If suitable habitat for American crocodiles is found on private lands, determine owner and appropriate conservation measures such as acquisition, easements, transfer of development rights, establishment of protective management plans, *etc*. Less than simple fee title acquisition may be required for crocodile habitat on private lands. Conservation agreements or easements or transfer of development rights may protect crocodile habitat on some private lands.

H2. Manage and restore suitable habitat of American crocodiles.

H2.1. Continue to maintain nesting sites adequate to maintain viability of the American crocodile. Crocodile Lake NWR on Key Largo, Everglades National Park, and Florida Power and Light's Turkey Point nuclear electrical generating facility currently provide the majority of nesting habitat for the American crocodile in South Florida. These areas must be adequately managed to sustain or increase the current level of nesting. Continue efforts to control exotic plants that have invaded portions of crocodile nesting habitat in these areas.

H2.2. Restore areas to suitable habitat. Much of the suitable habitat outside of Everglades and Biscayne national parks has been degraded or destroyed due to residential, commercial, or agricultural uses. Some of these areas may be suitable for restoration efforts. This will require: removal of exotic plants that degrade the quality of dispersal habitat for juvenile crocodiles, nesting sites, and basking areas; restoration of native vegetation in areas where the control of exotic vegetation or other human disturbances created large gaps in vegetated shoreline; and restoration of hydroperiods and hydropatterns in the Everglades and Big Cypress drainages so that hydrologic patterns mimic timing, flows, and depths that would have occurred under a rainfall-driven system. Natural hydroperiods will likely provide sufficient fresh water to periodically flush creek beds to maintain deepwater refugia for breeding adults. Restored hydroperiods also will decrease average salinities during late summer, when hatchlings require low-salinity water.

H2.1. Complete the Project to Modify Water Deliveries to Everglades NP and the Canal 111 Project. Both of these U.S. Army COE projects are designed to restore more natural patterns of water deliveries to eastern Florida Bay through Taylor Slough and Shark River Slough. Both projects should substantially improve habitat quality for American crocodiles in eastern Florida Bay. Although these projects have been authorized and construction on these projects initiated, they have not been completed. Both projects must be completed to increase the likelihood of the crocodiles' survival and recovery in the wild.

H2.2. Continue to monitor the effects of the Program of Experimental Water Deliveries to Everglades NP on the American crocodile to determine optimal operational schedules. As outlined in item **H2.1**. the COE is currently authorized to construct the Project to Modify Water Deliveries to Everglades National Park and the Canal 111 Project. Both of these projects are designed to restore more natural patterns of water deliveries to eastern Florida Bay through Taylor Slough and Shark River Slough and should substantially improve habitat quality for American crocodiles in eastern Florida Bay. However, the benefits of these projects to the American crocodile will depend on how the structures associated with the projects will be operated. The Program of Experimental Water Deliveries to Everglades NP iteratively assesses how the operations of water control structures affect the health of Everglades NP and associated biota. American crocodiles are currently being monitored as part of the Experimental Program; this monitoring should continue with a specific emphasis on determining the response of American crocodiles and their habitat to different operational schedules.

H2.3. **Continue habitat and population modeling to determine operational schedules for structures associated with the Program to Modify Water Deliveries to Everglades NP, Canal 111, and the Central and Southern Florida Flood Control Project that provide optimal habitat for the American crocodile**. The operations of structures associated with these three projects will determine the actual benefits of these projects to the American crocodile. For example, these projects could be operated in ways that either restore or create nursery habitat for juvenile American crocodiles (see item **H2.4.**). Some of the information necessary to determine how to operate structures associated with these projects to optimize habitat for American crocodiles will be generated by the monitoring program associated with the Experimental Program of Water Deliveries to Everglades National Park, but additional evaluations will be necessary. Additional models that will help determine optimal operational schedules are being developed as part of the USGS's (BRD) Across Tropic Level System Simulation. This modeling effort should continue and new efforts should be initiated to determine optimal operational schedules for COE structures in South Florida.

H.2.4. **Create additional nesting habitat for crocodiles in South Florida.** Recovery of the American crocodile is dependent on the availability of adequate nesting sites, and an increase in the amount of suitable nesting habitat could increase recruitment into the population.

H2.5. **Restore or create nursery habitat for American crocodiles in South Florida.** This will generally require restoration of suitable, lower-salinity regimes to nursery areas for juvenile American crocodiles. Restoration of mangrove wetlands within Crocodile Lake NWR has resulted in increased salinity in one important nursery area, rendering the area less suitable for hatchlings. On Florida's southeastern coast, three COE projects (Project to Modify Water Deliveries to Everglades NP, Canal 111 Project, and the Central and Southern Florida Flood Control Project) will have significant effects on salinity regimes in nursery habitat for American crocodiles. On Florida's southwestern coast, efforts to restore Rookery Bay, the Big Cypress drainage, and the Ten Thousand Islands Region could have similar benefits to the American crocodile. As these projects undergo further development, benefits to nursery habitat for American crocodiles should be included as performance criteria to determine project benefits.

H2.6. **Continue to enforce land-use restrictions in essential crocodile habitat**. The NPS and FWS preclude human use in important crocodile habitat in the areas these two agencies manage in Florida Bay and on Key Largo. These restrictions, as well as others that may be required if new crocodile congregations are located, will help protect crocodiles during their recovery. Periodic assessments should be conducted to determine the need for land-use restrictions.

H3. **Conduct research on the habitat relationships of the American crocodile**. Much of the habitat-based research needed for the recovery of the American crocodile is currently addressed in one or more research projects dealing with the maintenance and recovery of the Florida Bay ecosystem. However, specific research information on the relationship of

American crocodiles to salinity regimes, exotic species, and adjacent land uses will be critical to the design of future management actions for the American crocodile.

H4. Continue to monitor crocodile habitat.

H4.1. Continue to monitor crocodile nesting habitat to determine environmental factors that affect nesting success.

H4.2. Continue long-term assessments of pesticide and heavy metal contamination levels in South Florida ecosystems. Numerous contaminant assessment projects are ongoing in South Florida. Support of these projects and use of the periodic data they provide will be important in assessing the quality of crocodile habitat.

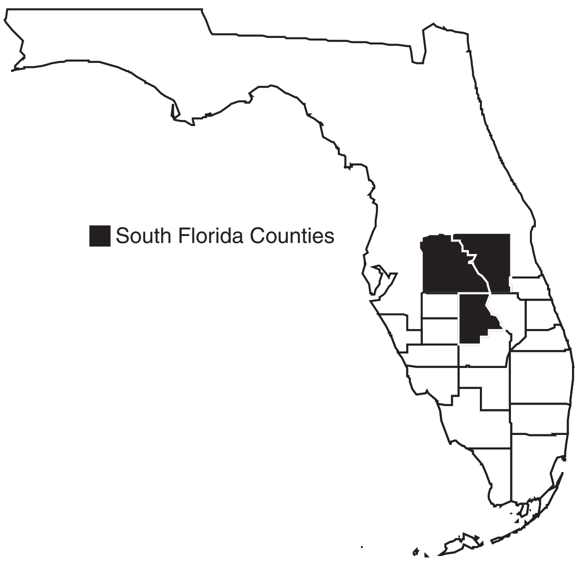
H5. Increase public awareness of the habitat needs of crocodiles. Tidally influenced areas provide important habitat for crocodiles, but these areas are also attractive to humans for recreational and residential uses. Efforts to protect crocodile habitat will probably not be well received because of the public's general misperceptions about crocodiles. Effective protection and restoration of habitat can only be achieved if these efforts demonstrate that such protection will also benefit other commercially and recreationally important species. Habitat protection should be approached from an ecosystem perspective, emphasizing conservation benefits to Florida Bay. The efforts that have been used to increase public awareness of the habitat needs of the West Indian manatee should serve as the model for these efforts.

Bluetail Mole Skink

Eumeces egregius lividus

Federal Status:	**Threatened (November 6, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of the bluetail mole skink.



The bluetail mole skink is a small, slender lizard that occupies xeric upland habitats of the Central Ridge in peninsular Florida. It requires open, sandy patches interspersed with sclerophyllous vegetation. Much of the bluetail mole skink's habitat has been destroyed or degraded due to residential, commercial, and agricultural development. Habitat protection and management are essential for the survival of this species. Efforts to conserve the bluetail mole skink and other rare species dependent on xeric upland communities have been initiated; a number of private and public xeric upland preserves have been established or are proposed for acquisition. Recovery of the bluetail mole skink will require protection and management of occupied and potentially restorable habitat. Reintroduction of the bluetail mole skinks into restored habitat may also be a valuable recovery tool.

This account represents a revision of the existing recovery plan for the bluetail mole skink (FWS 1993).

Description

The bluetail mole skink is a small, shiny, brownish to pink, cylindrical, lizard. Juveniles usually have a blue tail which makes up slightly more than half of the 13 cm length (Christman 1992; P. Moler, GFC, personal communication 1998). Regenerated tails and the tails of older individuals are typically pinkish. The legs are somewhat reduced in size and are used only during surface locomotion, not when the animal "swims" through the sand (Christman 1992). The coloration in the bluetail mole skink is brown with lighter paired dorsolateral stripes diverging posteriorly (Christman 1978). During the breeding season, males develop a colorful orange pattern on their sides.

Taxonomy

The taxonomy of the species *Eumeces egregius,* and for *E. e. lividus* specifically, is discussed in detail by Mount (1965), who indicated that the species was first recognized by Baird in 1858 as *Plistodon egregius.* In 1871, *P. onocrepis* was described by Cope. In 1875, the two species were reassigned to the genus *Eumeces*. Cope (1990) subsequently synonomized *E. onocrepis* with *E. egregius*. In 1935, two subspecies were defined, *E. e. egregius* and *E. e. onocrepis*. In 1957, *E. e. similis* was separated from *E. e. egregius*. Mount (1965) described two additional subspecies: *E. e. lividus* and *E. e. insularis.*

Distribution

The bluetail mole skink occurs in suitable habitat on the Lake Wales Ridge in Highlands, Polk, and Osceola counties in central Florida. It is apparently rare throughout its range, even in the most favorable habitats (Christman 1992), and is not uniformly distributed within xeric upland communities. To date, there are 34 locality records for this subspecies, all occurring on the Lake Wales Ridge and, with the exception of one observation, above 30 m in elevation.

Habitat

A variety of xeric upland communities provide habitat for *E. e. lividus,* including rosemary (*Ceratiola ericoides*) and oak-dominated scrub, turkey oak barrens, high pine, and xeric hammocks. Areas with few plant roots, open canopies, scattered shrub vegetation, and patches of bare, loose sand provide optimal habitats (Christman 1988, 1992). Bluetail mole skinks are typically found under leaves, logs, palmetto fronds, and other ground debris. Shaded areas presumably provide microhabitat conditions which are important for thermoregulation, egg incubation, and availability of prey (Mount 1963). Bluetail mole skinks tend to be clumped in distribution with highly variable densities, sometimes approaching 62.5 adults per ha (Christman 1992). This pattern appears to be linked to the distribution of surface litter and, thus, soil moisture and prey distribution.

Behavior

Reproduction

The reproductive biology of the bluetail mole skink is poorly known. Reproduction is presumably very much like that of *E. e. onocrepis* (Mount 1963), where mating occurs in the winter. In *E.e. onocrepis,* three to seven eggs are laid in a shallow nest cavity less than 30 cm below the surface. The eggs incubate for 31 to 51 days, during which time the female tends the nest. Individuals probably become reproductively active at 1 year of age (Mount 1963, Christman 1978).

Feeding

Foraging activities of the bluetail mole skink are primarily at the soil surface or at shallow depths to 5 cm (FWS 1993), usually during the morning or evening. Roaches, crickets, and spiders make up the bulk of the diet of mole skinks, including *E. e. lividus* (Mount 1963).

Bluetail mole skink. *Original photograph by Barry Mansell.*

Relationship to Other Species

The bluetail mole skink occupies habitat similar to that of the sand skink (*Neoseps reynoldsi*), however, these species do not compete because of resource partitioning. Sand skinks are primarily fossorial and take prey below the surface, whereas the bluetail mole skink hunts at the surface and consumes mostly terrestrial arthropods (Smith 1977, 1982).

Like the sand skink, the bluetail mole skink's abundance is inversely related to the abundance of the Florida scrub jay (*Aphelocoma coerulescens coerulescens*) (Mushinsky and McCoy 1995). It is unclear whether this relationship is due to ecological interactions between species or imperceptible differences in xeric habitat that favor one species over another. Though we know of no specific records of scrub jays preying on bluetail mole skinks, it is likely that they take them opportunistically. It has also been suggested that management of scrub habitat for the threatened scrub jay may create conditions which may not be compatible with the habitat requirements of the bluetail mole skink. The relationships among presence of scrub jays, oak canopy closure, and bluetail and sand skinks requires further investigation.

Status and Trends

The historic and anticipated future modification and destruction of xeric upland communities in central Florida were primary considerations in listing the bluetail mole skink as threatened under the ESA in 1987 (52 FR 42662). By some estimates, as much as 90 percent of the xeric upland communities on the Lake Wales Ridge have already been lost because of habitat destruction and degradation due to residential development and conversion to agriculture, primarily citrus groves (Florida Department of Natural Resources 1991). Remaining xeric habitat on private lands is especially vulnerable because projections of future human population growth suggest additional demands for residential development within the range of the bluetail mole skink.

Campbell and Christman (1982) characterized *Eumeces* as colonizers of a patchy, early successional, or disturbed habitat type which occurs throughout the sandhill, sand pine scrub, and xeric hammock vegetative associations as a result of biological (*Gopherus*, *e.g.*) or catastrophic factors. Susceptibility of mature sand pine to windthrow may be an important factor in maintaining bare, sandy microhabitats required by bluetail mole skinks and other scrub endemics (Myers 1991).

At the time of Federal listing, there were 20 locality records for the bluetail mole skink. Currently, 34 sites are known. The increase in locality records is largely the result of more intensive sampling of scrub habitats in recent years and does not imply that this species is more widespread than originally supposed. On the contrary, we believe that continued residential and agricultural development of xeric upland habitat in central Florida has destroyed or degraded extensive tracts of habitat containing the bluetail mole skink. Estimates of habitat loss range from 60 to 90 percent, depending on the xeric community type (Christman 1988, Christman and Judd 1990, Kautz 1993, Center for Plant Conservation 1995).

Management

The protection and recovery of bluetail mole skinks will require that habitat loss be stopped and that unoccupied but potentially suitable habitat be restored. The existing protection of the bluetail mole skink includes a number of private and public preserves within the Lake Wales Ridge. Current efforts to expand the system of protected xeric upland habitats on the Lake Wales Ridge, in concert with implementation of aggressive land management practices, represent the most likely opportunity for securing the future of this species. Comprehensive land acquisitions that protect areas occupied by the bluetail mole skink include: the FWS's Lake Wales Ridge NWR and the Florida CARL program's Lake Wales Ridge Ecosystem Project (FWS 1992).

Effective land management will be required to maintain or restore the wide diversity of xeric upland communities found in the protected sites described above. Just as natural xeric uplands contained a mosaic of open and vegetated patches that varied in time and space, we believe good land managment practices can create and maintain similar habitat conditions for the bluetail mole skink and other xeric upland-dependent species.

Fire has been used and is the preferred tool for managing xeric communities, such as those containing skinks. The natural patchiness resulting from fire provides suitable bluetail mole skink habitat. Partitioning of protected sites into numerous small burn units ensures that habitat heterogeneity is maintained under managed conditions. Although we presume that the benefits to vegetative communities resulting from the use of prescribed fire will also result in benefits to the bluetail mole skink, additional post-burning herpetological monitoring will be necessary to document this relationship.

Mechanical disturbances have been used successfully in some locations to manage xeric vegetation, especially where the use of fire is not practical. However, these techniques may be harmful to the bluetail mole skink and other non-vagile species. Depending on the technique used, bluetail mole skinks can be directly harmed or killed, or their habitat modified by mechanical treatment. Tree cutters, bushhogs, or rollerchopping equipment can crush individuals and destroy or degrade sandy substrates by introducing vegetative debris.

Protection of the bluetail mole skink from further habitat loss and degradation is the most important means of ensuring its continued existence. It is not certain whether existing protected areas are adequate for its survival because many life history and population characteristics relevant to long-term survival are unknown (FWS 1993).

Literature Cited

Campbell, H.W., and S.P. Christman. 1982. The herpetological components of Florida sandhill and sand pine scrub associations. Pages 163-171 *in* N. J. Scott, ed. Herpetological communities: A symposium of the Society for the Study of Amphibians and Reptiles and the Herpetologist's League, August, 1977. U. S. Fish and Wildlife Service, Wildlife Research Report.

Center for Plant Conservation. 1995. An action plan to conserve the native plants of Florida. Missouri Botanical Garden; St. Louis, Missouri.

Christman, S.P. 1978. Threatened: blue-tailed mole skink, *Eumeces egregius lividus* (Mount). Pages 38-40 *in* R. W. McDiarmid, ed. Rare and endangered biota of Florida. volume 3: amphibians and reptiles. University Press of Florida; Gainesville, Florida.

Christman, S.P. 1988. Endemism and Florida's interior sand pine scrub. Final project report no. GFC-84-010, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Christman, S.P. 1992. Endangered: blue-tailed mole skink, *Eumeces egregius lividus* (Mount). Pages 117-122 *in* P.E. Moler, ed. Rare and endangered biota of Florida. University Press of Florida, Gainesville, Florida.

Christman, S.P., and W.S. Judd. 1990. Notes on plants endemic to Florida scrub. Florida Scientist 53(1):52-73.

Florida Department of Natural Resources [DEP]. 1991. Annual report of the Conservation and Recreation Lands Program, DEP, Tallahassee, Florida.

Kautz, R.S. 1993. Trends in Florida wildlife habitat 1936-1987. Florida Scientist 56(1):7-24.

Moler, P.E. 1998. Comments on draft species account. January 9.

Mount, R.H. 1963. The natural history of the red-tailed skink, *Eumeces egregius* Baird. American Midland Naturalist 70:356-385.

Mount, R.H. 1965. Variation and systematics of the scincoid lizard *Eumeces egregius* (Baird). Bulletin of the Florida State Museum 9:183-213.

Mushinsky, H.R., and E.D. McCoy. 1991. Vertebrate species composition of selected scrub islands on the Lake Wales Ridge of central Florida. Final report no. GFC-87-149. Florida Game and Fresh Water Fish Commission, Nongame Wildlife Program; Tallahassee, Florida.

Myers, R.L. 1991. Scrub and high pine. Pages 150-193 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida.

Smith, C.R. 1977. Food resource partitioning of burrowing sand pine scrub reptiles. Herpetological Review 8(3):17.

Smith, C.R. 1982. Food resource partitioning of fossorial Florida reptiles. Pages 173-178 *in* N. J. Scott, ed. Herpetological communities: A symposium of the Society for the Study of Amphibians and Reptiles and the Herpetologist's League, August, 1977. U. S. Fish and Wildlife Service, Wildlife Research Report No. 13.

U. S. Fish and Wildlife Service [FWS]. 1992. Draft environmental assessment and land protection plan: Proposed establishment of Lake Wales Ridge National Wildlife Refuge. Department of the Interior, U.S. Fish and Wildlife Service; Atlanta, Georgia.

U.S. Fish and Wildlife Service [FWS]. 1993. Recovery plan for the sand skink and the blue-tailed mole skink. Atlanta, Georgia.

Recovery for the Bluetail Mole Skink

Eumeces egregius lividus

Recovery Objective: DELIST.

Recovery Criteria

In order to delist this species, efforts must continue towards the immediate protection of the remaining xeric upland communities where the bluetail mole skink occurs. We must ensure that existing protected habitat, in combination with xeric uplands proposed for protection through acquisition, is adequate for recovery. The bluetail mole skink can be delisted when: risk assessment and population viability analyses demonstrate that a sufficient number of sites containing bluetail mole skink populations are protected and managed to ensure a 95 percent probability of persistence of the species over the next 100 years; and when research and monitoring of the biology and ecology of this species determine the population is stable or increasing for no less than 6 years.

Species-level Recovery Actions

S1. Determine the status and distribution of bluetail mole skinks. Archbold Biological Station maintains a geographic information system (GIS) to compile species distribution information. Scrub habitat that may support populations of bluetail mole skinks that has not yet been surveyed or needs to be re-surveyed should be targeted for subsequent efforts, and tracts where the status of skinks is uncertain should be identified.

S1.1. Compile distribution data for bluetail mole skinks from all available sources. Existing data sources should be combined and synthesized using GIS overlays. Habitat occupied by bluetail mole skinks, suitable but unoccupied habitat, and unsurveyed but suitable habitat should be identified. Maintaining and updating a current GIS database on the distribution and status of skinks is essential for long-term monitoring needs and for developing habitat management strategies.

S1.2. Conduct distribution surveys to determine additional sites in need of protection. If additional surveys locate occupied habitat that is determined to be essential for the survival of bluetail mole skinks, efforts should be made to incorporate these areas into scrub protection initiatives. The development of site-specific management plans for habitat purchased in the Lake Wales Ridge NWR and the Lake Wales Ridge Ecosystem Project should include provisions for baseline and long-term monitoring efforts for bluetail mole skinks. Additional areas which may support skink populations should be surveyed, and if occupied and essential to the survival of the species, should be considered for protection under existing or new habitat-acquisition programs.

S2. Protect and enhance existing populations. If the proposed Federal and State purchase of scrub and associated xeric communities is achieved, the resulting network of publicly and privately owned and protected scrub will encompass about 16,200 ha on the Lake Wales Ridge. This mosaic of varying size scrub patches should prove adequate to protect this species indefinitely, provided that the communities are protected and suitable management practices favorable to skinks are identified and implemented. Site-specific management prescriptions that assure a mixture of successional stages and ecotonal areas required by skinks should be developed for tracts purchased in the Lake Wales Ridge NWR and Lake Wales Ridge Ecosystem Project initiatives.

S2.1. Conduct section 7 consultations on Federal activities that may affect bluetail mole skinks. Section 7 of the Endangered Species Act requires Federal agencies to consult with the FWS to ensure appropriate consideration of impacts to listed species from all Federal actions. The bluetail mole skink needs to be considered, along with other listed species in scrub habitat, in any proposed Federal actions (authorized, funded, or carried out by Federal agencies) that might adversely affect the species and their habitats. These could include but are not limited to road and facility construction, timber management practices, land clearing and conversion, wetland dredge and fill activities, and pesticide applications involving use of Federal funds.

S2.2. Protect skinks on public and private lands. Develop and implement land management techniques that maintain natural diversity. Periodic burning, cutting, mowing or other techniques are needed to maintain ecotonal areas between xeric habitats. Habitat must also be protected from off-road vehicle traffic and commercial forestry practices.

Where bluetail mole skinks are known to exist on private lands, efforts should be made to contact landowners, and information on the status and habitat requirements of the species provided. Recommendations should be provided for managing private lands. Long-term renewable leases and conservation agreements involving Federal, State, and local governmental agencies are options where outright acquisition is not acceptable to the landowner.

S2.3. Control domestic animal predation. Where domestic animals prey on bluetail mole skinks, it may be necessary to trap or develop deterrent programs to minimize mortality. Trapping efforts may be needed on public lands where free-ranging domestic animals threaten bluetail mole skinks or their habitat.

S2.4. Control pesticide use in or adjacent to bluetail mole skink habitat. Because pesticide use on adjacent agricultural and residential lands poses a potential risk to bluetail mole skinks, management plans should consider these risks and alleviate threats whenever possible.

S3. Conduct research on life history and population ecology of bluetail mole skinks. Adequate long-term protection of bluetail mole skinks depends on a thorough understanding of their life history. Many aspects of the life history of this species are poorly understood or remain entirely unstudied. Much of what is known about the bluetail mole skink's life history has been extrapolated from studies on the closely related *E. e. onocrepis*. While this may provide information about the basic biological strategies of mole skinks in general, more specific studies of the life history characteristics of *E. e. lividus* are needed to ensure that land management efforts are compatible with the habitat requirements of the bluetail mole skink.

S3.1. **Develop standardized survey techniques**. Research specific habitat requirements in relation to vegetation structure. Develop better survey methods to accurately monitor existing skink populations and their response to management prescriptions.

S3.2. **Support studies of reproduction, fecundity, and longevity**. Obtain data on mating behavior, reproductive success, productivity, longevity, and other basic population characteristics. Use of captive animals may be necessary to obtain some of this data.

S3.3. **Develop methods to determine home range size, age of dispersal, and dispersal distance of this species.** These data are needed to evaluate recolonization capabilities and susceptibility to local extinctions. Refine and standardize mark-recapture methodology to address these data needs. There are suitable protected sites at present to conduct baseline studies.

S4. **Monitor skink populations.** Once standardized survey techniques are developed, begin long-term monitoring on protected public and private lands. Start monitoring efforts at Archbold Biological Station, where periodic controlled burns are used to maintain scrub habitats. Initiate efforts to assess populations at other public and private scrub preserves as we learn more about the biology of this species and appropriate monitoring techniques.

S5. **Increase public awareness of bluetail mole skinks**. Efforts to protect this and other scrub species benefit from public education about the scrub ecosystem. Species-specific educational materials probably will not be as effective as habitat-based efforts that currently exist, because we know very little about the biology of this species.

Habitat-level Recovery Actions

H1. **Prevent degradation of existing scrub habitat.** The key to the long-term recovery of bluetail mole skink habitat lies in the immediate protection of as much of the remaining scrub ecosystem as is economically feasible within the Lake Wales Ridge.

H1.1. **Acquisition of scrub habitat.** Fee simple title, conservation easements, transfer of development rights, land trades, or other conservation measures will be necessary to protect remaining scrub habitat.

H1.1.1. **Continue Federal acquisition efforts**. Continue acquisition efforts within the Lake Wales Ridge NWR complex. Much of the habitat targeted for acquisition will be acquired by 1998. One or possibly two additional but currently unidentified parcels may subsequently be targeted for acquisition.

H1.1.2. **Support State acquisition efforts.** The CARL program Lake Wales Ridge Ecosystem Project includes over 30 key scrub areas Appendix F). The State's Save Our Rivers (SOR) acquisition program administered by the water management districts targets wetlands for protection, but some sites also contain xeric uplands, and potentially bluetail mole skink habitat.

H1.1.3. **Encourage acquisition by non-governmental organizations.** Encourage acquisition by non-governmental organizations. Occupied bluetail mole skink habitat not targeted in Federal and State acquisition programs may become available for private purchase and management. Scrub habitats already protected, such as those at Archbold Biological Station and The Nature Conservancy's Tiger Creek Preserve, Saddle Blanket Lakes, and Lake Apthorpe areas will continue to play an important role in the long-term persistence of bluetail mole skinks.

H1.2. **Manage scrub habitat**. Like most vegetative communities in Florida, the scrub requires periodic fire or other sources of disturbance to maintain its diversity and distribution.

H1.2.1. **Develop scrub habitat management guidelines.** The Nature Conservancy and Archbold Biological Station have gained experience in the management of scrub communities. Information gathered by these organizations should be consolidated into a set of standardized management guidelines that could be used by other landowners wishing to effectively manage scrub.

H1.2.2. **Develop cooperative scrub management programs**. Concurrently with **H1.2.1**, develop cooperative agreements for efficient scrub management. Public and private funding is limited and expenditures for land management can represent a large portion of operating expenses. Currently, five private organizations, and four State and two Federal agencies own or are responsible for the management of scrub habitat that may contain bluetail mole skinks. Large expenditures in equipment and personnel can be avoided through cooperative planning.

H1.2.3. **Control off-road access.** Fence or sign scrub habitat to eliminate off-road use. In many areas, off-road access has degraded habitat and destroyed individual rare plants. Soil stabilization, trash removal, and replanting may be necessary in some cases to effectively manage scrub.

H2. **Restore scrub to suitable habitat.** Identify areas of restorable habitat and develop a management plan to restore habitat. Much of the remaining scrub is degraded because fire has been excluded and the vegetation has become overgrown. Overgrown scrub can lose much of its function and value as it tends toward a more mesic condition.

H2.1. **Control exotic species**. Although exotic species are not currently a threat to most xeric communities, site-specific control measures may be needed, especially in ecotonal areas or human-disturbed areas.

H2.2. **Control overgrowth.** In most situations, unmanaged scrub tends to become dense and tall, conditions which are not favorable to many scrub-dependent species. Management of overgrown scrub must include thinning, burning, mowing, or other techniques to reduce vegetative density.

H3. **Conduct research to determine habitat needs for this species.** Basic life history requirements and habitat needs for this species are not known. As we learn more about the basic biology of this species we will also gain better insight into their habitat needs. Research on bluetail mole skink habitat should be concurrent with investigations into the biology of this species.

H4. **Monitor status of bluetail mole skink habitat**. Once we understand the habitat requirements for this species we will be better able to develop habitat management and monitoring recommendations. Until species-specific information is available, monitoring should ensure maintenance of ecotonal boundaries, diversity within scrub, and open sandy patches.

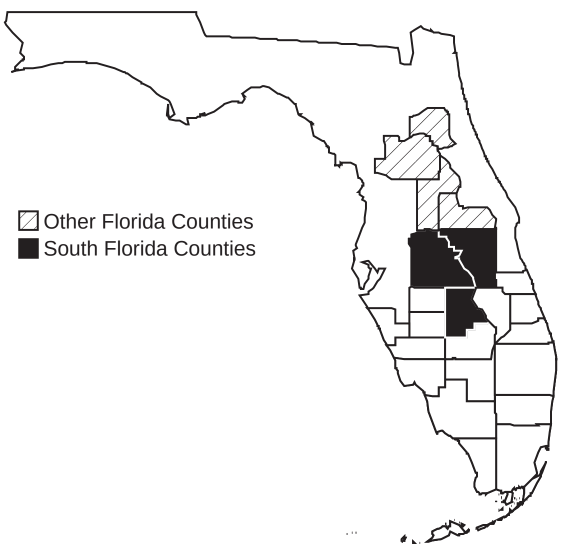
H5. **Increase public awareness of the scrub ecosystem**. Efforts should highlight habitat acquisition initiatives, importance of biodiversity, and biology of scrub-dependent species. Federal, State, and County governments, as well as private organizations, should support the development and dissemination of educational materials pertaining to the conservation of the scrub ecosystem and endemic scrub species. Materials such as brochures, posters, postcards, slide programs, and videotapes can improve public understanding of and increase appreciation for protection of scrub habitat. Environmental education programs across central Florida should be encouraged to distribute materials or develop lesson plans on scrub ecosystems, particular scrub species, and the importance of maintaining biological diversity.

Sand Skink

Neoseps reynoldsi

Federal Status:	**Threatened (November 6, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Revised (May 18, 1999)**
Geographic Coverage:	**Endangered**

Figure 1. County distribution of the sand skink.



The sand skink is a small, fossorial lizard that occurs on the sandy ridges of interior central Florida from Marion County south to Highlands County. The sand skink is highly adapted for life in the sand; it spends the majority of time below the surface "swimming" in loose sand in search of food, shelter, and mates. The species is vulnerable because of habitat loss due to agricultural and residential uses and from habitat degradation due to fire exclusion. Efforts to protect the sand skink and other xeric upland species are underway and include the acquisition, protection, and management of a number of xeric upland sites. Recovery of the sand skink will require management of conservation lands, restoration of habitat and possible reintroduction of individuals into successfully-rehabilitated habitat.

This account represents a revision to the existing recovery plan for the sand skink (FWS 1993).

Description

The sand skink (*Neoseps reynoldsi*) reaches about 13 cm, about half of which is tail. It is slender, shiny and usually gray to grayish-white, although it may occasionally be light tan. Hatchlings have a wide black band extending from the tip of the tail to the snout along each side. This band is reduced in adults and may only occur from the eye to snout on some individuals (Telford 1959). The sand skink's legs are vestigial and practically nonfunctional. Other adaptations to a fossorial existence include greatly reduced eyes, lack of external ear openings, a wedge-shaped snout, and a countersunk lower jaw.

Taxonomy

The monotypic genus *Neoseps* was established by Stejneger (1910) in describing the uniquely fossorial sand skink of the central Florida sand ridges.

Distribution

The sand skink is endemic to the sandy ridges of central Florida, occurring in Highlands, Lake, Marion, Orange, Osceola, Polk, and Putnam counties (Figure 1) (Christman 1988). Principal populations occur on the Lake Wales and Winter Haven Ridges in Highlands, Lake, and Polk counties (Christman 1992; Mushinsky and McCoy 1995; P. Moler, GFC, personal communication 1998). The sand skink is uncommon on the Mount Dora Ridge, including sites within the Ocala NF (Christman 1970, 1992). As of 1997, there were 114 locality records for the sand skink, most of which are found within the Lake Wales Ridge.

Habitat

The sand skink is widespread in xeric uplands with sandy substrates, but appears to be most abundant in ecotonal areas, typically between high pine and scrub (Telford 1996). It is also found in rosemary (*Ceratiola ericoides*) scrub, turkey oak barrens or sandy areas of the high pine community (Campbell and Christman 1982). Areas free of abundant plant roots, with open canopies, scattered shrubby vegetation, and patches of bare sand are optimal habitats (Christman 1978, 1992). However, recent surveys have located sand skinks in areas with dense undergrowth and extensive canopy closure (H. Mushinsky, University of South Florida, personal communication 1996), indicating that extensive loose, root free soils may not be a requisite for this species. Suitable habitat must also provide soil moisture conditions that provide for thermoregulation and egg incubation, as well as create conditions favorable for the skink's prey (Telford 1959).

The density of the sand skink varies considerably, ranging from about 5 to 23 individuals per 0.025 ha (Sutton 1996). Differences in abundance are attributed to habitat suitability. The sand skink is typically found 5 to 10 cm below the surface, where it burrows or "swims" (Carr 1940) through the sand to obtain its prey. Seasonally, sand skinks are most active from mid-February through mid-May and again in late summer-early fall. Activity patterns suggest sand skinks are active during the morning and evening, patterns typically associated with thermoregulatory behaviors (Andrews 1994).

Campbell and Christman (1982) had earlier characterized *Neoseps* as "colonizers of a patchy, early successional, or disturbed habitat type which occurs throughout the sandhill, scrub, and xeric hammock vegetative associations as a result of biological (*Gopherus*, *e.g.*) or catastrophic (fire) factors." Susceptibility of mature sand pine to windthrow may be an important factor in maintaining bare, sandy microhabitats required by sand skinks and other scrub endemics (Myers 1991). *Neoseps* has persisted in old growth stands of scrub (greater than 60 years old) on Archbold Biological Station in the vicinity of firelanes, suggesting that artificial clearings may be important to *N. reynoldsi*.

Sand skink. *Original photograph by Sam Telford.*

Behavior

Reproduction

Telford (1959) found sand skinks to be most active from early March through early May, whereas Sutton (1996) found skinks to be most active from mid-February to late April. These high-activity periods correspond to movements associated with breeding season activities. After high-activity periods, females are difficult to collect, apparently due to nesting activity. Approximately 55 days after mating, about two eggs are laid in the sand, under logs or debris, in early summer (Telford 1959). The eggs hatch from June through July. No information is available on the dispersal of this species or its territory size.

Sand skinks reach sexual maturity at 1 to 2 years (Telford 1959, Sutton 1996) and may remain reproductively active for 2 to 3 years (Sutton 1996).

Feeding

Sand skinks feed on a variety of hard and soft-bodied arthropods that occur below the ground surface. Diel patterns of activity suggest sand skinks are active during the day, and probably feed primarily during the morning and late afternoon when their preferred body temperatures are achieved (Sutton 1996). Most of their diet consists of beetle larvae and termites (*Prorhinotermes* spp.). Spiders, larval ant lions, lepidopteran larvae, roaches and adult beetles are also eaten (Myers and Telford 1965, Smith 1977).

Relationship to Other Species

Mushinsky and McCoy (1991) contrasted vertebrate species distribution in three size classes of “relatively-open canopied” and “relatively-closed canopied” scrub on the Lake Wales Ridge. Mushinsky and McCoy (1991) reported a negative correlation between the rank abundance of Florida scrub jays (*Aphelocoma c. coerulescens*) and abundance of sand skinks. It is unclear whether this relationship is due to ecological interactions between species or differences in xeric habitat that favor one species over another. Though we know of no specific records of scrub jays preying on sand skinks, it is likely that they take them opportunistically. It has also been suggested that management of scrub habitat often focuses on maintaining habitat for the threatened scrub jay, which may not be compatible with the habitat requirements of the sand skink. The relationship between presence of scrub jays, oak canopy closure, and the sand skink requires further investigation.

In many locations, sand skinks are sympatric with the peninsula mole skink (*Eumeces egregius onocrepis*), blue-tailed mole skink (*E. e. lividus*), Florida scrub lizard (*Sceloporus woodi*), and the Florida crowned snake (*Tantilla relicta*), but these species apparently do not compete because of resource partitioning (Smith 1977, 1982; Campbell and Christman 1982).

Status and Trends

The modification and destruction of xeric upland communities in central Florida was a primary consideration in listing the sand skink as threatened under the ESA in 1987 (52 FR 42662). By some estimates, as much as 90 percent of the scrub ecosystem has already been lost to residential development and conversion to agriculture, primarily citrus groves (Florida Department of Natural Resources 1991, Kautz 1993). Xeric uplands remaining on private lands are especially vulnerable to destruction because of increasing residential and agricultural pressures.

Except for a few locations where intensive research has been conducted, we have very little information about the presence or abundance of *N. reynoldsi*, not to mention the status and trends of this species in South Florida. The species' diminutive size and secretive habits make its study difficult. For example, the status and trends of sand skinks on Ocala NF remains uncertain, despite fairly intense research efforts. A 1992 survey was conducted to provide information on the distribution of sand skinks in the Ocala NF in relation to forest management practices (clear-cutting, burning, bracke and broadcast seeding). No sand skinks were captured during 18,578 trap nights from stands close to historical locality records for *Neoseps*, although a number of other fossorial reptiles were recovered. Telford (1992) cited the ephemeral nature of early successional scrub habitats due to dynamic successional changes as an important confounding factor in the evaluation of the sand skink's present status in the Ocala NF.

More recent studies have provided new information about the distribution of *N. reynoldsi*, but little information is currently available to assess the species' status or trends. Mushinsky and McCoy (1991) captured *N. reynoldsi* during their evaluation of vertebrate use of xeric uplands of central Florida. However, their study only provided presence/absence information. Similarly, Stout and Corey (1995) reported the presence of *N. reynoldsi* at several locations during their evaluation of the ecological implications of the fragmentation of xeric upland communities. The first estimates of absolute densities of *N. reynoldsi* in various habitat types and basic life history information were provided by Sutton (1996). Unfortunately, no long-term monitoring efforts have been undertaken to evaluate the status or trends of *N. reynoldsi* at these or other sites.

At the time of Federal listing in 1987, Florida Natural Areas Inventory had recorded 31 known sites for the sand skink. By 1997, 114 localities were known. This increase is largely the result of more intensive sampling of scrub habitats in recent years and does not imply that this species is more widespread than originally thought. On the contrary, we believe that continued residential and agricultural development of xeric upland habitat in central Florida has destroyed or degraded habitat containing *N. reynoldsi.* Estimates of habitat loss range from about 60 to 90 percent for xeric upland communities (Christman 1988, Christman and Judd 1990, Kautz 1993, Center for Plant Conservation 1995).

Management

Protection of the sand skink from further habitat loss and degradation is the most important means of ensuring its continued existence. It is not certain whether existing protected areas are adequate for its survival because many life history and population characteristics relevant to long-term survival are unknown (FWS 1993). Existing protection of occupied skink habitat consists primarily of private preserves such as Archbold Biological Station, Hendry Ranch, Tiger Creek Preserve, and Saddle Blanket Lakes Scrub Preserve, coupled with publicly owned lands such as Lake Arbuckle SP and SF, Lake Louisa SP, and Highlands Hammock SP (FWS 1993). Current efforts to expand the system of protected xeric upland communities on the Lake Wales Ridge, coupled with implementation of effective land management practices, represent the most likely opportunity for securing the future of this species. Recovery of the sand skink may require rehabilitation of suitable but unoccupied habitat or restoration of potentially suitable habitat. Because sand skinks do not readily disperse, introductions into restored or created unoccupied habitat may be necessary.

Effective management will be required to maintain or restore the wide diversity of xeric upland communities found in the protected sites described above. Just as natural xeric uplands contained a mosaic of open and vegetated patches that varied in time and space, we believe good land management practices can create and maintain similar habitat conditions for *N. reynoldsi* and other xeric upland-dependent-species.

Fire has been used and is the preferred tool for managing xeric communities, such as those containing sand skink habitat. The natural patchiness created by fire in xeric vegetative communities creates and restores suitable sand skink habitat. Partitioning of protected sites into numerous small burn units also ensures habitat heterogeneity. The response of sand skinks to fire is currently being evaluated (H. Mushinsky, University of South Florida, personal communication 1996).

Mechanical disturbances have been used successfully in some locations to manage xeric vegetation, especially where the use of fire is not practical. However, these techniques may be harmful to *N. reynoldsi* and other non-vagile species. The tires of tree cutters and bushhogs and the barrels of rollerchoppers may crush individuals and compress the substrate, which may create a barrier and destroy habitat. The FWS has currently funded research to evaluate the effects, if any, of mechanical treatments on plants and reptiles inhabiting xeric uplands

Literature Cited

Andrews, R.M. 1994. Activity and thermal biology of the sand-swimming skink *Neoseps reynoldsi:* diel and seasonal patterns. Copeia 1994:91-99.

Campbell, H.W., and S.P. Christman. 1982. The herpetological components of Florida sandhill and sand pine scrub associations. Pages 163-171 *in* N. J. Scott, ed. Herpetological communities: A symposium of the Society for the Study of Amphibians and Reptiles and the Herpetologist's League, August, 1977. U. S. Fish and Wildlife Service, Wildlife Research Report No. 13.

Carr, A.F., Jr. 1940. A contribution to the herpetology of Florida. University of Florida Publication, Biological Science Series 3(1):1-118.

Center for Plant Conservation. 1995. An action plan to conserve the native plants of Florida. Missouri Botanical Garden; St. Louis, Missouri.

Christman, S.P. 1970. The possible evolutionary history of two Florida skinks. Quarterly Journal of the Florida Acadamy of Science 33(4):291-293.

Christman, S.P. 1978. Threatened: sand skink, *Neoseps reynoldsi* (Stejneger). Pages 40-41 *in* R. W. McDiarmid, ed. Rare and endangered biota of Florida. volume 3: amphibians and reptiles. University Press of Florida; Gainesville, Florida.

Christman, S.P. 1988. Endemism and Florida's interior sand pine scrub. Final project report no. GFC-84-010, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Christman, S.P. 1992. Threatened: sand skink, *Neoseps reynoldsi* (Stejneger). Pages 135-140 *in* P.E. Moler, ed. Rare and endangered biota of Florida. University Press of Florida; Gainesville, Florida.

Christman, S.R. and W.S. Judd. 1990. Notes on plants endemic to Florida scrub. Florida Scientist 53(1):52-73.

Florida Department of Natural Resources [DEP]. 1991. Annual Report of the Conservation and Recreation Lands Program. DEP, Tallahassee, Florida.

Kautz, R.S. 1993. Trends in Florida wildlife habitat 1936-1987. Florida Scientist 56(1)7-24.

Moler, P.E. 1998. Comments on draft species account. January 9.

Mushinsky, H. R. 1996. Letter. March 12, 1996.

Mushinsky, H.R., and E.D. McCoy. 1991. Vertebrate species composition of selected scrub islands on the Lake Wales Ridge of central Florida. Nongame Wildlife Program Project report no. GFC-87-149, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Myers, R.L. 1991. Scrub and high pine. Pages 150-193 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

Myers, C.W., and S.R. Telford, Jr. 1965. Food of *Neoseps*, the Florida sand skink. Quarterly Journal of the Florida Academy of Science. 28:190-194.

Smith, C.R. 1977. Food resource partitioning of burrowing sand pine scrub reptiles. Herpetological Review 8(3):17.

Smith, C.R. 1982. Food resource partitioning of fossorial Florida reptiles. Pages 173-178 *in* N. J. Scott, ed. Herpetological communities: A symposium of the Society for the Study of Amphibians and Reptiles and the Herpetologist's League, August, 1977. U. S. Fish and Wildlife Service, Wildlife Research Report No. 13.

Stejneger, L. 1910. A new genus and species of lizard from Florida. Proceedings of the U.S. National Museum 39(1773):33-35.

Stout, I.J., and D.T. Corey. 1995. Effects of patch-corridor configurations on nongame birds, mammals and herptiles in longleaf pine-turkey oak sandhill communities. Nongame Project Report No. RFP-86-003, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Sutton, P.E. 1996. A mark and recapture study of the Florida sand skink *Neoseps reynoldsi* and a comparison of sand skink sampling methods. Unpublished master's thesis, University of South Florida; Tampa, Florida.

Telford, S.R., Jr. 1959. A study of the sand skink, *Neoseps reynoldsi*. Copeia 1959 (2):100-119.

Telford, S.R., Jr. 1992. Factors affecting the distribution of *Neoseps reynoldsi*, the sand skink, in Ocala National Forest. Report to U.S. Department of Agriculture, Forest Service; Atlanta, Georgia.

Telford, S. R., Jr. 1996. Multi-Species recovery teammeeting. February 28, 1996.

U. S. Fish and Wildlife Service [FWS]. 1992. Draft environmental assessment and land protection plan: Proposed establishment of Lake Wales Ridge National Wildlife Refuge. Department of the Interior, U.S. Fish and Wildlife Service; Atlanta, Georgia.

U.S. Fish and Wildlife Service [FWS]. 1993.Recovery plan for the sand skink and the blue-tailed mole skink. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Recovery for the Sand Skink

Neoseps reynoldsi

Recovery Objective: DELIST.

Recovery Criteria

In order to delist this species, efforts must continue towards the immediate protection of remaining xeric upland communities where the sand skink occurs. We must ensure that existing protected habitat, in combination with xeric uplands proposed for protection through acquisition, is adequate for recovery. The sand skink can be delisted when: risk assessment and population viability analyses demonstrate that a sufficient number of geographically distinct sand skink populations are protected to ensure a 95 percent probability of persistence of the species over the next 100 years; and when research and monitoring of the biology and ecology of this species determine the population is stable or increasing over no less than 6 years.

Species-level Recovery Actions

S1. **Determine the status and distribution of sand skinks.** Archbold Biological Station maintains a geographic information system (GIS) to compile species distribution information. Scrub habitat that may support populations of sand skinks that has not yet been surveyed or needs to be re-surveyed should be targeted for subsequent efforts and tracts where the status of skinks is uncertain should be identified.

S1.1. **Compile distribution data for sand skinks from all available sources.** Existing data sources should be combined and synthesized using GIS overlays. Habitat occupied by sand skinks, suitable but unoccupied habitat, and unsurveyed but suitable habitat should be identified. Maintaining and updating a current GIS database on the distribution and status of skinks is essential for long-term monitoring needs and for developing habitat management strategies.

S1.2. **Conduct distribution surveys to determine additional sites in need of protection**. If additional surveys locate occupied habitat that is determined to be essential for the survival of sand skinks, efforts should be made to incorporate these areas into scrub protection initiatives. The development of site-specific management plans for habitat purchased in the Lake Wales Ridge NWR and the Lake Wales Ridge Ecosystem Project should include provisions for baseline and long-term monitoring efforts for sand skinks. Additional areas that may support skink populations should be surveyed, and if occupied and essential to the survival of the species, should be considered for protection under existing or new habitat acquisition programs.

S2. **Protect and enhance existing populations**. If the proposed Federal and State purchase of scrub and associated xeric communities is achieved, the resulting network of publicly and privately owned and protected scrub will encompass about 16,200 ha on the Lake Wales Ridge. This mosaic of varying size scrub patches should prove adequate to protect this species indefinitely provided that the communities are protected and that suitable management practices favorable to skinks are identified and implemented. Site-specific management prescriptions that assure a mixture of successional stages and ecotonal areas required by skinks should be developed for tracts purchased in the Lake Wales Ridge NWR and Lake Wales Ridge Ecosystem Project initiatives.

S2.1. Conduct section 7 consultations on Federal activities that may affect sand skinks. Section 7 of the Endangered Species Act requires Federal agencies to consult with the FWS to ensure appropriate consideration of impacts to listed species from all Federal actions. The sand skink needs to be considered, along with other listed species in scrub habitat, in any proposed Federal actions (authorized, funded, or carried out by Federal agencies) that might adversely affect the species and their habitats. These could include but are not limited to road and facility construction, timber management practices, land clearing and conversion, wetland dredge and fill activities, and pesticide applications involving use of Federal funds.

S2.2. Protect skinks on public lands. Develop and implement land management techniques that maintain natural diversity. Periodic burning, cutting, mowing or other techniques are needed to maintain ecotonal areas between xeric habitats. Habitat must also be protected from off-road vehicle traffic and commercial forestry practices.

S2.3. Protect skinks on private lands. Where sand skinks are known to exist on private lands, efforts should be made to contact landowners, and information on the status and habitat requirements of the species should be provided. Recommendations should be provided for managing private lands. Long-term renewable leases and conservation agreements involving Federal, State, and local government agencies are options where outright acquisition is not acceptable to the landowner.

S2.4. Control pesticide use in or adjacent to sand skink habitat. Because pesticide use on adjacent agricultural and residential lands poses a potential risk to sand skinks, management plans should consider these risks and alleviate threats whenever possible.

S3. Conduct research on life history and population ecology of sand skinks. Adequate long-term protection of the sand skink depends on a thorough understanding of its life history. Many aspects of the life history of this species are poorly understood or remain entirely unstudied, therefore more specific studies of the life history characteristics of the sand skink are needed to ensure that land management efforts are compatible with the habitat requirements of the sand skink.

S3.1. Develop standardized survey techniques. Research specific habitat requirements in relation to vegetation structure. Also, develop better survey methods to assess population levels and status of sand skinks. and their response to management prescriptions. Methods to determine home range size, age of dispersal and dispersal distance are needed to evaluate recolonization capabilities and susceptibility to local extirpation. Mark-recapture methodology and radiotelemetry may soon provide feasible approaches to the study of these small, semi-fossorial reptiles. There are probably suitable protected sites at present to conduct baseline studies.

S3.2. **Support studies of reproduction, fecundity, and longevity**. Obtain data on mating behavior, reproductive success, productivity, longevity, and other basic population characteristics by using captive animals.

S4. **Monitor sand skink populations.** Once standardized survey techniques are developed, begin long- term monitoring on protected public and private lands. Start monitoring efforts at Archbold Biological Station where periodic controlled burns are used to maintain scrub habitats. Initiate efforts to assess populations at other public and private scrub preserves as we learn more about the biology of this species and appropriate monitoring techniques.

S5. **Increase public awareness of sand skinks**. Efforts to protect this, and other scrub species, benefit from public education efforts for the scrub ecosystem. Species-specific educational materials probably will not be as effective as habitat-based efforts that currently exist, because we know very little about the biology of this species.

Habitat-level Recovery Actions

H1. **Prevent degradation of existing scrub habitat.** The key to the long-term recovery of sand skink habitat lies in the immediate protection of as much of the remaining scrub ecosystem as is economically feasible within the Lake Wales Ridge.

H1.1. **Acquisition of scrub habitat.** Simple fee title, conservation easements, transfer of development rights, land trades, or other conservation measures will be necessary to protect remaining scrub habitat.

H1.1.1. **Continue Federal acquisition efforts**. Continue acquisition efforts within the Lake Wales Ridge NWR complex. Much of the habitat targeted for acquisition will be acquired by 1998. One or possibly two additional, but currently unidentified parcels may subsequently be targeted for acquisition.

H1.1.2. **Support State acquisition efforts**. The Florida Conservation and Recreation Lands (CARL) program Lake Wales Ridge Ecosystem Project includes over 30 key scrub areas (Appendix F) totaling 13,145 ha. The State's Save Our Rivers (SOR) acquisition program administered by the water management districts targets wetlands for protection, but some sites also contain xeric uplands, and potentially sand skink habitat, that also benefit from the SOR program.

H1.1.3. **Encourage acquisition by non-government organizations.** Occupied sand skink habitat not targeted in Federal and State acquisition programs may become available for private purchase and management. Scrub habitats already protected such as those at Archbold Biological Station and The Nature Conservancy's Tiger Creek Preserve, Saddle Blanket Lakes, and Lake Apthorpe areas will continue to play an important role in the long-term persistence of sand skinks.

H1.2. **Manage scrub habitat**. Like most vegetative communities in Florida, the scrub requires periodic fire or other sources of disturbance to maintain its diversity and distribution.

H1.2.1. **Develop scrub habitat management guidelines.** The Nature Conservancy and Archbold Biological Station have gained experience in the management of scrub communities. Information gathered by these organizations should be consolidated into a set of standardized management guidelines that could be used by other land owners wishing to effectively manage scrub.

H1.2.2. **Develop cooperative scrub management programs**. Concurrently with **H1.2.1**., develop cooperative agreements for completing management of scrub as efficiently as possible. Public and private funding is limited and expenditures for land management can represent a large portion of operating expenses. Currently, three private organizations, one Federal and three State agencies own or are responsible for the management of scrub habitat. Large expenditures in equipment and personnel can be avoided through cooperative planning of scrub management.

H1.2.3. **Control off-road access.** Fence or sign scrub habitat to eliminate off-road use. In many areas, off-road access has degraded habitat and destroyed individual rare plants. Soil stabilization, trash removal, and replanting may be necessary in some cases to effectively manage scrub.

H2. **Restore scrub to suitable habitat.** Identify areas of restorable habitat and develop management plan to restore habitat. Much of the remaining scrub is degraded because fire has been excluded and the vegetation has become overgrown. Overgrown scrub can lose much of its function and value as it tend towards a more mesic condition.

H2.1. **Control exotic species**. Although exotic species are not currently a threat to most xeric communities, site-specific control measures may be needed, especially in ecotonal areas or human disturbed areas.

H2.2. **Control overgrowth**. In most situations, unmanaged scrub tends to become dense and tall, conditions which are not favorable to many scrub-dependent species. Management of overgrown scrub must include thinning, burning, mowing, or other techniques to reduce vegetative density.

H3. **Conduct research to determine habitat needs for this species.** Basic life history requirements and habitat needs for this species are not known. As we learn more about the basic biology of this species, we will also gain better insight into its habitat needs. Research on sand skink habitat should be concurrent with investigations into the biology of this species.

H4. **Monitor status of sand skink habitat**. Once we understand the habitat requirements for this species we will be better able to develop habitat management and monitoring recommendations. Until species-specific information is available, monitoring should ensure maintenance of ecotonal boundaries, diversity within scrub, and open sandy patches.

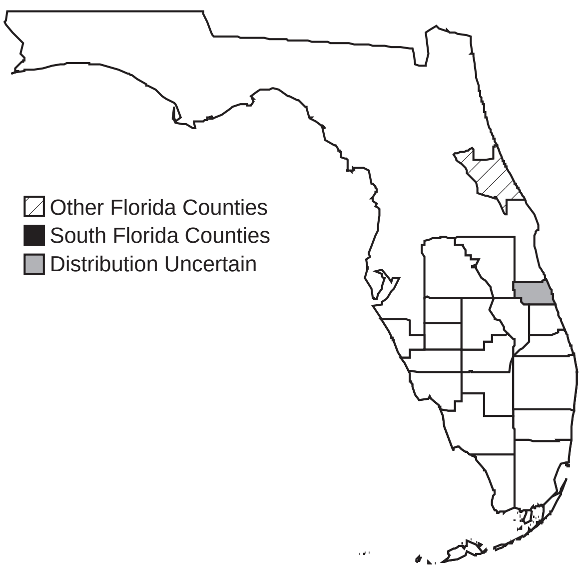
H5. **Increase public awareness of the scrub ecosystem**. Efforts should highlight habitat acquisition initiatives, importance of biodiversity, and biology of scrub-dependent species. Federal, State, and county governments, as well as private organizations, should support the development and dissemination of educational materials pertaining to the conservation of the scrub ecosystem and endemic scrub species. Materials such as brochures, posters, postcards, slide programs, and videotapes can improve public understanding of and increase appreciation for protection of scrub habitat. Environmental education programs across central Florida should be encouraged to distribute materials or develop lesson plans on scrub ecosystems, particular scrub species, and the importance of maintaining biological diversity.

Atlantic Salt Marsh Snake

Nerodia clarkii taeniata

Federal Status:	**Threatened (Nov. 29, 1977)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. County distribution of the Atlantic salt marsh snake; this species is only found in coastal habitats within its range.



The Atlantic salt marsh snake (*Nerodia clarkii taeniata*) is a small, slender snake that inhabits coastal salt marshes and mangrove swamps that vary in salinity from brackish to full strength seawater. It is unique because it is one of the few North American reptiles that lives in salt water habitats but has not developed salt glands. The Atlantic salt marsh snake was listed as a threatened species due to habitat loss and alteration, and potential hybridization with adjacent freshwater species.

This account represents South Florida's contribution to the range-wide recovery plan for the Atlantic salt marsh snake (FWS 1993).

Description

There are three subspecies of salt marsh snakes: the Gulf salt marsh snake (*Nerodia clarkii clarkii),* mangrove water snake (*N. c. compressicauda*), and Atlantic salt marsh snake (*N. c. taeniata*). These subspecies are distinguishable as follows: their dorsal patterns are formed from a basic pattern of four rows of dark blotches running from head to tail (two lateral and two dorsolateral rows) on a lighter background. In the striped forms, the blotches fuse linearly to form stripes; in the banded forms, the blotches fuse across the back to form bands. In partially striped individuals, it is invariably the anterior portion of the body that is striped, with the pattern posteriorly consisting of bands or rows of unfused blotches. The lateral stripes have a greater tendency than do the dorsolateral stripes to break down posteriorly into rows of blotches.

The Gulf salt marsh snake has a dorsal pattern that is completely striped, or nearly so, with dark brown to black stripes on a tan background. It is not unusual for the lateral stripes in this form to break down posteriorly into rows of blotches. The mangrove water snake may be uniformly orange in color, but it more often has a pattern of dark bands on a lighter background. Individuals from throughout the range of the mangrove water snake may be partially striped; in these specimens the striping is typically limited to the neck region, but occasional specimens may be more extensively striped. Coloration in the mangrove water snake is extremely variable, with the background being gray, straw, or reddish and the bands being black, brown, or red. Populations of mangrove water snakes characteristically include at least some individuals that exhibit reddish or orange pigmentation.

The Atlantic salt marsh snake is a partially striped salt marsh snake that reaches a maximum length of at least 82 cm, although it is typically less than 65 cm in length. The pattern consists of a gray to pale olive background with black to dark brown stripes anteriorly, the stripes breaking up into rows of spots posteriorly. The extent of the striping is variable, but most individuals from the coastal marshes of Volusia County are striped on at least the anterior 30 percent of the body. The ventral is black with a central row of large cream to yellowish spots. As in the case of the dorsal striping, this ventral pattern is best developed anteriorly and tends to break down posteriorly. The red pigmentation characteristic of mangrove water snakes is conspicuously lacking in Atlantic salt marsh snakes from the vicinity of Edgewater, Volusia County, and northward (i.e., the area from which the form was described). The threatened designation applies only to the Atlantic salt marsh snake.

Hebrard (1979) reported coloration for 23 specimens from the southern Indian River Lagoon, near the Volusia-Brevard county line. Of these, seven (30 percent) exhibited orange or reddish pigmentation either dorsally or ventrally. It is unclear at this time whether the reddish pigmentation reported by Hebrard should be interpreted as indicating intergradation with the mangrove water snake. The series of 25 specimens for which Hebrard provided pattern descriptions had dorsal stripes on 0 to 100 percent of the body; only eight (32 percent) had dorsal stripes on more than 30 percent of the body, but three (12 percent) reportedly had dorsal stripes on 100 percent of the body. (In terms of pattern formation, the vertebral stripe is actually the lighter background color which is visible between the two dark, dorsolateral stripes.)

There are several characters of morphology and color pattern that distinguish the salt marsh snakes from the related freshwater species of *Nerodia*, but one of the most reliable is the number of dorsal scale rows. The salt marsh snakes have the dorsal scales in 21 rows at midbody, whereas the freshwater banded water snake has the scales in 23 rows. Also, those populations of salt marsh snakes that are at least partially striped are easily distinguished from the freshwater form, which is completely banded.

Taxonomy

Nerodia clarkii has a complex taxonomic history, having been known under various combinations of generic, specific, and subspecific names. The North American water snakes were long included within the genus *Natrix*, but Rossman and Eberle (1977) restricted that genus to Eurasia and erected the genus *Nerodia* to include many of the North American species previously included within *Natrix*.

At the species level, the salt marsh snakes have at various times been treated as a separate species or as subspecies of two related freshwater species. Both *Nerodia c. clarkii* and *N. c. compressicauda* were initially described as

Atlantic salt marsh snake.
Original photograph courtesy of U.S. Fish and Wildlife Service.

separate species, based at least partly on reports of hybrids between *N. c. clarkii* and the freshwater broad-banded water snake (*N. fasciata confluens*), Clay (1938) reduced the salt marsh snakes to subspecies of *N. sipedon*, a name that at the time applied to all of the banded water snakes of eastern North America. Subsequently, Conant (1963) elevated *N. fasciata* to species status to include the three salt marsh snakes and the three southern freshwater subspecies: *N. f. fasciata*, *N. f. confluens*, and *N. f. pictiventris*. At the time that the Atlantic salt marsh snake was listed as threatened, it was regarded as a subspecies of the southern water snake, *N. fasciata* (Conant 1963). More recently, Lawson *et al.* (1991) conducted an extensive electrophoretic analysis of the *N. fasciata*-*N. clarkii* complex, including specimens from three hybrid swarms. They found no genetic introgression between the salt marsh snakes and the adjacent freshwater snakes and concluded that the salt marsh snakes warrant recognition as a separate species, *N. clarkii*. Hence, the appropriate name for the Atlantic salt marsh snake is now *N. c. taeniata*.

At the subspecific level, the Atlantic salt marsh snake has alternately been treated as a separate subspecies or synonymized with the mangrove water snake. It was described by Cope (1895) as *Natrix compressicauda taeniata*, a subspecies of the mangrove water snake. It was synonymized with *N. compressicauda* by Barbour and Noble (1915) but then resurrected as a separate subspecies by Carr and Goin (1942). Dunson (1979) again proposed that *taeniata* should be relegated to synonymy with *compressicauda.* The form that the FWS listed as threatened is the Atlantic salt marsh snake, *Nerodia fasciata taeniata* (now *N. clarkii taeniata*).

The taxonomic status of the Atlantic salt marsh snake will remain controversial until a thorough, rigorous systematic assessment is conducted. The Endangered Species Act (ESA) defines the term species as including ". . . any subspecies of fish or wildlife or plants, and any distinct population or segment of any species or vertebrate fish or wildlife which interbreeds when mature." Final resolution of the taxonomic status of the Atlantic salt marsh snake will provide further insight into proper management, but continued protection under the ESA appears justified whether it remains a distinct subspecies or a distinct population. Regardless of its taxonomic status, the Atlantic salt marsh snake is a relict of historical and/or ecological processes unique to Florida and should be preserved (Kochman 1992).

Distribution

The species to which the Atlantic salt marsh snake belongs, *N. clarkii*, is found in a narrow coastal strip from southern Texas, east along the Gulf coast, around the Florida peninsula, and up the east coast of Florida at least as far as the Halifax River, Volusia County. It is also known from the north coast of Cuba (Jaume 1974).

Cope's (1895) type series and the specimens used by Carr and Goin (1942) to resurrect *N. c. taeniata* came from the brackish coastal marshes of Volusia County, Florida. There is some uncertainty about the precise locality from which Cope's specimens came, but Carr and Goin (1942) restricted the type locality to the vicinity of National Gardens, which lies near the north end of the Halifax River. Salt marsh snakes have not been documented to the north in southern Flagler County. The Carr and Goin series was collected on the barrier island at New Smyrna Beach.

A problem attendant to the listing of any subspecies that is distributionally continuous and intergradient with another subspecies is the difficulty of defining the limit(s) of the listed form's distribution in the area where it contacts the related, unlisted subspecies. To the south, the Atlantic salt marsh snake intergrades with the mangrove water snake along the central Atlantic coast of Florida. As mentioned above, both the description and the resurrection of the subspecies were based on specimens from Volusia County, although Carr and Goin (1942) considered a single specimen from Indian River County also to be *N. c. taeniata*. They also mentioned a specimen of salt marsh snake from Melbourne, Brevard County, but did not indicate whether they considered that specimen to be *N. c. taeniata*. Wright and Wright (1957) considered *N. c. taeniata* to extend only as far south as the lower end of Mosquito Lagoon, in northern Brevard County, and Neill (1958) indicated that *N. c. taeniata* intergraded with the mangrove water snake on Merritt Island.

In the final listing of the Atlantic salt marsh snake (FR 42:60743-60745), the FWS indicated that "The Atlantic salt marsh snake is known only from coastal areas of Brevard, Volusia, and Indian River Counties." However, Hebrard and Lee (1981) examined a large series of salt marsh snakes from southern Mosquito Lagoon near the Volusia-Brevard county line and reported that they "resembled *Nerodia fasciata compressicauda* quite closely." Hebrard and Lee further noted that their specimens differed markedly in coloration and pattern from specimens of *N. c. taeniata* from further north in Volusia County. It is also worth noting that the snakes examined by Hebrard and Lee were collected in mangroves (species not indicated), whereas only about 10 miles farther north, where populations of typical Atlantic salt marsh snakes are found, the habitat consists primarily of glasswort (*Salicornia* spp.) flats and salt grass (*Distichlis spicata*)-bordered tidal creeks with only scattered black mangroves (*Avicennnia germinans*). The zone of intergradation appears to coincide with the increasing dominance of mangrove swamps; eventually, as mangrove swamps become predominant so does *N. c. compressicauda*. Kochman (1992) concluded that "salt marsh snakes from farther south in Brevard and Indian River Counties, although occasionally striped, appear to comprise a zone of intergradation with *N. c. compressicauda*." P. Moler (GFC, personal communication 1996) agrees with Kochman.

Until a survey and taxonomic assessment have been conducted, it will not be possible to determine the southern distributional limit of the Atlantic salt marsh snake. We used the distributional map provided during the listing of this subspecies (Figure 1), even though recent information suggests the Atlantic salt marsh snake may be restricted to the brackish, coastal marshes of Volusia County, from the Halifax River south to the northern portions of the Indian River Lagoon (FWS 1993).

Habitat

Atlantic salt marsh snakes are restricted to brackish, tidal marshes. They most often have been found in association with saltwort flats and salt grass-bordered tidal creeks. It is not known if they occur in the adjacent black needlerush (*Juncus roemerianus*) habitat. Atlantic salt marsh snake use of marsh habitats may be limited by water level, with extreme fluctuations making the marsh too hydric or xeric (G. Goode, East Volusia County Mosquito Control, personal communication 1997). When inactive or pursued, they frequently retreat into one of the numerous fiddler crab (*Uca pugilator*) burrows that riddle the edge of the marsh and the banks of the tidal creeks (Carr and Goin 1942, Kochman 1992).

Behavior

Most snakes adapted to life in salt water (families Hydrophiidae, Achrocordidae, and Homalopsidae) possess salt glands, through which they excrete excess salts (Dunson 1975). The salt marsh snakes apparently lack salt glands (Schmidt-Nielsen and Fange 1958), but they nonetheless exhibit very low dehydration rates in seawater (Pettus 1963, Dunson 1978, 1980). Salt marsh snakes are apparently able to survive in seawater through their reduced rates of cutaneous water and salt exchange and their refusal to drink seawater even when they become dehydrated. By contrast, when held in seawater, their freshwater congeners quickly become dehydrated, which prompts them to drink. This merely exacerbates their dehydration and leads to death (Pettus 1963). Salt marsh snakes readily drink fresh water when it becomes available from rain or dew (Kochman 1992).

Although the Atlantic salt marsh snake is most easily observed at night, it may be active at any time of day. Its activity is influenced by tidal cycles, which strongly influence the availability of food (Neill 1958). Although Carr and Goin (1942) indicated that all of their specimens were collected "just as the tide was beginning to overflow the flats," Kochman (1992) indicated that it was observed most often "during low tidal stages, when it apparently feeds on small fishes that become trapped in the shallow water." It feeds primarily on small fish, but it readily takes frogs when available.

Reproduction

This species is ovoviviparous. Captive individuals have given birth to 3 to 9 young from August to October (Kochman 1992). Fecundity is low relative to the adjacent freshwater species, *N. fasciata*, which may give birth to 50 or more young.

Relationship to Other Species

It is well known that salt marsh snakes occasionally hybridize with the closely related freshwater species, especially in areas of habitat disturbance (Kochman 1977, Dunson 1979, Lawson *et al.* 1991). Lawson *et al.* (1991) demonstrated that, despite the reproductive compatibility of the two forms, there appears to be little or no genetic introgression between them in areas of undisturbed habitat. The extent of genetic introgression associated with the local breakdown of reproductive isolation between the two species has not yet been examined.

Status and Trends

The Atlantic salt marsh snake was listed on the basis of two primary concerns: 1) loss of habitat resulting from intensive drainage and development in coastal salt marshes; and 2) the accompanying disruption of reproductive isolating mechanisms, which can lead to hybridization with the Florida banded water snake, and potential swamping of the Atlantic salt marsh snake gene pool by the much larger Florida banded water snake gene pool (FWS 1993).

At the time of its listing, the Atlantic salt marsh snake was thought to include salt marsh snakes as far south as Indian River County (FWS 1977). As suggested above, its distribution may actually be much more restricted, limited to the brackish, coastal marshes of Volusia County. If this is the case, the Atlantic salt marsh snake's vulnerability to habitat destruction and modification is even greater than previously realized (FWS 1993).

Rising sea levels are not an immediate threat but in the long term may reduce the amount of habitat available to the Atlantic salt marsh snake. As sea levels rise, salinity in the estuaries will also rise correspondingly and possibly change the vegetation of the marsh, eventually flooding the area and making it inhospitable for the snake (FWS 1993).

Historically, Atlantic salt marsh snake habitat probably represented a small portion of the salt marsh and changed periodically from recurring tropical storms. However, with development of Florida's Atlantic coast, habitat has been permanently lost. This development, coupled with narrow habitat flexibility and a limited range (primarily Volusia County), has resulted in reduced populations of Atlantic salt marsh snakes (FWS 1993).

Recent records for populations identifiable as Atlantic salt marsh snakes are available from the barrier island a short distance north of Ponce Inlet, the mainland shoreline east of the New Smyrna Beach airport, two localities on the barrier island at New Smyrna Beach, an island in the Indian River east of Edgewater, and from a single specimen identified as *N. c. taeniata* captured just south of the Flagler County line (FWS 1993). It is not known if a viable population exists in this area or to the north in Flagler County.

Destruction of habitat by residential and commercial construction and habitat degradation due to ditching, diking, and water level manipulation have adversely affected *N. c. taeniata* and its habitat. Since little was known of the population size or distribution of Atlantic salt marsh snakes during the period of rapid, unregulated, coastal development of the 1940s through 1960s, it is impossible to quantify habitat loss or direct effects on the *N. c. taeniata* population. However, during review of dredge-and-fill activities from 1983-1992, a minimum of 36 projects were permitted in Volusia County's salt marsh habitat. These projects included dredge-and-fill, shoreline protection projects, construction of piers and marinas, mosquito ditching, and water control structures. However, only 13.2 ha of salt marsh were destroyed by these projects, most (12.2 ha, 18 projects) before 1988. Loss of salt marsh habitat appears to have slowed since 1988 (1.1 acres, 18 projects) indicating improved protection under existing local, State, and Federal conservation policies.

Management

Conservation measures have consisted of limited survey work; genetic comparison with other salt marsh snakes and southern banded water snakes; and creation, restoration, and protection of suitable habitat.

Sporadic surveys conducted from 1978 to 1988 by personnel of the GFC and the FWS confirmed the continued presence of the Atlantic salt marsh snake at several localities in Volusia County. Personnel of the East Volusia County Mosquito Control District are currently conducting surveys for Atlantic salt marsh snakes associated with mosquito control impoundments on islands in the northern portions of the Indian River Lagoon (G. Goode, East Volusia County Mosquito Control District, personal communication 1997). A survey was conducted on Merritt Island NWR in the late 1970s, and a large population of salt marsh snakes was identified in the vicinity of the Volusia-Brevard county line, but this population seemed to show signs of intergradation with the mangrove water snake (Hebrard and Lee 1981).

Localities in the vicinity of New Smyrna Beach were sampled by GFC for genetic studies (Lawson *et al.* 1991). Electrophoretic analyses indicated that the salt marsh snakes are closely related to, but specifically distinct from, the southern banded water snake, and that the three subspecies of the salt marsh snake are electrophoretically indistinguishable from each other (Lawson *et al.* 1991). Tissues were saved for possible comparison of mitochondrial DNA variation in the salt marsh snakes, and that work is underway.

Additionally, to avoid risks of genetic and/or catastrophic events, an attempt should be made to establish self-sustaining populations throughout the subspecies range (FWS 1993). The FWS' recovery plan suggests that self-sustaining populations contain 100 to 200 adult snakes in at least 10 secure, discrete sites dispersed throughout Volusia County. Management of established populations should also include development and implementation of a monitoring program for 5 or more years.

Literature Cited

Barbour, T., and G. Noble. 1915. Notes on the water snake *Natrix compressicauda*. Proceedings of the Academy of Natural Sciences 67:29-35.

Carr, A.F., Jr., and C.J. Goin. 1942. Rehabilitation of *Natrix sipedon taeniata* Cope. Proceedings of the New England Zoological Club 21:47-54.

Clay, W.M. 1938. A synopsis of the North American water snakes. Copeia 1938:173-182.

Conant, R. 1963. Evidence for the specific status of the water snake *Natrix fasciata*. American Museum Novit. 2122:1-38.

Cope, E.D. 1895. On some new North American snakes, *Natrix compressicauda taeniata* subsp. nov. American Naturalist 29:676-680.

Dunson, W.A. 1975. The biology of sea snakes. University Park Press; Baltimore, Maryland.

Dunson, W.A. 1978. Role of the skin in sodium and water exchange of aquatic snakes placed in seawater. American Journal of Physiology 235(3):151-159.

Dunson, W.A. 1979. Occurrence of partially striped forms of the mangrove snake *Nerodia fasciata compressicauda* Kennicott and comments on the status of *N. f. taeniata* Cope. Florida Scientist 42(2):102-112.

Dunson, W.A. 1980. The relation of sodium and water balance to survival in seawater of estuarine and fresh water races of the snakes *Nerodia fasciata*, *N. sipedon* and *N. valida*. Copeia 1980(2):268-280.

Goode. G. 1997. Telephone communication. 7 January 1997.

Hebrard, J.J. 1979. Atlantic salt marsh snake survey: Merritt Island National Wildlife Refuge 1979. Unpublished report, U.S. Fish and Wildlife Service; Jacksonville, Florida.

Hebrard, J.J., and R.C. Lee. 1981. A large collection of brackish water snakes from the central Atlantic coast of Florida. Copeia 1981(4):886-889.

Jaume, M.L. 1974. La más rara culebra de Cuba. Torreria (n.s.) 35:1-8.

Kochman, H.I. 1977. Differentiation and hybridization in the *Natrix fasciata* complex (Reptilia: Serpentes): a non-morphological approach. Unpublished Master's Thesis, University of Florida; Gainesville, Florida.

Kochman, H.I. 1992. Atlantic salt marsh snake. Pages 111-116. *in* P.E. Moler, ed. The rare and endangered biota of Florida. University of Florida Press; Gainesville, Florida.

Lawson, R., A.J. Meier, P.G. Frank, and P.E. Moler. 1991. Allozyme variation and systematics of the *Nerodia fasciata*-*Nerodia clarkii* complex of water snakes (Serpentes:Colubridae). Copeia 1991(3):638-659.

Moler, P. 1996. U. S. Fish and Wildlife Service multi-species recovery team meeting. 28 February 1996.

Neill, W.T. 1958. The occurrence of amphibians and reptiles in salt water areas, and a bibliography. Bulletin of Marine Science of the Gulf and Caribbean 8:1-97.

Pettus, D. 1963. Salinity and subspeciation in *Natrix sipedon*. Copeia 1963(3):499-504.

Rossman, D.A., and W.G. Eberle. 1977. Partition of the genus *Natrix*, with preliminary observations on evolutionary trends in natricine snakes. Herpetologica 33:34-43.

Schmidt-Nielsen, K., and R. Fange. 1958. Salt glands in marine reptiles. Nature 182:783-785.

U.S. Fish and Wildlife Service [FWS]. 1993. Atlantic salt marsh snake recovery plan; Atlanta, Georgia.

Wright, A.H., and A.A. Wright. 1957. Handbook of snakes of the United States and Canada. Volume 1. Comstock Publishing Associates; Ithaca, New York.

Recovery for the Atlantic Salt Marsh Snake

Nerodia clarkii taeniata

Recovery Objective: DELIST the species once recovery criteria are met**.**

South Florida Contribution: DELIST the species once recovery criteria are met**.**

Recovery Criteria

Because we are still uncertain whether this subspecies occurs in South Florida (Indian River County), we have no more specific delisting criteria than what is outlined in the existing recovery plan for the species.

The Atlantic salt marsh snake can be considered for delisting when there is no evidence of significant genetic introgression (genetic exchange limited to a very narrow hybrid zone) from the Florida banded water snake (*Nerodia fasciata pictiventris*) into adjacent populations of *Nerodia clarkii taeniata*; when habitat is adequately protected and habitat loss is maintained at or below current levels for the next 5 years; and when self-sustaining populations of 100 to 200 adult snakes are established at each of 10 secure, discrete sites dispersed throughout Volusia County (there are no numerical goals for South Florida for this species). These numerical goals are subject to revision as more information becomes available on the biology of the Atlantic salt marsh snake; populations must be monitored for at least 5 years before considering delisting.

Species-level Recovery Actions

S1. Determine the distribution and status of the Atlantic salt marsh snake in South Florida.

S1.1. Conduct surveys of suitable habitat in Indian River County to determine the extent of suitable habitat that is occupied and the distributional limits of the Atlantic salt marsh snake. These surveys may identify areas of intergradation with the mangrove water snake (*N. c. compressicauda*) and also may identify areas of hybridization with *N. fasciata*. Delineation of the distribution will allow habitat protection efforts to be focused on areas actually occupied by the Atlantic salt marsh snake in South Florida.

S1.2. Determine relative abundance within occupied habitats, identify the most important populations and habitat, and develop a population censusing technique. If populations are identified in the distributional survey, determine relative abundance in different habitats (*e.g. Juncus roemerianus* marsh). This will provide additional direction in identifying habitat protection needs. Populations will need to be monitored to detect population trends. A population indices technique is needed to obtain trend data. Systematic searches of the potholes in the salt flats at low tide to observe snakes or find snake tracks in the mud may be developed into a population index.

S2. Protect and enhance existing populations.

S2.1. Land acquisition. Where feasible, identify essential habitats for the Atlantic salt marsh snake and pursue public ownership of these areas through Federal, State, and non-governmental programs.

S2.2. Enforce regulations. Use existing regulatory measures such as section 7 of the ESA, section 404 of Clean Water Act and Fish and Wildlife Coordination Act to provide protection to Atlantic salt marsh snakes.

S3. Conduct research on the biology of the Atlantic salt marsh snake.

S3.1. Conduct a taxonomic assessment of the salt marsh snakes in Volusia, Brevard, and Indian River counties. A taxonomic assessment is required to determine diagnostic criteria to use in evaluating populations identified in the distributional survey. Approaches should include traditional morphometric and meristic analyses and an examination of mitochondrial DNA polymorphisms.

S3.1.1 Conduct morphometric and meristic analyses. This subspecies was described at a time when little was known about salt marsh snakes elsewhere on the Atlantic coast. Available diagnoses do not permit an adequate determination of the geographical limits of the taxon. Perform an initial assessment to determine data to be collected from snakes encountered in the distributional survey; thereafter, the survey should proceed concurrently, in order to make additional material available for a taxonomic analysis.

S3.1.2 Perform analysis of mitochondrial DNA polymorphisms. This work will further assist in determining the relationship between this form and the mangrove water snake.

S4. Monitor population(s) of Atlantic salt marsh snakes in habitats where it is found to determine its status and trends.

S5. Increase awareness by disseminating information about Atlantic salt marsh snakes. Although intentional killing is not thought to be a significant factor contributing to the threatened status of this form, an effort should be made to minimize take by informing the public of its protected status.

S5.1. Produce and distribute educational posters about the identification and protected status of the Atlantic salt marsh snake. Inform the public about the protected status of the Atlantic salt marsh snake. Posters should be displayed at marinas, bait shops, and schools within the range of the Atlantic salt marsh snake.

S5.2. Produce and distribute pamphlets to inform landowners about the protected status of the Atlantic salt marsh snake. Property owners adjacent to Atlantic salt marsh snake habitat should be informed of the potential presence of this snake and its protected status.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat.

H1.1 Identify specific beneficial habitat management practices. Specific management techniques need to be identified through research and applied to appropriate salt marsh habitats. The effects of open water marsh management (rotary ditching to increase water flow) need to be documented. The applicability of salt marsh restoration activities needs to be evaluated in relation to Atlantic salt marsh snakes. Additionally, burning of mangroves (in areas where mangroves have been killed by freezes) may create additional habitat if the burns revert to the *Salicornia* spp.-*Distichlis spicata* habitat type.

H1.2. Enforce regulations. Use existing regulatory measures such as section 7 of the ESA, section 404 of Clean Water Act and Fish and Wildlife Coordination Act to provide protection to salt marsh habitat. Strict application of section 7 (consultation) and 404 regulations within the range of the Atlantic salt marsh snake should reduce loss of existing habitat. Require that mitigation proposals from permitted dredge-and-fill projects obtain conservation easements for protecting existing salt marsh habitat or create and/or restore such habitats.

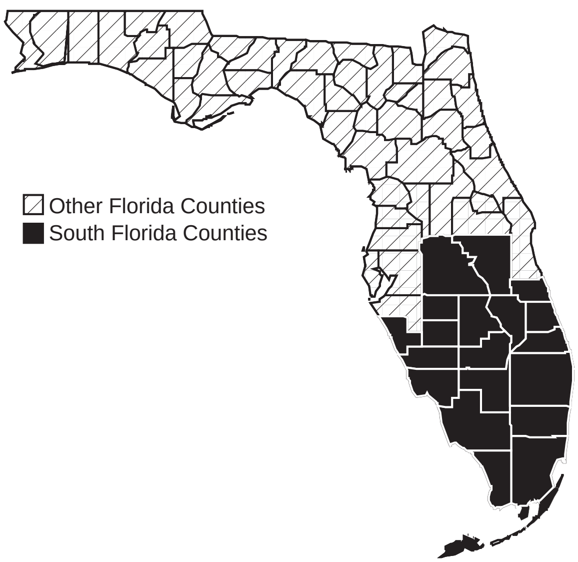
H1.3. Monitor water quality for contaminants. Periodic water quality monitoring in salt marsh habitat should be done to determine possible contamination. Urban runoff, including pesticides and fertilizers applied to lawns, and mosquito spraying, may degrade salt marsh habitats, making them unsuitable for Atlantic salt marsh snakes.

Eastern Indigo Snake

Drymarchon corais couperi

Federal Status:	**Threatened (January 31, 1978)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. Florida distribution of the eastern indigo snake.



The eastern indigo snake is a large, black, non-venomous snake found in the southeastern U.S. It is widely distributed throughout central and South Florida, but primarily occurs in sandhill habitats in northern Florida and southern Georgia. The eastern indigo snake was listed as a threatened species as a result of dramatic population declines caused by over-collecting for the domestic and international pet trade as well as mortalities caused by rattlesnake collectors who gassed gopher tortoise burrows to collect snakes. Since its listing, habitat loss and fragmentation by residential and commercial expansion have become much more significant threats to the eastern indigo snake.

This account represents South Florida's contribution to the range-wide recovery plan for the eastern indigo snake (FWS 1982).

Description

The eastern indigo snake is the longest snake in the United States (R. Hammer, Metro Dade Park and Recreation, personal communication 1998), reaching lengths of up to 265 cm (Ashton and Ashton 1981). Its color is uniformly lustrous-black, dorsally and ventrally, except for a red or cream-colored suffusion of the chin, throat, and sometimes the cheeks. Its scales are large and smooth (the central 3 to 5 scale rows are lightly keeled in adult males) in 17 scale rows at midbody. Its anal plate is undivided. Its antepenultimate supralabial scale does not contact the temporal or postocular scales.

In the Florida Keys, adult eastern indigo snakes seem to have less red on their faces or throats compared to most mainland specimens and those in north Florida typically have little to no red (Lazell 1989; P. Moler, GFC, personal communication 1998).

Taxonomy

The indigo snake *(Drymarchon corais)* ranges from the southeastern U.S. to northern Argentina (Moler 1992). This species has eight recognized subspecies, two of which occur in the U.S. (Conant 1975, Moler 1985a): the eastern indigo (*D. c. couperi*) and the Texas indigo (*D. c. erebennus*).

The eastern indigo snake was originally described as *Coluber couperi* by Holbrook in 1842 and was later reassigned to the genus *Georgia* by Baird and Girard in 1853. Cope transferred it to the genus *Spilotes* in 1860 and later (1862) described it as a subspecies of *Spilotes corais*. Cope assigned the species *corais* to the genus *Compsosoma* in 1900. In 1917, Stejneger and Barbour resurrected the genus name *Drymarchon*, (*Drymarchon corais*; Daudin 1827), including the eastern indigo snake as *Drymarchon corais couperi*.

Distribution

Historically, the eastern indigo snake occurred throughout Florida and in the coastal plain of Georgia, Alabama and Mississippi (Löding 1922, Haltom 1931, Carr 1940, Cook 1954, Diemer and Speake 1983, Moler 1985a). It may have occurred in southern South Carolina, but its occurrence there cannot be confirmed. Georgia and Florida currently support the remaining, endemic populations of the eastern indigo snake (Lawler 1977). In 1982, only a few populations remained in the Florida panhandle, and the species was considered rare in that region. Nevertheless, based on museum specimens and field sightings, the eastern indigo snake still occurs throughout Florida, even though they are not commonly seen (Moler 1985a) (Figure 1).

In South Florida, the eastern indigo snake is thought to be widely distributed.. Given their preference for upland habitats, eastern indigos are not commonly found in great numbers in the wetland complexes of the Everglades region, even though they are found in pinelands, tropical hardwood hammocks, and mangrove forests in extreme South Florida (Duellman and Schwartz 1958, Steiner *et al.* 1983).

Eastern indigo snakes also occur in the Florida Keys. They have been collected from Big Pine and Middle Torch Keys, and are reliably reported from Big Torch, Little Torch, Summerland, Cudjoe, Sugarloaf and Boca Chica Keys (Lazell 1989). Moler (GFC, personal communication 1996) documented eastern indigo snakes on North Key Largo and feels they are probably restricted to Crocodile Lake NWR and the protected hammock areas on that Key. Given the ubiquitous nature of the eastern indigo snake throughout the remainder of its range, we believe it probably occurs on other keys.

Habitat

Over most of its range, the eastern indigo snake frequents several habitat types, including pine flatwoods, scrubby flatwoods, high pine, dry prairie, tropical hardwood hammocks, edges of freshwater marshes, agricultural fields, coastal dunes, and human-altered habitats. Eastern indigo snakes need a mosaic of

Eastern indigo snake. *Original photograph courtesy of U.S. Fish and Wildlife Service.*

habitats to complete their annual cycle. Interspersion of tortoise-inhabited sandhills and wetlands improves habitat quality for this species (Landers and Speake 1980, Auffenberg and Franz 1982). Eastern indigo snakes require sheltered "retreats" from winter cold and desiccating conditions. In laboratory experiments, they appear to be especially susceptible to desiccation (Bogert and Cowles 1947). Wherever the eastern indigo snake occurs in xeric habitats, it is closely associated with the gopher tortoise (*Gopherus polyphemus*), the burrows of which provide shelter from winter cold and desiccation (Bogert and Cowles 1947, Speake *et al*. 1978, Layne and Steiner 1996). This dependence seems especially pronounced in Georgia, Alabama, and the panhandle area of Florida, where eastern indigo snakes are largely restricted to the vicinity of sandhill habitats occupied by gopher tortoises (Diemer and Speake 1981, Moler 1985b, Mount 1975). Reliance on xeric sandhill habitats throughout the northern portion of the eastern indigo's range can be attributed primarily to the availability of thermal refugia afforded by gopher tortoise burrows during winter. Few such refugia are widely available off of the sandhill regions of southern Georgia and northern Florida. In wetter habitats that lack gopher tortoises, eastern indigo snakes may take shelter in hollowed root channels, hollow logs, or the burrows of rodents, armadillo (*Dasypus novemcinctus*), or land crabs (*Cardisoma guanhumi*) (Lawler 1977, Moler 1985b, Layne and Steiner 1996).

In the milder climates of central and southern Florida, eastern indigo snakes exist in a more stable thermal environment, where availability of thermal refugia may not be as critical to the snake's survival. Throughout peninsular Florida, this species may be found in all terrestrial habitats which have not suffered high-density urban development. They are especially common in the hydric hammocks throughout this region (Moler 1985a). In central and coastal Florida, eastern indigos are mainly found within many of the State's high, sandy ridges. In extreme South Florida, these snakes are typically found in pine flatwoods, pine rocklands, tropical hardwood hammocks, and in most other undeveloped areas (Kuntz 1977). Eastern indigo snakes also use some agricultural lands (*e.g.,* citrus) and various types of wetlands (Layne and Steiner 1996).

Even though thermal stress may not be a limiting factor throughout the year in South Florida, eastern indigo snakes still seek and use underground refugia in the region. On the sandy central ridge of South Florida, eastern indigos use gopher tortoise burrows more (62 percent) than other underground refugia (Layne and Steiner 1996). Other underground refugia used by this species include burrows of armadillos, cotton rats (*Sigmodon hispidus*), and land crabs; burrows of unknown origin; natural ground holes; hollows at the base of trees or shrubs; ground litter; trash piles; and in the crevices of rock-lined ditch walls (Layne and Steiner 1996). These refugia are used most frequently where tortoise burrows are not available, principally in low-lying areas off of the central and coastal ridges.

Smith (1987) radio-marked hatchling, yearling, and gravid eastern indigo snakes and released them in different habitat types on St. Marks NWR in Wakulla County, Florida. Smith monitored the behavior, habitat use, and oviposition sites selected by gravid females and concluded that diverse habitats, including high pineland, pine-palmetto flatwoods, and permanent open ponds, were important for seasonal activity. In this study, habitat use also differed by age-class and season; adult snakes often used gopher tortoise burrows during April and May, while juveniles used root and rodent holes. The eastern indigo snake used gopher tortoise burrows as oviposition sites in high pineland areas, but stump holes were chosen in flatwoods and pond edge habitats (Smith 1987).

Monitoring of radio-marked eastern indigo snakes on the central ridge of South Florida indicates that they use a wide variety of natural, disturbed, and non-natural habitat types in this part of the state throughout the year. On the ridge itself, eastern indigos favor mature oak scrub, turkey oak sandhill, and abandoned citrus grove habitats, whereas snakes found off of the sandy ridges use flatwoods, seasonal ponds, improved pasture, and active and inactive agricultural lands. There was no apparent selection for one habitat type over another, as the use of habitats closely reflected the relative availability and distribution of the vegetation types in these areas (Layne and Steiner 1996).

In extreme South Florida (the Everglades and Florida Keys), eastern indigo snakes are found in tropical hardwood hammocks, pine rocklands, freshwater marshes, abandoned agricultural land, coastal prairie, mangrove swamps, and human-altered habitats (Steiner *et al*. 1983). It is suspected that they prefer hammocks and pine forests, since most observations occur there and use of these areas is disproportionate compared to the relatively small total area of these habitats (Steiner *et al*. 1983).

Behavior

Reproduction

Most information on the reproductive cycle of eastern indigo snakes is from data collected in north Florida. Here, breeding occurs between November and April, and females deposit four to 12 eggs during May or June (Moler 1992). Speake *et al.* (1987) reported an average clutch size of 9.4 for 20 captive bred females. Eggs are laid from late May through August, and young hatch in approximately 3 months. Peak hatching activity occurs between August and September, and yearling activity peaks in April and May (Groves 1960, Smith 1987). Limited information on the reproductive cycle in south-central Florida suggests that the breeding and egg laying season may be extended. In this region, breeding extends from June to January, laying occurs from April to July, and hatching occurs during mid-summer to early fall (Layne and Steiner 1996).

Female indigo snakes can store sperm and delay fertilization of eggs. There is a single record of a captive snake laying five eggs (at least one of which was fertile) after being isolated for more than four years (Carson 1945). It has long been assumed that this event resulted from sperm storage. However, there have been several recent reports of parthenogenetic reproduction by virginal snakes. Hence, sperm storage may not have been involved in Carson's (1945) example (P. Moler, GFC, personal communication 1998). There is no information on how long eastern indigo snakes live in the wild; in captivity, the longest an eastern indigo snake lived was 25 years, 11 months (Shaw 1959).

Feeding

The eastern indigo snake is an active terrestrial and fossorial predator that will eat any vertebrate small enough to be overpowered. Layne and Steiner (1996) documented several instances of indigos flushing prey from cover and then chasing it. While rare, these snakes may also climb shrubs or trees in search of prey. An adult eastern indigo snake's diet may include fish, frogs, toads, snakes (venomous as well as nonvenomous), lizards, turtles, turtle eggs, juvenile gopher tortoises, small alligators, birds, and small mammals (Keegan 1944, Babis 1949, Kochman 1978, Steiner *et al*. 1983). Juvenile eastern indigo snakes eat mostly invertebrates (Layne and Steiner 1996).

Movements

Indigo snakes range over large areas and into various habitats throughout the year, with most activity occurring in the summer and fall (Smith 1987, Moler 1985b, Speake 1993). In Georgia, the average range of the eastern indigo snake is 4.8 ha during the winter (December to April), 42.9 ha during late spring and early summer (May to July), and 97.4 ha during late summer and fall (August to November) (Speake *et al.* 1978). Warmer weather during the winter months in South Florida may afford the eastern indigo snake a larger range than 4.8 ha (D. Breininger, Dynamac Corporation, personal communication 1998). Adult males have larger home ranges than adult females and juveniles; their ranges may encompass as much as 224 ha and 158 ha in the summer (Moler 1985b, Speake 1993). By contrast, a gravid female may use from 1.4 to 42.9 ha (Smith 1987). These estimates are comparable with those found by Layne and Steiner (1996) in south-central Florida, who determined adult male home ranges average about 74 ha (max. 199.2 ha), whereas adult female home ranges average about 19 ha (max. 48.6 ha).

Relationship to Other Species

Eastern indigo snakes require a sheltered "refuge" from winter cold and dry conditions. Wherever the eastern indigo snake occurs in xeric habitats, it is closely associated with the gopher tortoise, the burrows of which provide shelter from winter cold and the desiccating sandhill environment (Bogert and Cowles 1947, Speake *et al.* 1978). This dependence seems especially pronounced in Georgia, Alabama, and the panhandle area of Florida, where eastern indigo snakes are largely restricted in the winter to sandhill habitats occupied by gopher tortoises (Diemer and Speake 1981, Moler 1985b, Mount 1975). In more mesic habitats that lack gopher tortoises, eastern indigo snakes may take shelter in hollowed root channels, rodent burrows, armadillo burrows, hollow logs, or crab burrows (Lawler 1977, Moler 1985b).

Status and Trends

As stated earlier, the eastern indigo snake was listed because of a population decline caused by habitat loss, over-collecting for the pet trade, and mortality from gassing gopher tortoise burrows to collect rattlesnakes (Speake and Mount 1973, Speake and McGlincy 1981) (43 FR 4028). At the time of listing, the main factor in the decline of this species was attributed to exploitation for the pet trade. As a result of effective law enforcement, the pressure from collectors has declined but still remains a concern (Moler 1992).

The eastern indigo snake will use most of the habitat types available in its home range, but prefers open, undeveloped areas (Kuntz 1977). Because of its relatively large home range, this snake is especially vulnerable to habitat loss, degradation, and fragmentation (Lawler 1977, Moler 1985b). Lawler (1977) noted that eastern indigo snake habitat has been destroyed by residential and commercial construction, agriculture, and timbering. He stated that the loss of natural habitat is increasing because of these threats; in Florida, indigo snake habitat is being lost at a rate of five percent per year (Lawler 1977). Low density residential housing is also a potential threat to this species, increasing the likelihood of snakes being killed by property owners and domestic pets. Extensive tracts of wild land are the most important refuge for large numbers of eastern indigo snakes (Diemer and Speake 1981, Moler 1985b).

Additional human population growth will increase the risk of direct mortality of the eastern indigo snake from property owners, domestic animals, and highway mortality. Pesticides that bioaccumulate through the food chain may present a potential hazard to the snake as well. Pesticides used on crops or for silviculture would pose a pulse effect to the indigo (Speake 1993). Secondary exposure to rodenticides used to control black rats may also occur (Speake 1993). Considering the low numbers of this species, any additional threats to its survival could cause local extirpations.

The wide distribution and large territory size of the eastern indigo snake complicate evaluation of its population status and trends. We believe that activities such as collecting and gassing of tortoise burrows have been largely abated through effective enforcement of protective laws. However, despite these apparent gains, the threats described above are acting individually and synergistically against the eastern indigo snake. Although we have no quantitative data with which to evaluate the trend of eastern indigo snakes in South Florida, we surmise the population as a whole is declining because of current rates of habitat destruction and degradation.

Natural communities continue to be altered for agricultural, residential, and commercial purposes, most of which are incompatible with the habitat needs of eastern indigo snakes (Kautz 1993). Habitat destruction and alteration are probably most substantial along the coasts, in the Keys, and along the high ridges of south-central Florida, where human population growth is expected to continue to accelerate. Agricultural interests (principally citrus) continue to destroy large expanses of suitable natural indigo snake habitat throughout much of South Florida.

Even with continued habitat destruction and alterations, this species will probably persist in most localities where large, unfragmented pieces of natural habitat remain. Unfortunately, current and anticipated future habitat fragmentation will probably result in a large number of isolated, small groups of indigo snakes. Fragmented habitat patches probably cannot support a sufficient number of individuals to ensure viable populations.

Management

To protect and recover the eastern indigo snake, large expanses of unaltered habitat must be protected. Unfortunately, the amount of land required and its distribution over the landscape is not known because population viability analysis or spatially explicit modeling have not been completed. We know nothing, therefore, of the minimum population size required to maintain and recover eastern indigo snakes or of the size and distribution necessary for effective preserves.

We have no information on population viability and habitat needs; therefore, several "educated guesses" have been made regarding the amount of land needed to protect eastern indigo snakes. Early estimates suggested several thousand hectares may be sufficient to ensure the local survival of a small number of individuals (Speake *et al.* 1978). More recently, Moler (GFC, personal communication 1996), Jackson (1984), and Speake (1993) suggest that preserves must be at least 4,000 ha. If we assume an average home range to be about 75 ha for males and 19 ha for female eastern indigo snakes, preserves of this size may be able to support about 53 males and 210 females. These estimates assume total overlap of home ranges between males and females and that all of the preserve area would be suitable habitat. Population modeling will be needed to determine if isolated populations of this size can be expected to persist.

Most of the large protected lands in South Florida have been purchased for the protection of sensitive natural and cultural resources. Presumably, management of these lands is directed towards maintaining and enhancing the diversity of plant and animal assemblages within these properties. If these management goals are achieved, eastern indigo snakes, as well as other species, will directly benefit because of improved habitat conditions. Unfortunately, many interests are now competing for the use of public lands.

Land managers must consider these uses and their effect upon the eastern indigo snake and other imperiled species.

We do not know whether the size and distribution of protected public lands will ensure the persistence of viable populations of this species. As mentioned above, population viability analysis or spatially explicit modeling are needed to determine the number and distribution of habitats and population density necessary to recover the eastern indigo snake. If more or larger preserves are required to maintain and recover this species, it will be important to disseminate this information to agencies and institutions that are able to influence land acquisition and protection efforts.

In instances where land use changes may adversely affect the eastern indigo, land managers or private landowners should develop protective measures to minimize impacts. The South Florida Field Office of the FWS has developed a set of protective measures to minimize potential adverse effects to the eastern indigo snake resulting from land development projects. These measures include the creation and distribution of educational materials regarding eastern indigo snake identification, biology and habitat requirements, the standardization of gopher tortoise burrow survey techniques, and the establishment of snake release protocols.

Literature Cited

Ashton, R.E., and P.S. Ashton. 1981. Handbook of reptiles and amphibians of Florida. Windward Publishing, Inc.; Miami, Florida.

Auffenberg, W., and R. Franz. l982. The status and distribution of *Gopherus polyphemus*. Pages 95-126 *in* R.B. Bury, ed. North American tortoises: conservation and ecology. U.S. Fish and Wildlife Service Research Report No. 12. Government Printing Office; Washington, D.C.

Babis, W.A. 1949. Notes on the food of the indigo snake. Copeia 1949 (2):147.

Breininger, D. 1998. Comments on the technical/agency draft multi-species recovery plan for South Florida.

Bogert, C.M., and R.B. Cowles. 1947. Results of the Archbold expeditions. No. 58. Moisture loss in relation to habitat selection in some Floridian reptiles. American Museum Novitates 1358:1-55.

Carr, A. E., Jr. 1940. A contribution to the herpetology of Florida. University of Florida Publications, Biological Science Series: Volume III, No. 1.

Carson, H.L. 1945. Delayed fertilization in a captive indigo snake with note of feeding and shedding. Copeia 1945(4):222-224.

Conant, R. 1975. A field guide to reptiles and amphibians of eastern and central North America. Second edition. Houghton Mifflin Company; Boston, Massachusetts.

Cook, F.A. 1954. Snakes of Mississippi. Mississippi Game and Fish Commission; Jackson, Mississippi.

Duellman, W.E., and A. Schwartz. 1958. Amphibians and reptiles of southern Florida. Bulletin Florida State Museum, Biological Science 3:181-324.

Diemer, J.E., and D.W. Speake. 1981. The status of the eastern indigo snake in Georgia. Pages 52-61 *in* R. Odum and J. Guthrie, eds. Proceedings of the nongame and endangered wildlife symposium, Georgia Department of Natural Resources, Game and Fish Division, Technical Bulletin WL 5.

Diemer, J.E., and D.W. Speake. 1983. The distribution of the eastern indigo snake, *Drymarchon corais couperi*, in Georgia. Journal of Herpetology 17(3):256-264.

Groves, F. 1960. The eggs and young of *Drymarchon corais couperi*. Copeia 1960 (1):51-53.

Haltom, W.L. 1931. Alabama reptiles. Alabama Geological Survey and Natural History Museum, Paper No. 11:1-145.

Hammer, R. 1998. Comments on the technical/agency draft multi-species recovery plan for South Florida.

Jackson, D.R. 1984. Letter from the Nature Conservancy to the U.S. Fish and Wildlife Service, Jackson, Mississippi. On file with the U.S. Fish and Wildlife Service; Vero Beach, Florida.

Kautz, R.S. 1993. Trends in Florida wildlife habitat 1936-1987. Florida Scientist 56:7-24.

Keegan, H.L. 1944. Indigo snakes feeding upon poisonous snakes. Copeia 1944 (1):59.

Kochman, H.I. 1978. Eastern indigo snake. *Drymarchon corais couperi*. Pages 68-69 *in* R.W. McDiarmid, ed. Rare and endangered biota of Florida. University Presses of Florida; Gainesville, Florida.

Kuntz, G.C. 1977. Endangered species: Florida Indigo. Florida Naturalist:15-19.

Landers, J.L., and D.W. Speake. 1980. Management needs of sandhill reptiles in southern Georgia. Proceedings of the annual conference of the southeastern association of fish and wildlife agencies 34:515-529.

Layne, J.N., and T.M. Steiner. 1996. Eastern indigo snake (*Drymarchon corais couperi*): summary of research conducted on Archbold Biological Station. Report prepared under Order 43910-6-0134 to the U.S. Fish and Wildlife Service; Jackson, Mississippi.

Lawler, H.E. 1977. The status of *Drymarchon corais couperi* (Holbrook), the eastern indigo snake, in the southeastern U.S.A. Herpetological Review 8(3):76-79.

Lazell, J.D., Jr. 1989. Wildlife of the Florida Keys: a natural history. Island Press; Washington D.C.

Löding, H.P. 1922. A preliminary catalog of Alabama reptiles and amphibians. Alabama Geological Survey and Natural History Museum, Paper No. 5:1-59.

Moler, P.E. 1985a. Distribution of the eastern indigo snake, *Drymarchon corais couperi*, in Florida. Herpetological Review 16(2):37-38.

Moler, P.E. 1985b. Home range and seasonal activity of the eastern indigo snake, *Drymarchon corais couperi*, in northern Florida. Final performance report, Study E-1-06, III-A-5. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Moler, P.E. 1992. Eastern indigo snake. Pages 181-186 *in* P.E. Moler, ed. Rare and endangered biota of Florida, volume III, Amphibians and Reptiles. University Press of Florida; Gainesville, Florida.

Moler, P. 1996. FWS Multi-Species Recovery Team meeting. February 28, 1996.

Moler, P. 1998. Comments on the technical/agency draft multi-species recovery plan for South Florida. January 9, 1998.

Mount, R.H. 1975. The reptiles and amphibians of Alabama. Auburn University Experimental Station; Auburn, Alabama.

Shaw, C.E. 1959. Longevity of snakes in the U.S. as of January 1, l959. Copeia 1959(4):336-337.

Smith, C.R. 1987. Ecology of juvenile and gravid eastern indigo snakes in north Florida. Unpublished M.S. thesis, Auburn University; Auburn, Alabama.

Speake, D.W. 1993. Indigo snake recovery plan revision. Final report to the U.S. Fish and Wildlife Service; Jacksonville, Florida.

Speake, D.W., and R.H. Mount. 1973. Some possible ecological effects of "rattlesnake roundups" in the southeastern coastal plain. Proceedings of the annual conference of the southeastern association of fish and wildlife agencies 27:267-277.

Speake, D.W., J.A. McGlincy, and T.R. Colvin. 1978. Ecology and management of the eastern indigo snake in Georgia: A progress report. Pages 64-73 *in* R.R. Odum and L. Landers, eds. Proceedings of rare and endangered wildlife symposium, Georgia Department of Natural Resources, Game and Fish Division, Technical Bulletin WL 4.

Speake, D.W., and J.A. McGlincy, 1981. Response of indigo snakes to gassing of their dens. Proceedings of the annual conference of the southeastern association of fish and wildlife agencies. 35:135-138.

Speake, D.W., D. McGlincy, and C. Smith. 1987. Captive breeding and experimental reintroduction of the eastern indigo snake. Pages 84-90 *in* R.R. Odom, K.A. Riddleberger, and J.C. Ozier eds. Proceedings. 3rd southeastern nongame and endangered wildlife symposium, Georgia Department of Natural Resources, Game and Fish Division.

Steiner, T.M., O.L. Bass, Jr., and J.A. Kushlan. 1983. Status of the eastern indigo snake in southern Florida National Parks and vicinity. South Florida Research Center Report SFRC-83/01, Everglades National Park; Homestead, Florida.

U.S. Fish and Wildlife Service [FWS]. 1982. Eastern indigo snake recovery plan. U.S. Fish and Wildlife Service, Atlanta, Georgia.

Recovery for the Eastern Indigo Snake

Drymarchon corais couperi

Recovery Objective: **ENSURE** numerous populations exist and are protected

South Florida Contribution: **STABILIZE** and increase population.

Recovery Criteria

There is a general lack of information on the status and trends of eastern indigo snakes in South Florida. Although the primary threat identified when the eastern indigo snake was listed has been ameliorated, we believe that an additional threat of habitat loss and fragmentation continues to affect the survival and recovery of this species. The objective to stabilize and increase numbers of eastern indigo snakes in South Florida will require protection of individuals as well as the habitat where they are known to occur. Additional research and monitoring of the snake's life history will also be necessary. More data on the demographics of this species are needed before we can determine an appropriate amount of habitat to ensure persistence of the species. One measure of demographic data that could determine an increasing population would be a rate of increase (r) greater than 0.0 as a 3-year running average over at least 10 years.

Once it is determined that sufficient, suitable habitat exists in South Florida for the eastern indigo snake population to stabilize or increase, delisting criteria can be considered. The development of delisting criteria will require the analysis of demographic data to demonstrate that there are adequate, contiguous tracts of upland habitat in South Florida to ensure at least a 95 percent probability of persistence for the eastern indigo snake for 100 years.

Species-level Recovery Actions

S1. Determine the distribution of the eastern indigo snake in South Florida.

The distribution of the eastern indigo snake in South Florida is poorly documented. However, because this species is wide-ranging throughout a variety of habitats, we feel it is infeasible to survey all terrestrial habitats it could occupy.

S1.1. Compile distribution data for eastern indigo snakes from all available sources. Existing data sources on the distribution of indigo snakes throughout South Florida should be compiled and entered into a Geographic Information System database.

S2. Protect and enhance existing populations of indigo snakes in South Florida.

S2.1. Support land acquisition programs through Federal, State, and private efforts. The 1982 recovery plan estimated that at least 4,000 ha is needed to sustain a viable population of eastern indigo snakes. The acquisition of diverse habitat will increase the potential for recovery of this and other listed species in South Florida.

S2.2. **Protect eastern indigo snakes on public lands.** The eastern indigo snake utilizes a variety of upland habitat types in Florida, particularly pine flatwoods, high pine, scrubby flatwoods, and scrub communities. Habitat management practices should be implemented to maintain biodiversity and minimize impacts from motor vehicles and commercial forestry practices. Ecotonal areas between upland/xeric habitats should be maintained using controlled burns at intervals appropriate for specific community types.

S2.3. **Protect eastern indigo snakes on private lands.** Landowners should be informed about indigo snakes and their habitat requirements. Include this information in general habitat management guidelines that address the needs of other listed species, and suggest management options to landowners. Encourage favorable management practices such as controlled burning whenever possible. The possibility of long-term renewable leases and conservation agreements involving Federal, Tribal, State, and local government agencies should be investigated where outright acquisition is not acceptable to the landowner.

S2.4. **Identify, evaluate, and eliminate other threats to the survival of the indigo snake.** Regulations are in place to control the pet trade and gassing of gopher tortoise burrows. In addition to the outright loss of habitat associated with conversion to residential or agricultural uses, potential threats such as predation from domestic animals and pesticide contamination may become more problematic and threaten the continued persistence of eastern indigo snakes in some areas. Because pesticide use on adjacent agricultural and residential lands poses a potential risk to eastern indigos, management plans should consider these risks and alleviate threats whenever possible. Trapping efforts may be needed on public lands where free-ranging domestic animals threaten this species.

S2.5. **Enforce available protective measures.**

S2.5.1. **Conduct section 7 consultations on Federal activities that may affect eastern indigo snakes**. Federal agencies should consult with the FWS on any activity (authorized, funded, or carried out) that may affect the eastern indigo snake. Such activities include, but are not limited to, pesticide use, road building, construction of new facilities, military training exercises, wetland fill, clearing for new runways, etc. Because this species is found in a variety of habitats, it should be considered in almost all consultations.

S2.5.2 **Implement the FWS South Florida Field Office's eastern indigo snake guidelines.** The guidelines should be used for section 7 and section 10 consultations, and be incorporated into permits where feasible.

S3. **Continue studies on the biology and ecology of the indigo snake.** Adequate long-term protection of the eastern indigo snake depends on a thorough understanding of its life history. Because this species occurs in low densities naturally, it is difficult to survey and study. As a result, many aspects of its life history are poorly understood.

S3.1 **Investigate techniques to effectively survey eastern indigo snakes.** The use of subterranean cameras or scopes to investigate gopher tortoise burrows, particularly during winter months, has proven useful in some circumstances. However, other methods, such as the use of pheromones to attract males, should be investigated.

This information is necessary to assess population levels and status of this species, and to accurately monitor existing populations and the response to management prescriptions.

S3.2. **Continue research to better evaluate home range size, age of dispersal, and dispersal distance of the eastern indigo snake**. More data are needed on these biological requirements to develop and evaluate management actions. Information on movements is critical for the development and management of conservation reserves for this species.

S3.3. **Conduct additional life history studies to build the general knowledge base for the eastern indigo snake.** Information on reproductive success, fecundity, longevity, and other basic population demographics is needed to assess the status and trends of the population.

S3.4. **Conduct population modeling** (*i.e.* risk assessment) once basic demographic data are known.

S3.5. **Determine the status and distribution of eastern indigo snakes in disturbed habitat.** Identify whether eastern indigo snakes are able to persist in habitats modified by residential, commercial, and agricultural uses.

S4. **Monitor populations.** Once standardized survey techniques are developed, begin long-term monitoring on conservation lands where eastern indigo snakes are known to occur. This information is needed to determine status and trends for the population.

S5. **Improve public attitude and behavior towards the eastern indigo snake.** Public opinion concerning snakes in general and eastern indigo snakes in particular should be improved so that the common tendency to kill snakes on sight will be decreased. The general public can be reached through videos, television programs, lectures, and articles in newspapers and magazines. For South Florida, educational materials should be made available in Spanish and Creole. Emphasis should be placed on the harmless and beneficial nature of the species and the threats to its survival and recovery.

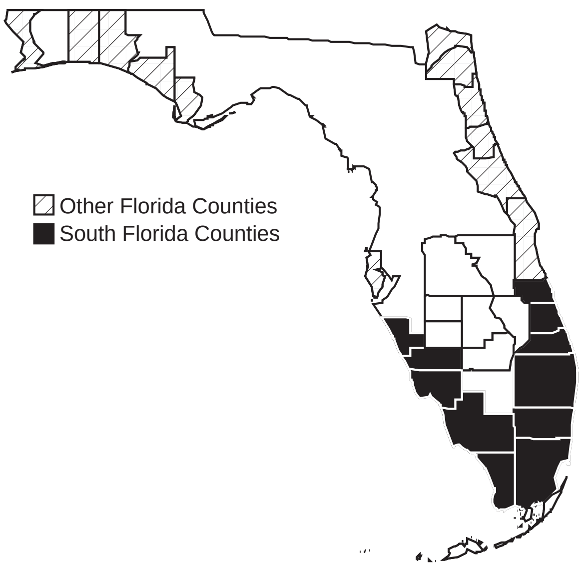
S5.1 **Discourage the use of rat poison in or near eastern indigo snake habitat.** The use of poison to control rats in areas inhabited by this species should be discouraged as indirect poisoning of may occur.

Green Sea Turtle

Chelonia mydas

Federal Status:	**Endangered (Florida, Pacific coast of Mexico; July 28, 1978) Threatened (except as above; July 28, 1978)**
Critical Habitat:	**Designated (September 1998): Waters of Culebra Island, Puerto Rico, and its outlying keys.**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution: May 1999**
Geographic Coverage:	**South Florida**

Figure 1. Florida nesting distribution of the green sea turtle.



The green sea turtle nests regularly in South Florida, predominantly on the east coast between Volusia and Broward counties. The green sea turtle accounts for about 1.9 percent of total nesting reported statewide. The green turtle nesting and hatching season in South Florida extends from May through November. Sea turtles, in general, are susceptible to anthropogenic impacts in the marine environment, as well as on their nesting beaches. This account provides an overview of the biology of the green sea turtle throughout its range. The discussion of environmental threats and management activities, however, pertains only to South Florida. Serious threats to the green sea turtle on South Florida's nesting beaches include: artificial lighting, beach nourishment, beach armoring, increased human presence, and exotic beach and dune vegetation.

This account is modified from the 1991 Recovery Plan for the U.S. Population of Atlantic Green Turtle and represents South Florida's contribution to the range-wide recovery plan for this species (NMFS and FWS 1991).

Description

The green turtle is among the largest of the sea turtles; adults commonly reach 1 m in carapace length and 150 kg in mass. The mean size of female green turtles nesting in Florida is 1.5 m standard straight carapace length and 136.1 kg body mass (Witherington and Ehrhart 1989). Hatchling green turtles weigh approximately 25 g, and the carapace is about 50 mm long. The dorsal surface is black, and the ventral surface is white. The plastron of Atlantic green turtles remains a yellowish white throughout life, but the carapace changes in color from solid black to a variety of shades of grey, green, brown and black in starburst or irregular patterns.

Characters that distinguish the green turtle from other sea turtle species are a smooth carapace with four pairs of lateral (or costal) scutes and a single pair of elongated prefrontal scales between the eyes. The nuchal scute does not touch the first costal scute and the inframarginal scutes do not have pores. Each flipper has a single claw and the carapace is oval-shaped and depressed. The crawls of nesting green turtles are deeply cut, with symmetrical diagonal marks made by the front flippers (Pritchard *et al.* 1983).

Taxonomy

The green sea turtle was described by Linnaeus in 1758 as *Testudo mydas* with Ascension Island as the type locality. Schweigger first applied the binomial we use today, *Chelonia mydas,* in 1812. The taxonomic status of the green turtle is not clear. There is believed to be little genetic exchange among isolated breeding colonies, and, thus, these colonies may deserve sub-specific recognition. Although trinomials have been applied to various populations in the past, they are generally not in use today. Advances in DNA research are helping to solve these taxonomic questions by identifying genetically isolated populations. For a complete discussion of the systematics of green turtles, see Pritchard and Trebbau (1984) and Hirth (1980a).

Distribution

The green sea turtle is a circum-global species in tropical and sub-tropical waters. The worldwide distribution of green turtles has been described by Groombridge (1982). In the U.S., green turtles are found around the U.S. Virgin Islands and Puerto Rico, and in the continental U.S. from Texas to Massachusetts. Areas that are known as important feeding areas for green turtles in Florida include: Indian River Lagoon, the Florida Keys, Florida Bay, Homosassa River, Crystal River and Cedar Key.

Major green turtle nesting colonies in the Atlantic occur on Ascension Island, Aves Island, Costa Rica and Surinam. In U.S. Atlantic waters, green turtles nest in small numbers in the U.S. Virgin Islands and in Puerto Rico. Although they nest in all coastal counties in South Florida (Figure 1), the largest nesting occurs along the east coast of Florida, particularly in Brevard, Indian River, St. Lucie, Martin, Palm Beach and Broward counties. Nesting along the southwest coast of Florida was documented for the first time in 1994 (Foley 1997).

Habitat

Green turtles occupy three habitat types: high-energy oceanic beaches, convergence zones in the pelagic habitat, and benthic feeding grounds in relatively shallow, protected waters. Females deposit egg clutches on high-energy beaches, usually on islands, where a deep nest cavity can be dug above the high water line. Hatchlings leave the beach and apparently move into convergence zones in the open ocean where they spend an undetermined length of time (Carr 1986). When turtles reach a carapace length of approximately 20 to 25 cm, they leave the pelagic habitat and enter benthic feeding grounds. These foraging habitats are commonly pastures of seagrasses and/or algae, but

Green sea turtle.
Original photograph courtesy of U.S. Fish and Wildlife Service.

small green turtles can also be found over coral reefs, worm reefs, and rocky bottoms. Some feeding grounds only support certain size classes of green turtles; the turtles apparently move among these foraging areas--called developmental feeding grounds--as they grow. Other feeding areas, such as Miskito Cays, Nicaragua, support a complete size range of green turtles from 20 cm to breeding adults. Coral reefs or rocky outcrops near feeding pastures are often used as resting areas, both at night and during the day.

Critical Habitat

Critical habitat was designated for the green sea turtle in September 1998. Although this designation does not include Florida, is does include the waters of Culebra Island, Puerto Rico, and its outlying keys. Critical habitat for green sea turtles identifies specific areas which have those physical or biological features essential to the conservation of the green sea turtle and/or may require special management considerations.

Behavior

The discussion of behavior in this account is brief. Several excellent reviews of the biological characteristics of green turtles that have been published in recent years include Hirth 1980a, Groombridge 1982, Ogren 1984, Pritchard and Trebbau 1984, and Ehrhart and Witherington 1992.

Reproduction and Demography

Female green turtles emerge on nesting beaches at night to deposit eggs; the process takes an average of two hours. Descriptions of the behavioral sequences have been reviewed by Ehrhart (1982). From one to seven clutches are deposited within a breeding season at 12 to 14 day intervals. The average number is usually given as two to three clutches (Carr *et al.* 1978), but accurate data on the number of clutches deposited per season are difficult to obtain. Mean clutch size is usually 110 to 115 eggs, but this average varies among populations. Average clutch size reported for Florida was 136 eggs in 130 clutches (Witherington and Ehrhart 1989). Only occasionally do females produce clutches in successive years. Usually 2 to 4, or more years intervene between breeding seasons. Mating occurs in the water off the nesting beaches. Very little is known about the reproductive biology of males, but it is thought that males may migrate to the nesting beach every year (Balazs 1983). Hatching success of undisturbed nests is usually high, but on some beaches, predators destroy a high percentage of nests (Stancyk 1982). Large numbers of nests are also destroyed by inundation and erosion. Temperature-dependent sex determination has been demonstrated for green turtles (see review in Standora and Spotila 1985). Eggs incubated below a pivotal temperature—which may vary among populations—produce primarily males, and eggs incubated above the pivotal temperature produce primarily females. Reviews of the reproductive biology of green turtles can be found in Hirth (1980b), Ehrhart (1982) and Bjorndal and Carr (1989).

Growth rates of pelagic-stage green turtles have not been measured under natural conditions. However, growth rates of green turtles have been measured on the benthic feeding grounds. Green turtles grow slowly. In the southern Bahamas, green turtles grew from 30 to 75 cm in 17 years, and growth rate decreased with increasing carapace length (Bjorndal and Bolten 1988). Growth rates measured in green turtles from Florida (Frazer and Ehrhart 1985), U.S. Virgin Islands (Boulon and Frazer 1990) and Puerto Rico (Collazo *et al.* 1992) fall within the range of growth rates measured in the southern Bahamas (Bjorndal and Bolten 1988). Based on growth rate studies of wild green turtles, estimates of age at sexual maturity range from 20 to 50 years (Balazs 1982, Frazer and Ehrhart 1985).

Migration

The navigation feats of the green turtle are well known, but poorly understood. We know that hatchlings and adult females on the nesting beach orient toward the ocean using photic cues (Ehrenfeld 1968, Mrosovsky and Kingsmill 1985). We do not know what cues are employed in pelagic movements, in movements among foraging grounds, or in migrations between foraging grounds and nesting beaches. Because green turtles nest on high energy beaches and feed in quiet, low-energy marine pastures, these areas tend to be located some distance apart. Green turtles that nest on Ascension Island forage along the coast of Brazil, some 1,000 km away (Carr 1975). Genetic analysis using restriction fragment analysis and direct sequencing of mitochondrial DNA have shown that green turtles return to nest on their natal beaches (Allard *et al.* 1994, Bowen *et al.* 1989, Bowen *et al.* 1992, Meylan *et al*. 1990).

Foraging

It is assumed that post-hatchling, pelagic-stage green turtles are omnivorous, but there are no data on diet of this age class. It is known that once green turtles shift to benthic feeding grounds they are herbivores. They feed on both seagrasses and algae. Information on diet and nutrition of green turtles has been reviewed (Mortimer 1982a, Bjorndal 1985). The location of the foraging grounds of green turtles that nest in Florida is not known.

A population of juvenile green turtles (2-60 kg) forage as herbivores in the central Indian River Lagoon near Sebastian (Ehrhart *et al*. 1986), from Mosquito Lagoon in Brevard County south to Palm Beach County, and along coastal areas of Sabelleriid worm reefs and anastasia rock (A. Meylan, DEP, personal communication 1998). Post-nesting females have recently been tracked by satellite telemetry from the beaches of the Archie Carr NWR to the shallow, benthic habitats of the Florida Keys (P. Tritaik, FWS, personal communication 1998).

Relationship to Other Species

In South Florida, the green sea turtle shares nesting beaches with the threatened loggerhead sea turtle (*Caretta caretta*) in every county where it nests, and with the endangered leatherback sea turtle (*Dermochelys coriacea*), most commonly in Martin and Palm Beach counties. Other federally listed species that occur in coastal dune and coastal strand habitat, and that need to be considered when managing nesting beaches, are the southeastern beach mouse (*Peromyscus polionotus niveiventris*) and the beach jacquemontia (*Jacquemontia reclinata*). Beach nourishment projects, in particular, could affect these species as well as the turtles. The range of the beach mouse in South Florida is estimated to include Indian River County south to Broward County. The beach jacquemontia is found in Palm Beach County south to Miami, Miami-Dade County.

A variety of natural and introduced predators, such as raccoons *(Procyon lotor)*, feral hogs, foxes, ants, and ghost crabs prey on incubating eggs and hatchling sea turtles. The principal predator of sea turtle eggs, the raccoon, may take up to 96 percent of all eggs in nests deposited on a beach (Davis and Whiting 1977, Hopkins and Murphy 1980, Stancyk *et al.* 1980, Talbert *et al.* 1980, Schroeder 1981, Labisky *et al.* 1986). In 1996, Hobe Sound NWR experienced depredation in 23 percent of the nests enumerated (FWS 1996). In addition to the destruction of eggs, certain predators may take considerable numbers of hatchlings just prior to or upon emergence from the sand.

Predation of hatchling and very young turtles is assumed to be significant and predation of subadult through adult stage turtles is assumed less common, but valid estimates of mortality due to predation at various life history stages are extremely difficult, if not impossible, to obtain and have not been determined. Hatchlings entering the surf zone and pelagic stage hatchlings may be preyed upon by a wide variety of fish species and, to a lesser extent, marine birds. Stancyk (1982) in an extensive literature review reported predators of juvenile and adult turtles to include at least six species of sharks, killer whales, bass, and grouper. Tiger sharks appear to be the principal predator of subadult and adult turtles. While stranded turtles may exhibit shark-inflicted injuries, caution must be exercised in attributing a cause of death, as these wounds can be inflicted postmortem.

Table 1. Average number of green sea turtle nests by county from 1985 to 1995.

County	Average
Indian River	55
St. Lucie	48
Martin	163
Palm Beach	301
Broward	58
Miami-Dade	4.5
Monroe	6.5
Collier*	9
Lee**	3.5
Charlotte*	9
Sarasota*	5

*Nesting activity reported from 1994 only
**Nesting activity reported from 1994-1995 only

Status and Trends

The green turtle is listed as endangered by the International Union for Conservation of Nature and Natural Resources (IUCN) and is listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). On July 28, 1978 (43 FR 32800), under the U.S. Endangered Species Act of 1973, the green sea turtle was listed as threatened except for the breeding populations in Florida and on the Pacific coast of Mexico, where they were listed as endangered. Green turtles continue to be heavily exploited by man, and degradation of nesting and feeding habitats is a serious problem. Overexploitation by man has already caused the extinction of large green turtle populations, including those that once nested on Bermuda and the Cayman Islands. The status of green turtle populations is difficult to determine because of the long generation time and inaccessibility of early life stages. The number of nests deposited in Florida appears to be increasing, but whether this upward trend is due to an increase in the number of nests or is a result of more thorough monitoring of the nesting beaches is uncertain.

The following discussion of sea turtle nesting within the South Florida Ecosystem, as well as comparisons to statewide nesting trends, was derived from data provided by Meylan *et al.* (1995) and DEP (1996).

Statewide, green sea turtle nests amounted to 1.9 percent of total sea turtle nesting during 1979 to 1992. From 1988 to 1992, while survey efforts remained relatively constant, the total number of reported green sea turtle nests statewide fluctuated between 455 and 2,509. In addition, it appears that green sea turtle nesting exhibits a 2-year cycle in activity. Although Meylan *et al.* (1995) report that an increase in green sea turtle nesting has been observed statewide, the reason for this increase is unknown and is regarded with cautious optimism.

Although the majority of green turtle nesting occurred in Brevard County (39.5 percent), just outside of the South Florida Ecosystem, Palm Beach County supported the second highest percentage of green turtle nests during that period with 23.1 percent of nests. The average number of nests that annually occur within the South Florida Ecosystem are shown in Table 1. Although the green sea turtle nests in all coastal counties in South Florida, these data show that Palm Beach County is clearly the most important nesting location. We chose to only represent the past 10 years of survey data in Table 1, because there was less beach surveyed and the data were not complete prior to 1985. In addition, nesting along the southwest coast of Florida was documented for the first time in 1994 (Foley 1997).

Environmental Threats

A number of threats exist to sea turtles in the marine environment, including: oil and gas exploration, development, and transportation; pollution; trawl, purse seine, hook and line, gill net, pound net, longline, and trap fisheries; underwater explosions; dredging; offshore artificial lighting; power plant entrapment; entanglement in debris; ingestion of marine debris; marina and dock development; boat collisions; and poaching. These threats and protective measures are discussed in detail in the Recovery Plan for U.S. Population of the Atlantic Green Turtle (NMFS and FWS 1991). In South Florida, and for this recovery plan, we are focusing on the threats to nesting beaches, including: beach erosion, armoring, and nourishment; artificial lighting; beach cleaning; increased human presence; recreational beach equipment; exotic dune and beach vegetation; nest loss to abiotic factors; and poaching.

Beach Erosion: Erosion of nesting beaches can result in partial or total loss of suitable nesting habitat. Erosion rates are influenced by dynamic coastal processes, including sea level rise. Man's interference with these natural processes through coastal development and associated activities has resulted in accelerated erosion rates and interruption of natural shoreline migration (National Research Council 1990).

Beach Armoring: Where beachfront development occurs, the site is often fortified to protect the property from erosion. Virtually all shoreline engineering is carried out to save structures, not dry sandy beaches, and ultimately results in environmental damage. One type of shoreline engineering, collectively referred to as beach armoring, includes sea walls, rock revetments, riprap, sandbag installations, groins, and jetties. Beach armoring can result in permanent loss of a dry nesting beach through accelerated erosion and prevention of natural beach/dune accretion and can prevent or hamper nesting females from accessing suitable nesting sites. Clutches deposited seaward of these structures may be inundated at high tide or washed out entirely by increased wave action near the base of these structures.

As these structures fail and break apart, they spread debris on the beach trapping both adults and hatchlings, impede access to suitable nesting areas and cause higher incidences of false crawls (non-nesting emergences). Sandbags are particularly susceptible to rapid failure and result in extensive debris on nesting beaches. Rock revetments, riprap, and sandbags can cause nesting turtles to abandon nesting attempts or to construct improperly sized and shaped egg cavities when inadequate amounts of sand cover these structures. Information obtained during preparation of the sea turtle recovery plans indicated that approximately 21 percent (234 km) of Florida's beaches were armored at that time (NMFS and FWS 1991).

Groins and jetties are designed to trap sand during transport in longshore currents or to keep sand from flowing into channels in the case of the latter. These structures prevent normal sand transport and accrete beaches on one side of the structure while starving neighboring beaches on the other side, thereby resulting in severe beach erosion (Pilkey *et al.* 1984) and corresponding degradation of suitable nesting habitat.

Drift fences, also commonly called sand fences, are erected to build and stabilize dunes by trapping sand moving along the beach and preventing excessive sand loss. Additionally, these fences can serve to protect dune systems by deterring public access. Constructed of narrowly spaced wooden or plastic slats or plastic fabric, drift fences when improperly placed can impede nesting attempts and/or trap emergent hatchlings and nesting females.

Beach Nourishment: Beach nourishment consists of pumping, trucking, or scraping sand onto the beach to rebuild what has been lost to erosion. Although beach nourishment may increase the potential nesting area, significant adverse effects to sea turtles may result if protective measures are not taken. Placement of sand on an eroded section of beach or an existing beach in and of itself may not provide suitable nesting habitat for sea turtles. Beach nourishment can impact turtles through direct burial of nests and by disturbance to nesting turtles if conducted during the nesting season. Beach nourishment may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content if the placed sand is dissimilar from the original beach sand (Nelson and Dickerson 1988a). These changes can affect nest site selection, digging behavior, incubation temperature (and hence sex ratios), gas exchange parameters within incubating nests, hydric environment of the nest, hatching success, and hatchling emerging success (Mann 1977, Ackerman 1980, Mortimer 1982b, Raymond 1984a).

Beach compaction and unnatural beach profiles that may result from beach nourishment activities could adversely affect sea turtles regardless of the timing of the projects. Very fine sand and/or the use of heavy machinery can cause sand compaction on nourished beaches (Nelson *et al*. 1987, Nelson and Dickerson 1988a). Significant reductions in nesting success have been documented on severely compacted nourished beaches (Raymond 1984a). Increased false crawls result in increased physiological stress to nesting females. Sand compaction may increase the length of time required for female sea turtles to excavate nests, also causing increased physiological stress to the animals (Nelson and Dickerson 1988c). Nelson and Dickerson (1988b) evaluated compaction levels at 10 renourished east coast Florida beaches and concluded that 50 percent were hard enough to inhibit nest digging, 30 percent were questionable as to whether their hardness affected nest digging, and 20 percent were probably not hard enough to affect nest digging. They further concluded that, in general, beaches nourished from offshore borrow sites are harder than natural beaches, and, while some may soften over time through erosion and accretion of sand, others may remain hard for 10 years or more.

On nourished beaches, steep escarpments may develop along their water line interface as they adjust from an unnatural construction profile to a more natural beach profile (Coastal Engineering Research Center 1984, Nelson *et al*. 1987). These escarpments can hamper or prevent access to nesting sites. Female turtles coming ashore to nest can be discouraged by the formation of an escarpment, leading to situations where they choose marginal or unsuitable nesting areas to deposit eggs (*e.g.*, in front of the escarpments, which often results in failure of nests due to repeated tidal inundation). Escarpments may also form during turtle nesting season postnourishment, which creates a seemingly safe place for nesting turtles, only to be washed out (DEP personal communication 1998). This effect can be minimized by leveling the beach prior to the nesting season.

A change in sediment color due to beach nourishment could change the natural incubation temperatures of nests. This, in turn, could alter natural sex ratios. To provide the most suitable sediment for nesting sea turtles, the color of the nourished sediments must resemble the natural beach sand in the area.

Natural reworking of sediments and bleaching from exposure to the sun would help to lighten dark nourishment sediments; however, the time frame for sediment mixing and bleaching to occur could be critical to a successful sea turtle nesting season.

Nourishment projects result in heavy machinery, pipelines, increased human activity, and artificial lighting on the project beach. These activities are normally conducted on a 24-hour basis and can adversely affect nesting and hatching activities. Pipelines and heavy machinery can create barriers to nesting females emerging from the surf and crawling up the beach, causing a higher incidence of false crawls and an unnecessary energy expenditure. Increased human activity on the project beach at night may cause further disturbance to nesting females. Artificial lights along the project beach and in the nearshore area of the borrow site may deter nesting females and disorient or misorient emergent hatchlings from adjacent non-project beaches.

Beach nourishment projects require continual maintenance (subsequent nourishment) as beaches erode, therefore their negative impacts to turtles are repeated on a regular basis. Nourishment of highly eroded beaches (especially those with a complete absence of dry beach) can be beneficial to nesting turtles if conducted properly. Careful consideration and advance planning and coordination must be carried out to ensure timing, methodology, and sand sources are compatible with nesting and hatching requirements.

Artificial Lighting: Extensive research has demonstrated that the principal component of the sea-finding behavior of emergent hatchlings is a visual response to light (Daniel and Smith 1947, Hendrickson 1958, Carr and Ogren 1960, Ehrenfeld and Carr 1967, Dickerson and Nelson 1989, Witherington and Bjorndal 1991). Artificial beachfront lighting from buildings, streetlights, dune crossovers, vehicles, and other types of beachfront lights have been documented in the disorientation (loss of bearings) and misorientation (incorrect orientation) of hatchling turtles (McFarlane 1963, Philibosian 1976, Mann 1977, Ehrhart 1983).

The results of disorientation or misorientation are often fatal. Many lighting ordinance requirements do not become effective until 11 p.m., whereas over 30 percent of hatchling emergence occurs prior to this time (Witherington *et al.* 1990). As hatchlings head toward lights or meander along the beach, their exposure to predators and likelihood of desiccation is greatly increased. Misoriented hatchlings can become entrapped in vegetation or debris, and many hatchlings are found dead on nearby roadways and in parking lots after being struck by vehicles. Hatchlings that successfully find the water may be misoriented after entering the surf zone or while in nearshore waters. Intense artificial lighting can even draw hatchlings back out of the surf (Daniel and Smith 1947, Carr and Ogren 1960). During the period 1989 to 1990, a total of 37,159 misoriented hatchlings were reported to the Florida Department of Natural Resources (now DEP). Undoubtedly a large but unquantifiable number of additional misorientation events occurred but were not documented due to obliteration of observable sign, depredation, entrapment in thick vegetation, loss in storm drains, or obliteration of carcasses by vehicle tires.

The problem of artificial beachfront lighting is not restricted to hatchlings. In June 1992, a nesting loggerhead was killed by an automobile as it wandered onto Highway AlA at Patrick Air Force Base in Cocoa Beach, Florida, misoriented by lights from the west side of the highway. Raymond (1984a) indicated that adult loggerhead emergence patterns were correlated with variations in beachfront lighting in south Brevard County, Florida, and that nesting females avoided areas where beachfront lights were the most intense. Witherington (1992) found that both green and loggerhead sea turtles showed a significant tendency to avoid stretches of beach lighted with white mercury-vapor luminaires. Witherington (1986) noted that loggerheads aborted nesting attempts at a greater frequency in lighted areas. Problem lights may not be restricted to those placed directly on or in close proximity to nesting beaches. The background glow associated with intensive inland lighting, such as that emanating from nearby large metropolitan areas, may deter nesting females and disorient or misorient hatchlings navigating the nearshore waters. Cumulatively, along the heavily developed beaches of the southeastern U.S., the negative effects of artificial lights are profound.

Beach Cleaning: Beach cleaning refers to the removal of both abiotic and biotic debris from developed beaches. There are several methods employed including mechanical raking, hand raking, and picking up debris by hand. Mechanical raking can result in heavy machinery repeatedly traversing nests and potentially compacting sand above nests. Resulting tire ruts along the beach may hinder or trap emergent hatchlings. Mann (1977) suggested that mortality within nests may increase when externally applied pressure from beach cleaning machinery is common on soft beaches with large grain sand. Mechanically pulled rakes and hand rakes can penetrate the surface and disturb the sealed nest or may actually uncover pre-emergent hatchlings near the surface of the nest. In some areas, collected debris is buried directly on the beach, and this can lead to excavation and destruction of incubating egg clutches. Disposal of debris near the dune line or on the high beach can cover incubating egg clutches and subsequently hinder and entrap emergent hatchlings and may alter natural nest temperatures.

Increased Human Presence: Residential and tourist use of developed (and developing) nesting beaches can result in negative impacts to nesting turtles, incubating egg clutches and hatchlings. The most serious threat caused by increased human presence on the beach is the disturbance to nesting females. Nighttime human activity can cause nesting females to abort nesting attempts at all stages of the behavioral process. Murphy (1985) reported that disturbance can cause turtles to shift their nesting beaches, delay egg laying, and select poor nesting sites. Heavy utilization of nesting beaches by humans (pedestrian traffic) may result in lowered hatchling emerging success rates due to compaction of sand above nests (Mann 1977), and pedestrian tracks can interfere with the ability of hatchlings to reach the ocean (Hosier *et al.* 1981). Campfires and the use of flashlights on nesting beaches misorient hatchlings and can deter nesting females (Mortimer 1979).

Recreational Beach Equipment: The placement of physical obstacles (*e.g.*, lounge chairs, cabanas, umbrellas, Hobie cats, canoes, small boats and beach cycles) on nesting beaches can hamper or deter nesting attempts and interfere with incubating egg clutches and the sea approach of hatchlings. The documentation of false crawls at these obstacles is becoming increasingly common as more recreational beach equipment is left in place nightly on nesting beaches. Additionally, there are documented reports of nesting females becoming entrapped under heavy wooden lounge chairs and cabanas on South Florida nesting beaches (NMFS and FWS 1991). The placement of recreational beach equipment directly above incubating egg clutches may hamper hatchlings during emergence and can destroy eggs through direct invasion of the nest (NMFS and FWS 1991).

Exotic Dune and Beach Vegetation: Non-native vegetation has invaded many coastal areas and often outcompetes native species such as sea oats, railroad vine, sea grape, dune panic grass, and pennywort. The invasion of less stabilizing vegetation can lead to increased erosion and degradation of suitable nesting habitat. Exotic vegetation may also form impenetrable root mats which can prevent proper nest cavity excavation, invade and desiccate eggs, or trap hatchlings. The Australian pine *(Casuarina* spp.*)* is particularly detrimental. Dense stands of this species have taken over many coastal strand areas throughout central and South Florida. Australian pines cause excessive shading of the beach that would not otherwise occur. Studies in Florida suggest that nests laid in shaded areas are subjected to lower incubation temperatures, which may alter the natural hatchling sex ratio (Marcus and Maley 1987, Schmelz and Mezich 1988). Fallen Australian pines limit access to suitable nest sites and can entrap nesting females. Davis and Whiting (1977) reported that nesting activity declined in Everglades National Park where dense stands of Australian pine took over native beach berm vegetation on a remote nesting beach. Conversely, along highly developed beaches, nesting may be concentrated in areas where dense stands of Australian pines create a barrier to intense beachfront and beach vicinity lighting (NMFS and FWS 1991).

Nest Loss to Abiotic Factors: Erosion or inundation and accretion of sand above incubating nests appear to be the principal abiotic factors that may negatively affect incubating egg clutches. While these factors are often widely perceived as contributing significantly to nest mortality or lowered hatching success, few quantitative studies have been conducted (Mortimer 1989). Studies on a relatively undisturbed nesting beach by Witherington (1986) indicated that excluding a late season severe storm event, erosion and inundation played a relatively minor role in destruction of incubating nests. Inundation of nests and accretion of sand above incubating nests as a result of the late season storm played a major role in destroying nests from which hatchlings had not yet emerged. Severe storm events (*e.g.*, tropical storms and hurricanes) may result in significant nest loss, but these events are typically aperiodic rather than annual occurrences. In the southeastern U.S., severe storm events are generally experienced after the peak of the hatching season and hence would not be expected to affect the majority of incubating nests. Erosion and inundation of nests are exacerbated through coastal development and shoreline engineering. These threats are discussed above under beach armoring.

Predation: Predators, particularly exotics such as fire ants (*Solenopsis invicta*); and human-associated ones including raccoons *(Procyon lotor)* and opossums (*Didelphis virginiana*) are becoming increasingly detrimental to nesting beaches.

Poaching: In the U.S., killing of female turtles is infrequent. However, in a number of areas, egg poaching and clandestine markets for eggs are not

Table 2. Major green turtle nest survey/protection projects in South Florida (1985-1990).

Project	Beach length (km)	Number of nests/year	Conservation Measures
Sebastian Inlet SRA	4.8	7-56	S/PR
Hutchinson Island	36.5	45-132	S
St. Lucie Inlet SP	3.8	7-17	S/SP
Hobe Sound NWR	5.7	3-30	S/SP
Town of Jupiter Island	12.1	45-228	S
J.D. MacArthur SP	2.9	9-65	S/SP
City of Boca Raton	5.6	2-43	S/NS/NR
Broward County Beaches	39.0	4-106	S/NR
Miami-Dade Co. Beaches	22.5	3-11	S/NR
Wabasso Beach	8.0	14-55	S/PR

NS=Nest Screening NR=Nest Relocation
PR=Predator Removal S=Survey

uncommon. From 1983 to 1989, the Florida Marine Patrol, DEP, made 29 arrests for illegal possession of turtle eggs.

Disease

There is little information available to assess the comprehensive effects of disease and/or parasites on wild populations of green sea turtles. The vast majority of diseases and conditions which have been identified or diagnosed in sea turtles are described from captive stock, either turtles in experimental headstart programs or mariculture facilities (Wolke 1989). One notable exception is the occurrence of fibropapillomatosis in the green sea turtle, first described by Smith and Coates (1938). Fibropapillomatosis is a disease characterized by one or more non-cancerous fibrous tumors, commonly located on areas of soft skin. The tumors can be debilitating and, in severe cases, fatal. They can result in reduced vision, disorientation, blindness, physical obstruction to normal swimming and feeding, an apparent increased susceptibility to parasitism by marine leeches, and an increased susceptibility to entanglement in monofilament fishing line (Balazs 1986). Blood counts and serum profiles of green turtles inflicted with fibropapillomas indicate marked debilitation (Jacobson 1987). Fibropapillomas are now common on immature green sea turtles in the central Indian River system, Florida Bay, and in the Florida Keys (Ehrhart *et al.* 1986, Witherington and Ehrhart 1987, Schroeder 1987a). In the central Indian River lagoon, approximately half of all green sea turtles captured have been found to bear papillomas of varying severity (Ehrhart *et al.* 1986). Fibropapillomas are also commonly found on Hawaiian green turtles. Since 1989, incidence of this disease at Kancohe Bay, Oahu, has ranged from 49 to 92 percent (Barrett 1996). Though green sea turtles collected in Puerto Rico and the U.S. Virgin Islands have shown a very low occurrence of fibropapillomas (NMFS and FWS 1991), recent reports from those areas indicate the incidence of disease is greater.

Management

There are a number of management activities ongoing in South Florida to benefit the green sea turtle. Table 2 lists some of the major Federal, State, and private nest survey and protection projects in the South Florida Ecosystem. In addition to management of coastal habitats, NMFS and FWS (1991) discuss additional conservation measures for the green sea turtle in the marine environment. Additional reviews of sea turtle conservation efforts in the southeastern U.S. appear in Possardt (1991).

Conservation of sea turtle nesting habitat is continuing on several NWRs in South Florida, including Archie Carr, Hobe Sound, Ten Thousand Islands, and the complex of satellite refuges in the Florida Keys. Acquisition of high-density nesting beaches between Melbourne Beach and Wabasso Beach, Florida, is continuing to complete the Archie Carr NWR. Approximately 35 percent of the green sea turtle nesting in the U.S. occurs along this 33 km stretch of beach. The State of Florida purchased the first parcel specifically for the refuge in July 1990. Federal acquisition began in 1991. When completed, the refuge will protect up to 16 km of nesting beach. Since the initial acquisition, Brevard County and the Richard King Mellon Foundation have joined in as acquisition partners. Hobe Sound NWR, located north of West Palm Beach in Martin County, contains 5.25 km of Atlantic coast shoreline for nesting habitat. In addition to providing some of the most productive sea turtle nesting habitat in the U.S., the refuge is also home to Florida scrub-jays (*Aphelocoma coerulescens*) and gopher tortoises *(Gopherus polyphemus*). The most longstanding beach management program has been to reduce destruction of nests by natural predators, such as raccoons. Control of numerous exotic plants such as Australian pine and Brazilian pepper (*Schinus terebinthifolius*) are also major issues in managing the refuge.

One of the most difficult habitat protection efforts throughout South Florida is trying to minimize or eliminate the construction of seawalls, riprap, groins, sandbags, and improperly placed drift or sand fences. State and Federal laws designed to protect the beach and dune habitat in South Florida include the Coastal Barrier Resources Act of 1982 and the Coastal Zone Protection Act of 1985. These have had varying degrees of success at maintaining suitable nesting sites for sea turtles. Prior to 1995, DEP permits were required for all coastal armoring projects prior to construction. When issuing these permits, DEP incorporated sea turtle protection measures, and sea turtle concerns were generally well addressed.

However, in 1995, the Florida Legislature passed a law giving coastal counties and municipalities the authority to approve construction of coastal armoring during certain emergency situations. (All non-emergency armoring situations must still receive a DEP permit prior to construction.) Although the new law weakened prior regulations on armoring, it does require that emergency armoring structures approved by a coastal county or municipality be temporary and that the structure be removed or a permit application submitted to DEP for a permanent rigid coastal structure within 60 days after the emergency installation of the structure. In addition, to implement this new law, DEP finalized a formal agency rule on coastal armoring on September 12, 1996.

The new rule recommends that local governments obtain the necessary approval from the FWS prior to authorizing armoring projects. The new rule also requires that several measures be undertaken to address sea turtle concerns for non-emergency armoring and for placement of permanent rigid coastal structures subsequent to an emergency (temporary) armoring event. For example, the new regulations require that (1) special conditions be placed on permitted activities to limit the nature, timing, and sequence of construction, as well as address lighting concerns; (2) structures not be used where the construction would result in a significant adverse impact; and (3) armoring be removed if it is determined to not be effective or to be causing a significant adverse impact to the beach and dune system.

Beach nourishment is a better alternative for sea turtles than seawalls and jetties. When beach nourishment was done mostly in the summer, all nests had to be moved from the beach prior to nourishment. Now FWS and State natural resource agencies review beach nourishment projects to ensure appropriate timing of nourishment during the nesting and hatching season. In southwest Florida's Gulf coast (Sarasota County through Monroe County), the green sea turtle nesting and hatching season is from May 15 through October 31. In southeast Florida's, Atlantic coast (Indian River County through Miami-Dade County), the nesting and hatching season is from May 1 through November 30. Any management decisions regarding beach nourishment, beach armoring and other coastal construction, marina and dock development, and artificial lighting should consider these dates. Beaches where compaction after nourishment is a problem are plowed to a depth of 92 cm to soften the sand so that it is useable for nesting turtles (Nelson and Dickerson 1987). Progress is being made toward better timing of projects and sand quality.

Progress is being made by counties and cities to prevent disorientation and misorientation of hatchlings due to artificial lighting (Ernest *et al.* 1987, Shoup and Wolf 1987). In South Florida, lighting ordinances have been passed by Indian River, St. Lucie, Martin, Palm Beach, Broward, Monroe, Collier, Charlotte, Sarasota and Lee counties, as well as numerous municipalities. Most recently, Witherington and Martin (1996) provide a thorough discussion of the effects of light pollution on sea turtle nesting beaches and on hatchling and adult turtles. They also offer a variety of effective management solutions for ameliorating this problem.

Information on the status and distribution of the green turtle is critical to its conservation. Monitoring the various life stages of the turtles on nesting beaches is being conducted to evaluate current and past management practices. Data are collected on the number of nests laid, the number of nests that successfully hatch, and the number of hatchlings that reach the ocean. Standardized ground surveys on index beaches are underway throughout Florida by the FWS, DEP, and by private groups and universities. Index beaches include 80 percent of the nesting activity in Florida. Because of slow growth rates and subsequent delayed sexual maturity, all monitoring will need to be conducted over a long period of time to establish population trends.

Mortality of green sea turtles has been monitored since 1980 through the implementation of a regional data collection effort. This voluntary stranding network from Maine to Texas is coordinated by the NMFS and serves to document the geographic and seasonal distribution of sea turtle mortality (Schroeder 1987a,b). During 1987-89, four index zones were systematically surveyed. It is clear that strandings represent an absolute minimum mortality. However, they can be used as an annual index to mortality and are an indication of the size and distribution of turtles being killed. They can also provide valuable biological information on food habits, reproductive condition and sex ratios.

Research is underway at NMFS in Honolulu and at the University of Florida to determine the cause of the fibropapillomatosis disease affecting the green sea turtle. Evidence of a herpes-like virus was found, but it is unclear whether this is a primary or secondary infection. Management recommendations to reduce the incidence and impact of this disease include improving habitat quality in areas where occurrence is high, using strict hygiene techniques when handling affected turtles, and minimizing translocations of affected turtles (Barrett 1996).

Public support for sea turtle conservation efforts is essential for the long-term success of conservation programs. This is particularly true when conservation measures are controversial or expensive. To heighten public awareness and understanding of sea turtle conservation issues, a number of educational activities and efforts are underway. For example, personnel conducting turtle projects often advise tourists on what they can do to minimize disturbance to nesting turtles, protect nests, and prevent hatchlings from being disoriented. Many beaches have been posted with signs informing people of the laws protecting sea turtles and providing either a local or a hotline number to report violations.

Private conservation organizations such as the Center for Marine Conservation, Greenpeace, and the National Audubon Society, as well as Federal and State agencies have produced and distributed a variety of audio-visual aids and printed materials about sea turtles. These include: the brochure "Attention Beach Users," a booklet (Raymond 1984b) on the various types of light fixtures and ways of screening lights to lessen their effects on hatchings, "Lights Out" bumper stickers and decals, a coloring book, video tapes, slide/tape programs, full color identification posters of the different species of sea turtles, and a hawksbill poster. Florida Power and Light Company also has produced a booklet (Van Meter 1990) and two leaflets with information on sea turtles, as well as a coastal roadway lighting manual.

Literature Cited

Ackerman, R.A. 1980. Physiological and ecological aspects of gas exchange by sea turtle eggs. American Zoologist 20:575-583.

Allard, M.W., M.M. Miyamoto, K.A.Bjorndal, A.B. Bolten, and B.W. Bowen. 1994. Support for natal homing in green turtles from mitochondrial DNA sequences. Copeia 1994 (1): 34-41.

Balazs, G.H. 1982. Growth rates of immature green turtles in the Hawaiian Archipelago. Pages 117-125 *in* K.A. Bjorndal, ed. Biology and conservation of sea turtles. Smithsonian Institution Press; Washington, D.C.

Balazs, G.H. 1983. Recovery records of adult green turtles observed or originally tagged at French Frigate Shoals, northwestern Hawaiian Islands. NOAA Technical Memorandum NMFS-SWFC-36.

Balazs, G.H. 1986. Incidence of fibropapillomas in Hawaiian green turtles. (Abstract). Sixth anual workshop on sea turtle biology and conservation, 19-21 March 1986, Waverly, Georgia. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

Barrett, S. 1996. Disease threatens green sea turtles. U.S. Fish and Wildlife Service Endangered Species Bulletin. Volume XXI, Number 2.

Bjorndal, K.A. 1985. Nutritional ecology of sea turtles. Copeia 1985:736-751.

Bjorndal, K.A., and A.B. Bolten. 1988. Growth rates of immature green turtles, *Chelonia mydas,* on feeding grounds in the southern Bahamas. Copeia 1988:555-564.

Bjorndal, K.A., and A. Carr. 1989. Variation in clutch size and egg size in the green turtle nesting population at Tortuguero, Costa Rica. Herpetologica 45:181-189.

Bowen, B.W., A.B. Meylan, and J.C. Avise. 1989. An odyssey of the green sea turtle: Ascension Island revisited. Proceedings of the National Academy of Sciences USA 86 (1989): 573-576.

Bowen, B.W., A.B. Meylan, J.P. Ross, C.J. Limpus, H.H. Balazs, and J.C. Avise. 1992. Global population structure and natural history of the green turtle (*Chelonia mydas*) in terms of matriarchal phylogeny. Evolution 46 (4): 865-881.

Boulon, R.H., and N.B. Frazer. 1990. Growth of wild juvenile Caribbean green turtles, *Chelonia mydas.* Journal of Herpetology. 24: 441-445.

Carr, A. 1975. The Ascension Island green turtle colony. Copeia 1975: 547-555.

Carr, A. 1986. Rips, FADS, and little loggerheads. Bioscience 36:92-100.

Carr, A.F., and L.H. Ogren. 1960. The ecology and migrations of sea turtles, 4. The green turtle in the Caribbean Sea. Bulletin of the American Museum of Natural History 121:1-48.

Carr, A.F., M.H. Carr, and A.B. Meylan. 1978. The ecology and migrations of sea turtles, 7. The west Caribbean green turtle colony. Bulletin of the American Museum of Natural History 162:1-46.

Coastal Engineering Research Center. 1984. Shore protection manual, volumes I and II. U.S. Army Corps of Engineers Waterways Experiment Station; Vicksburg, Mississippi.

Collazo, J.A., R.H. Boulon, and T. Tallevast. 1992. Relative abundance, size class composition and growth patterns in wild green turtles at Culebra, Puerto Rico. Journal of Herpetology 26(3):293-300.

Daniel, R.S., and K.U. Smith. 1947. The sea-approach behavior of the neonate loggerhead turtle. Journal of Comparative Physiological Psychology 40:413-420.

Davis, G.E., and M.C. Whiting. 1977. Loggerhead sea turtle nesting in Everglades National Park, Florida, USA. Herpetologica 33:18-28.

Dickerson, D.D., and D.A. Nelson. 1989. Recent results on hatchling orientation responses to light wavelengths and intensities. Page 41 *in* S.A. Eckert, K.L. Eckert, and T.H. Richardson, compilers. Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA Technical Memorandum NMFS-SEFC-232.

Ehrenfeld, D.W., 1968. The role of vision in the sea-finding orientation of the green turtle *Chelonia mydas.* II. Orientation mechanism and range of spectral sensitivity. Animal Behavior 16:281-287.

Ehrenfeld, D.W., and A. Carr. 1967. The role of vision in the sea-finding orientation of the green turtle *(Chelonia mydas).* Animal Behavior 15:25-36.

Ehrhart, L.M., 1982. A review of sea turtle reproduction. Pages 29-38. *in* K.A. Bjorndal (ed.), biology and conservation of sea turtles. Smithsonian Institution Press; Washington, D.C.

Ehrhart, L.M., 1983. A survey of nesting by the green turtle, *Chelonia mydas,* and loggerhead turtle, *Caretta caretta,* in south Brevard County, Florida. Unpublished Report to World Wildlife Fund U.S.; Washington, D.C.

Ehrhart, L.M., R.B. Sindler, and B.E. Witherington. 1986. Preliminary investigation of papillomatosis in green turtles: phase I--frequency and effects on turtles in the wild and in captivity. Final report to U.S. Department Commerce; NOAA, NMFS, Miami Laboratory. Contract No. 40-GENF-6-0060l. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

Ehrhart, L.M., and B.E. Witherington.1992. Green turtle *Chelonia mydas*. Pages 90-94 *in* P.E. Moler, ed. rare and endangered biota of Florida, volume III. University Press of Florida, Gainesville, Florida.

Ernest, R.G., R. Erick, and C.J. Bove. 1987. Development of a comprehensive sea turtle protection ordinance for St. Lucie County, Florida. Paper presented at the seventh annual workshop on sea turtle biology and conservation. 25-27 Feb. 1987; Orlando, Florida.

Florida Department of Environmental Protection [DEP] 1996. Unpublished data. Reported nesting activity of the green turtle, *Chelonia mydas*, in Florida, 1993-1995. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

Florida Department of Environmental Protection [DEP]. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30, 1998.

Foley, A. 1997. First documented nesting by the green turtle (*Chelonia mydas*) along the southwest coast of Florida. Presented at the 17th annual sea turtle symposium, Orlando, Florida. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

Frazer, N.B., and L.M. Ehrhart. 1985. Preliminary growth models for green, *Chelonia mydas,* and loggerhead, *Caretta caretta,* turtles in the wild. Copeia 1985:73-79.

Groombridge, B., 1982. The IUCN Amphibia-Reptilia red data book, part I. Testudines, Crocodylia, Rhynchocephalia. IUCN; Gland, Switzerland.

Hendrickson, J.R. 1958. The green sea turtle, *Chelonia mydas* (Linneas) in Malaya and Sarawak. Proceedings of the Zoological Society of London 130:455-535.

Hirth, H.F. 1980a. *Chelonia mydas* (Linnaeus), green turtle. Catalogue of American amphibians and reptiles 249:1-4.

Hirth, H.F. 1980b. Some aspects of the nesting behavior and reproductive biology of sea turtles. American Zoologist 20:507-523.

Hopkins, S.R., and T.M. Murphy. 1980. Reproductive ecology of *Caretta caretta* in South Carolina. South Carolina Wildlife Marine Resources Department. Completion Report. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

Hosier, P.E., M. Kochhar, and V. Thayer. 1981. Off-road vehicle and pedestrian track effects on the sea-approach of hatchling loggerhead turtles. Environmental Conservation 8:158-161.

Jacobson, E.R. 1987. Pathologic studies on fibropapillomas of green sea turtles, *Chelonia mydas.* Paper presented at the seventh annual workshop on sea turtle biology and conservation, March 1987; Wekiwa Springs, Florida. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

Labisky, R.F., M.A. Mercadante, and W.L. Finger. 1986. Factors affecting reproductive success of sea turtles on Cape Canaveral Air Force Station, Florida, 1985. Final report to the U.S. Air Force, U.S. Fish and Wildlife Service Cooperative Fish and Wildlife Research Unit, Agreement No. 14-16-0009-1544, Work Order No. 25. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

Mann, T. M. 1977. Impact of developed coastline on nesting and hatchling sea turtles in southeastern Florida. Unpublished M.S. Thesis; Florida Atlantic University, Boca Raton.

Marcus, S.J., and C.G. Maley. 1987. Comparison of sand temperatures between a shaded and unshaded turtle nesting beach in south Florida. (Abstract) Seventh annual workshop on sea turtle biology and conservation, March 1987; Wekiwa Springs State Park, Florida. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

McFarlane, R.W. 1963. Disorientation of loggerhead hatchlings by artificial road lighting. Copeia 1963:153.

Meylan, A.B., B.W. Bowen, and J.C. Avise. 1990. A genetic test of the natal homing versus social facilitation models for green turtle migration. Science 248: 724-727.

Meylan, A.B., Schroeder, and A. Mosier. 1995. Sea turtle nesting activity in the State of Florida 1979-1992. Florida Marine Research Publications Number 52; St. Petersburg, Florida.

Meylan, A. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30, 1998.

Mortimer, J.A. 1979. Ascension Island: British jeopardize 45 years of conservation. Marine Turtle News 10:7- 8.

Mortimer, J. A. 1982a. Feeding ecology of sea turtles. Pages 102-109 *in* K.A. Bjorndal, ed. Biology and conservation of sea turtles. Smithsonian Institution Press; Washington, D.C.

Mortimer, J.A. 1982b. Factors influencing beach selection by nesting sea turtles. Pages 45-51 *in* K.A. Bjorndal, ed. Biology and conservation of sea turtles. Smithsonian Institution Press; Washington, D.C.

Mortimer, J.A. 1989. Research needed for management of the beach habitat. Pages 236-246 *in* L. Ogren, F. Berry, K. Bjorndal, H. Kumpf, R. Mast, G. Medina, H. Reichart, and R. Witham, eds. Proceedings of the second western Atlantic turtle symposium. NOAA Technical Memorandum NMFS-SEFC-226.

Mrosovsky, N., and S.F. Kingsmill. 1985. How turtles find the sea. Zeitschrift fuer Tierpsychologie 67:237-256.

Murphy, T.M. 1985. Telemetric monitoring of nesting loggerhead sea turtles subjected to disturbance on the beach. Fifth annual workshop on sea turtle biology and conservation, 13-16 March 1985; Waverly, Georgia. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

National Marine Fisheries Service [NMFS] and U.S. Fish and Wildlife Service [FWS]. 1991. Recovery plan for U.S. population of Atlantic green turtle. National Marine Fisheries Service; Washington, D.C.

National Research Council. 1990. Managing coastal erosion. National Academy Press, Washington, D.C.

Nelson, D.A., and D. Dickerson. 1987. Correlation of loggerhead turtle nesting digging with beach sand consistency. Paper presented at the seventh annual workshop on sea turtle biology and conservation. 25-27 February 1987; Orlando, Florida.

Nelson, D.A., and D.D. Dickerson. 1988a. Effects of beach nourishment on sea turtles. *in* L.S. Tait, ed. Proceedings of the beach preservation technology conference ‘88. Florida Shore & Beach Preservation Association, Incorporated; Tallahassee, Florida.

Nelson, D.A., and D.D. Dickerson. 1988b. Hardness of nourished and natural sea turtle nesting beaches on the east coast of Florida. Unpublished report. U.S. Army Corps of Engineers Waterways Experiment Station; Vicksburg, Mississippi.

Nelson, D.A. and D.D. Dickerson. 1988c. Response of nesting sea turtles to tilling of compacted beaches, Jupiter Island, Florida. Unpublished report. U.S. Army Corps of Engineers Waterways Experiment Station; Vicksburg, Mississippi.

Nelson, D.A., K. Mauck, and J. Fletemeyer. 1987. Physical effects of beach nourishment on sea turtle nesting, Delray Beach, Florida. Technical report EL-87-15. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

Ogren, L. 1984. Overview of the biology of the green turtle. Pages 78-80 *in* P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren, and M. Weber, eds. Proceedings of the western atlantic turtle symposium. Rosenstiel School of Marine and Atmospheric Science Printing; Miami, Florida.

Philibosian, R. 1976. Disorientation of hawksbill turtle hatchings, *Eretmochelys imbricata,* by stadium lights. Copeia 1976:824.

Pilkey, O.H., Jr., D.C. Sharma, H.R. Wanless, L.J. Doyle, O.H. Pilkey, Sr., W.J. Neal, and B.L. Gruver. 1984. Living with the east Florida shore. Duke University Press; Durham, North Carolina.

Possardt, E.E. 1991. A conservation program for sea turtles in the southeastern continental U.S. Journal of Alabama Academy of Sciences 62: 35-48.

Pritchard, P.C.H., and P. Trebbau. 1984. The turtles of Venezuela. Contributions to Herpetology, 2. Society for the Study of Amphibians and Reptiles. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

Pritchard, P.C.H.. P.R. Bacon, F.H. Berry, J. Fletemeyer, A.F. Carr, R.M. Gallagher. R.R. Lankford, R. Marquez, L.H. Ogren, W.G. Pringle, Jr., H.M. Reichardt, and R. Witham. 1983. Sea turtle manual of research and conservation techniques. Western Atlantic Turtle Symposium.

Raymond, P.W. 1984a. The effects of beach restoration on marine turtles nesting in south Brevard County, Florida. Unpublished M.S. Thesis; University of Central Florida, Orlando.

Raymond, P.W. 1984b. Sea turtle hatchling disorientation and artificial beachfront lighting. Center for Environmental Education; Washington, D.C.

Schmelz, G.W., and R.R. Mezich. 1988. A preliminary investigation of the potential impact of Australian pines on the nesting activities of the loggerhead turtle. Pages 63-66 *in* B.A. Schroeder, compiler. Proceedings of the eighth annual conference on sea turtle biology and conservation. NOAA Technical Memorandum NMFS-SEFC-214. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

Schroeder, B.A. 1981. Predation and nest success in two species of marine turtles *(Caretta caretta* and *Chelonia mydas*) at Merritt Island, Florida. Florida Scientist 44(l):35.

Schroeder, B.A. 1987a. 1987 First quarter report of the sea turtle stranding and salvage network, Atlantic and Gulf coasts of the U.S.. NMFS/SEFC, Miami Laboratory, Coastal Resources Division Contrib. No. CRD-86/87-26. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

Schroeder, B.A. 1987b. Strandings of marine turtles along the U.S. Atlantic and Gulf of Mexico coasts (1986). Paper presented at the seventh annual workshop on sea turtle biology and conservation. 25-27 February 1987; Orlando, Florida. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service, Vero Beach, Florida.

Shoup, L.P., and R.E. Wolf. 1987. Boca Raton Beach area outdoor lighting restrictions for the protection of sea turtles. Paper presented at the seventh annual workshop on sea turtle biology and conservation. 25-27 February 1987; Orlando, Florida.

Smith, G.M., and C.W. Coates. 1938. Fibro-epithelial growths of the skin in large marine turtles, *Chelonia mydas* (Linnaeus). Zoologica 23:93-98.

Stancyk, S.E. 1982. Non-human predators of sea turtles and their control. Pages 139-152 *in* K.A. Bjorndal, ed. Biology and conservation of sea turtles. Smithsonian Institution Press; Washington, D.C.

Stancyk, S.E., O.R. Talbert, and J.M. Dean. 1980. Nesting activity of the loggerhead turtle *Caretta caretta* in South Carolina, II: protection of nests from raccoon predation by transplantation. Biological Conservation 18:289-298.

Standora, E.A., and J.R. Spotila. 1985. Temperature dependent sex determination in sea turtles. Copeia 1985:711-722.

Talbert, O.R., Jr., S.E. Stancyk, J.M. Dean, and J.M. Will. 1980. Nesting activity of the loggerhead turtle *(Caretta caretta)* in South Carolina I: a rookery in transition. Copeia 1980:709-718.

Tritaik, P. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. February 3, 1998.

U.S. Fish and Wildlife Service [FWS]. 1996. Hobe Sound National Wildlife Refuge, 1996 Sea turtle nesting report. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service; Vero Beach, Florida.

Van Meter, V.B. 1990. Florida's sea turtles. Florida Power and Light Company; Miami, Florida.

Witherington, B.E. 1986. Human and natural causes of marine turtle clutch and hatchling mortality and their relationship to hatchling production on an important Florida nesting beach. Unpublished M.S. Thesis; University of Central Florida, Orlando.

Witherington, B.E. 1992. Behavioral responses of nesting sea turtles to artificial lighting. Herpetologica 48:31-39.

Witherington, B.E., and L.M. Ehrhart. 1987. A preliminary characterization of the disease papillomatosis affecting green turtles at the Indian River lagoon system, Florida. (Abstract). Seventh annual workshop on sea turtle biology and conservation, March 1987; Wekiwa Springs State Park, Florida.

Witherington, B.E., and L.M. Ehrhart. 1989. Status and reproductive characteristics of green turtles *(Chelonia mydas)* nesting in Florida. Pages 351-352 *in* L. Ogren, F. Berry, K. Bjorndal, H. Kumpf, R. Mast, G. Medina, H. Reichart, and R. Witham, eds. Proceedings of the second western atlantic turtle symposium. NOAA Technical Memorandum NMFS-SEFC-226. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service; Vero Beach, Florida.

Witherington, B.E., K.A. Bjorndal, and C.M. McCabe. 1990. Temporal pattern of nocturnal emergence of loggerhead turtle from natural nests. Copeia 1990:1165-1168.

Witherington, B.E., and K.A. Bjorndal. 1991. Influences of artificial lighting on the seaward orientation of hatchling loggerhead turtles *Caretta caretta.* Biological Conservation 55: 139-149.

Witherington, B.E., and R.E. Martin. 1996. Understanding, assessing, and resolving light pollution problems on sea turtle nesting beaches. FMRI Technical Report TR-2. Florida Marine Research Institute; St. Petersburg, Florida.

Wolke, R.E. 1989. Pathology and sea turtle conservation. Unpublished report.

Recovery for the Green Sea Turtle

Chelonia mydas

Recovery Objective: DELIST the species once recovery criteria has been met.

South Florida Contribution: SUPPORT delisting actions.

Recovery Criteria

The South Florida recovery contribution parallels the existing recovery plans for the sea turtles. South Florida's objective for the loggerhead turtle, green turtle, leatherback turtle and hawksbill turtle will be achieved when: the level of nesting for each species is continuously monitored and increases to the species-specific recovery goal; beaches supporting greater than 50 percent of the nesting activity are in public ownership; all important nesting beaches are protected and appropriately managed to prevent further degradation; non-native nuisance species have been controlled or eliminated on public lands; at least 60 percent hatch success is documented on major nesting beaches; effective lighting ordinances or lighting plans are implemented; and beaches are restored or rehabilitated to be suitable for nesting where appropriate.

Species-level Recovery Actions

S1. **Continue standardized surveys of nesting beaches.** Nesting surveys are undertaken on the majority of nesting beaches. In the past, beach coverage varied from year to year, as did the frequency of surveys, experience and training of surveyors, and data reporting. Consequently, no determination of nesting population trends had been possible with any degree of certainty. However, in 1989, to better assess trends in nesting, DEP, in cooperation with FWS, initiated an Index Nesting Beach Survey (INBS) program to collect nesting data that can be used to statistically and scientifically analyze population trends. The INBS program should continue to gather a long-term data base on nesting activities in Florida that can be used as an index of nesting population trends.

S2. **Protect and manage populations on nesting beaches.** Predators, poaching, tidal inundation, artificial lighting and human activities on nesting beaches diminish reproductive success. Monitoring of nesting activity is necessary to implement and evaluate appropriate nest protection measures and determine trends in the nesting population.

S2.1. **Evaluate nest success and implement appropriate nest protection measures.** Nesting and hatching success and hatchling emerging success on beaches occurring on State or Federal lands and all other important local or regional nesting beaches should be evaluated. Appropriate nest protection measures should be implemented by FWS and DEP, and appropriate local governments or organizations, to ensure greater than 60 percent hatch rate. Until recovery is ensured, however, projects on all Federal and State lands and key nesting beaches, such as those in Brevard, Indian River, St. Lucie, Martin, and Palm Beach counties, should strive for a higher rate of hatching success. In all cases, the least manipulative method should be employed to avoid interfering with known or unknown natural biological processes. Artificial incubation should be avoided. Where beach hatcheries are necessary, they should be located and constructed to allow self release, and hatch rates approaching 90 percent should be attained. Nest protection measures should always enable hatchling release the same night of hatching.

S2.2. Determine influence of factors such as tidal inundation and foot traffic on hatching success. Tidal inundation can diminish hatching success, depending on frequency, duration, and developmental stage of embryos. Some nests are relocated due to the perceived threat from tides. The extent to which eggs can tolerate tidal inundation needs to be quantified to enable development of guidelines for nest relocation relative to tidal threats. The effect of foot traffic on hatching success is unknown, although many beaches with significant nesting also have high public use. FWS should support research and, in conjunction with DEP, develop recommendations for nest protection from tidal threat and foot traffic.

S2.3. Reduce effects of artificial lighting on hatchlings and nesting females. Studies have shown that light pollution can deter female sea turtles from coming onto the beach to nest; in fact, brightly lit beaches have been determined to be used less frequently for nesting. Also, females attempting to return to sea after nesting can be disoriented by beach lighting and have difficulties making it back to the ocean. In some cases, nesting females have ended up on coastal highways and been struck by vehicles. Artificial beach lighting is even more detrimental to hatchling sea turtles, which emerge from nests at night. Under natural conditions, hatchlings move toward the brightest, most open horizon, which is over the ocean. However, when bright light sources are present on the beach, they become the brightest spot on the horizon and attract hatchlings in the wrong direction, making them more vulnerable to predators, desiccation, exhaustion, and vehicles.

S2.3.1. Implement and enforce lighting ordinances and resolve lighting problems in areas where lighting ordinances have not been adopted. FWS and DEP should identify and resolve artificial lighting impacts to sea turtles in South Florida. Since 1987, hatchling disorientation incidents observed by DEP marine turtle permit holders and park personnel have been reported through standardized reporting forms. Report forms serve as documentation for lighting problems on nesting beaches and allow the identification of specific problem light sources. FWS and DEP should use these report forms to locate and resolve lighting problems, with the help of local governments, through public education efforts, and by directly contacting the owners of the problem lights and making recommendations for their modification. FWS and DEP should also proactively conduct pre-season lighting inspections to identify and make recommendations for correcting problem light sources before they result in disorientation events.

Where lighting ordinances have been adopted and enforced, hatchling disorientation and misorientation have been drastically reduced. All coastal counties and communities with nesting beaches should adopt ordinances (March through October on the Atlantic Coast and May through October on the Gulf Coast). Many incorporated communities within Broward and Palm Beach counties, Florida, are particularly problematic because of the high-density nesting beaches and the lack of effective lighting regulations. DEP should ensure appropriate lighting on new construction projects and ensure follow-up surveys to assess continued compliance with lighting plans.

S2.3.2. Evaluate extent of hatchling disorientation and misorientation on all important nesting beaches. FWS, DEP, and counties should continue to evaluate hatchling disorientation and misorientation problems on all important nesting beaches. Many lighting ordinance requirements do not become effective until 11 p.m., whereas over 30 percent of hatchling emergence occurs prior to this time (Witherington et al. 1990). FWS, DEP, and county governments should also support research to gather additional quantitative data on hatchling emergence times and nesting times on representative beaches throughout South Florida to support the most effective time requirements for lighting ordinances.

S2.3.3. Prosecute individuals or entities responsible for hatchling disorientation and misorientation under the Endangered Species Act or appropriate State laws. Hatchling disorientation and misorientation from artificial lights can cause high mortality and be the major source of hatchling mortality on some nesting beaches if not controlled. Law enforcement efforts should be focused where lighting ordinances are not being implemented or enforced on major nesting beaches and where repeated violations are not corrected.

S2.4. Ensure beach nourishment and coastal construction activities are planned to avoid disruption of nesting and hatching activities. These activities can cause significant disruption of nesting activities during the nesting season when viewed cumulatively over the nesting range. Nest relocation can involve manipulation of large numbers of nests, which can result in lowered hatch success and altered hatchling sex ratios, and therefore is not an acceptable alternative to altering the timing of projects during the peak nesting period. COE, FWS, and DEP should ensure beach nourishment and other beach construction activities are not permitted during the nesting season on important nesting beaches.

S2.5. Ensure law enforcement activities eliminate poaching and harassment. Poaching, while not a significant cause of nest loss regionally, is occasionally a local problem. Poaching has been repeatedly reported around the Ten Thousand Islands NWR and adjacent islands in southwest Florida. In addition, intentional and unintentional disturbance and harassment of nesting turtles is an increasing problem on many beaches. FWS should work closely with DEP to identify problem areas and focus intensive law enforcement efforts to eliminate poaching and deter harassment of nesting turtles.

S3. Continue to gather information on species and population biology.

S3.1. Determine etiology of fibropapillomatosis. Research on the fibropapilloma disease should be continued and expanded. Fibropapillomatosis (FP) is a disease of sea turtles characterized by the development of multiple tumors on the skin and also internal organs, most frequently the lungs and kidneys. The tumors interfere with swimming, eating, breathing, seeing, and reproduction, and turtles with heavy tumor burdens become severely debilitated and die. FP has seriously impacted green sea turtle populations in Florida (about 50 percent of juvenile green turtles in Indian River Lagoon and Florida Bay have fibropapillomas) and is now emerging as a significant threat to the loggerhead as well. FP is a transmissible disease caused by a virus, and, while both a unique herpesvirus and retroviruses have been identified in FP tumors, neither has yet been proven to be the cause of the disease. Researchers are concerned that there may be environmental (contaminant) cofactors for this disease in nearshore areas. Continuation and expansion of research on the disease is essential to developing an approach to remedying the problem.

S3.2. Maintain the Sea Turtle Stranding and Salvage Network. Most accessible United States beaches in the Atlantic and Gulf of Mexico are surveyed for stranded sea turtles by volunteer or contract personnel. Through the Sea Turtle Stranding and Salvage Network, stranding data are archived and summarized by the NMFS Miami Laboratory. These data provide an index of sea turtle mortality and are thought to be a cost-effective means of evaluating the effectiveness of the (Turtle Exclusion Device) TED regulations. These data also provide basic biological information on sea turtles and are useful in determining other sources of mortality. The systematic stranding surveys of index areas need to be continued in South Florida. Periodic review of the efficacy of surveys should also be conducted.

S3.3. Centralize administration and coordination of tagging programs. Sea turtle researchers commonly tag turtles encountered during their research projects, and usually maintain independent tagging data bases. The lack of centralization for administering these tagging data bases often results in confusion when tagged turtles are recaptured, and delays in reporting of recaptures to the person originally tagging the turtle. NMFS and FWS should investigate the possibilities of establishing a centralized tagging data base, including Passive Integrated Transponder (PIT) tags.

S3.3.1. Centralize tag series records. A centralized tag series data base is needed to ensure that recaptured tagged turtles can be promptly reported to persons who initially tagged the animal. The tag series data base would include listings of all tag series that have been placed on sea turtles in the wild, including the name and address of the researcher. This would eliminate problems in determining which researcher is using which tag series or types of tags, and would preclude unnecessary delays in reporting of tag returns. NMFS and/or FWS should establish and maintain this data base.

S3.3.2. Centralize turtle tagging records. In addition to the need for a centralization of tag series records, there are advantages in developing a centralized turtle tagging data base. Such a data base would allow all turtle researchers to trace unfamiliar tag series or types to their source, and also to have immediate access to important biological information collected at the time of original capture. The major disadvantage is that this data base would require frequent editing and updating, and would be costly and somewhat time consuming to maintain. It would also make it possible for unethical researchers to exploit the work of others, while providing no guarantees that such contributions would be acknowledged. NMFS and FWS should determine whether such a data base can be established and is feasible to maintain.

S3.4. Develop requirements for care and maintenance of turtles in captivity, including diet, water quality, tank size, and treatment of injury and disease. Sea turtles are maintained in captivity for rehabilitation, research, or educational display. Proper care will ensure the maximum number of rehabilitated turtles can be returned to the wild and a minimum number removed from the wild for research or education purposes. None of these requirements has been scientifically evaluated to determine the best possible captive conditions for sea turtles. FWS and NMFS should support the necessary research to develop these criteria, particularly relating to diet and the treatment of injury and disease. These criteria should be published and required for any permit to hold sea turtles in captivity. FWS, NMFS and/or DEP should inspect permitted facilities at least annually for compliance with permit requirements.

S4. Monitor trends in nesting activity. DEP and FWS should continue to refine standardized nest survey criteria, identify additional index survey beaches to be monitored, and continue to conduct training workshops for surveyors. Consequently, DEP and FWS should ensure that routine monitoring of nesting beaches is done on at least a weekly basis during the time that green turtles are nesting, including the timeframes of any nesting that occurs outside of the regular survey period.

S5. Continue information and education activities. Sea turtle conservation requires long-term public support over a large geographic area. The public must be factually informed of the issues, particularly when conservation measures conflict with human activities, such as commercial fisheries, beach development, and public use of nesting beaches. Public education is the foundation upon which a long-term conservation program will succeed or fail.

S5.1. Update existing slide programs and information leaflets on sea turtle conservation for the general public. FWS has developed a bi-lingual slide tape program on sea turtle conservation and should keep the program current and available for all public institutions and conservation organizations. FWS and DEP should continually update and supply the public with informational brochures on sea turtle ecology and conservation needs.

S5.2. Disseminate information from brochures and reports on recommended lighting modifications or measures to reduce hatchling disorientation and misorientation. Recently published literature contains information on the types of light, screening or shading that is best for turtles (*e.g.*, Witherington and Martin 1996).

S5.3. Develop public service announcements (PSA) regarding the sea turtle artificial lighting conflict, and disturbance of nesting activities by public nighttime beach activities. A professionally produced public service announcement for radio and TV would provide tremendous support and reinforcement of the many coastal lighting ordinances. It would generate greater support through understanding. FWS and DEP should develop a high quality PSA that could be used throughout the Southeast during the nesting season.

S5.4. **Ensure facilities permitted to hold and display captive sea turtles have appropriate informational displays.** Over 50 facilities are permitted to hold sea turtles for rehabilitation, research, and public education. Many are on public display and afford opportunities for public education. Display of accurate information on the basic biology and conservation problems of sea turtles should be a requirement of all permittees. All facilities should be visited by FWS, NMFS and/or DEP to ensure captive sea turtles are being displayed in a way to meet these criteria.

S5.5. **Post informational signs at public access points on nesting beaches.** Public access points to nesting beaches provide excellent opportunities to inform the public of necessary precautions for compatible public use on the nesting beach and to develop public support through informational and educational signs. FWS, NPS, DEP and other appropriate organizations should post such educational and informational signs on nesting beaches as appropriate.

Habitat-level Recovery Actions

H1. **Protect and manage nesting habitat.** Coastal development has already destroyed or degraded many miles of nesting habitat in South Florida. Although sea turtle nesting occurs on over 2,240 km of beaches within the southeast United States, development pressures are so great that cumulative impacts could result in increased degradation or destruction of nesting habitat and eventually lead to a significant population decline if not properly managed.

H1.1. **Ensure beach nourishment projects are compatible with maintaining good quality nesting habitat.** Beach nourishment can improve nesting habitat in areas of severe erosion and is a preferred alternative to beach armoring. However, placement of sand on an eroded section of beach or an existing beach in and of itself may not provide suitable nesting habitat for sea turtles. Although beach nourishment may increase the potential nesting area, significant negative impacts to sea turtles may result if protective measures are not incorporated during construction.

H1.1.1. **Evaluate sand transfer systems as an alternative to beach nourishment.** Sand transfer systems can diminish the necessity for frequent beach renourishment and thereby reduce disruption of nesting activities and eliminate sand compaction. The construction and operation of these systems must be carefully evaluated to ensure important nearshore habitats are not degraded or sea turtles injured or destroyed.

H1.1.2. **Refine a sand budget formulation methodology for Sebastian Inlet.** Inlets interrupt the natural flow of longshore sediment transport along the shoreline. The interrupted flow of sand is diverted either offshore in ebb tide shoals, into bays or lagoons in flood tide shoals, or in navigation channels (National Research Council 1990). As a result, erosion occurs downdrift of the interrupted shoreline. There are six man-made inlets on the Atlantic coast from Indian River County to Broward County. In Indian River County, for example, erosion has been nearly 2 m per year at Sebastian Inlet SRA (just south of Sebastian Inlet), when the average erosion rate for the county is just under .3 m per year (J. Tabar, Indian River County, personal communication 1996). DEP, Sebastian Inlet Tax District, and Indian River County should conduct engineering studies to refine a sand budget formulation methodology for the Sebastian Inlet.

Other needs include: annually bypassing sand to downdrift beaches, conducting further studies of the long-term effects of the flood shoal on the inlet-related sediment budget, identifying the long-term impacts of sand impoundments and sediment volume deficit to downdrift areas, and determining the area of inlet influence.

H1.2. **Prevent degradation of nesting habitat from seawalls, revetments, sand bags, sand fences, or other erosion control measures.** One of the most difficult habitat protection efforts throughout South Florida is trying to minimize or eliminate the construction of seawalls, riprap, groins, sandbags, and improperly placed drift or sand fences. In 1995, the Florida Legislature passed a law giving coastal counties and municipalities the authority to approve construction of coastal armoring during certain emergency situations. (All non-emergency armoring situations must still receive a DEP permit prior to construction.) Although the new law weakened prior regulations on armoring, it does require that emergency armoring structures approved by a coastal county or municipality be temporary and that the structure be removed, or a permit application submitted to DEP for a permanent rigid coastal structure, within 60 days after the emergency installation of the structure. In addition, to implement this new law, DEP finalized a formal agency rule on coastal armoring on September 12, 1996.

H1.2.1. **Ensure laws regulating coastal construction and beach armoring are enforced.** The 1996 DEP rule recommends that local governments obtain an incidental take permit from FWS under section 10 of the Endangered Species Act and develop a sea turtle habitat conservation plan prior to authorizing armoring projects. The new rule also requires that several measures be undertaken to address sea turtle concerns for non-emergency armoring and for placement of permanent rigid coastal structures subsequent to an emergency (temporary) armoring event. For example, the new regulations require that (1) special conditions be placed on permitted activities to limit the nature, timing, and sequence of construction, as well as address lighting concerns; (2) structures not be used where the construction would result in a significant adverse impact; and (3) armoring be removed if it is determined to not be effective or to be causing a significant adverse impact to the beach and dune system.

H1.2.2. **Ensure failed erosion control structures are removed.** Failed erosion control structures such as uncovered plastic bags or tubes and fragmented concrete or wooden structures degrade nesting habitat and deter nesting activities. DEP should ensure failed structures are removed from nesting beaches.

H1.2.3. **Develop standard requirements for sand fence construction.** Sand fences can effectively build dune systems and improve nesting habitat; however, improperly designed sand fences can trap nesting females or hatchlings and prevent access to suitable nesting habitat. DEP and FWS should develop and evaluate sand fencing designs and establish standard requirements for sand fence construction.

H1.3. **Identify important nesting beaches experiencing greater than 40 percent nest loss from erosion and implement appropriate habitat restoration measures (without relocation).** Some important nesting beaches now suffer severe erosion as a result of inlet maintenance or jetty construction. In some situations, limited safe locations for relocating nests place constraints on nest relocation programs. Nest relocation programs should be considered as a short-term measure at best to protect nests in these situations, with primary efforts directed toward habitat restoration. DEP and FWS should review all important nesting beaches and identify those with 40 percent or more nest loss due to erosion or tidal inundation. Habitat restoration plans should be developed and implemented for identified nesting beaches.

H1.4. **Acquire or otherwise ensure the long-term protection of important nesting beaches.** Acquisition of important sea turtle nesting beaches would ensure long-term protection of U.S. nesting habitat. Acquisition and protection of undisturbed nesting habitat would enhance sea turtle nesting and hatching success.

H1.4.1. **Continue to acquire in fee title all undeveloped beaches between Melbourne Beach and Wabasso Beach, Florida, for the Archie Carr National Wildlife Refuge.** The Archie Carr NWR was designated by Congress in 1989 in recognition of the need for long stretches of quiet, undisturbed sandy beaches, with little or no artificial lighting, to ensure the reproductive success and survival of sea turtles. The refuge is located within a 33-km stretch of beach on the barrier islands of Brevard and Indian River counties on the Atlantic coast of Florida. Approximately 30 to 35 percent of all green sea turtle nesting in the U.S. occurs along this stretch of beach. The proposed acquisition plan for the refuge set a goal for purchase of 15 km within four sections of this 33-km stretch. Three of the sections are located in Brevard County and one in Indian River County.

Partners in the land acquisition effort for the refuge and adjacent buffer areas on the barrier island include FWS, DEP, Brevard County, Indian River County, Richard King Mellon Foundation, The Conservation Fund, and The Nature Conservancy. To date, contributions from the State of Florida and local county partnerships account for over 70 percent of land acquisition expenditures, while contributions from the Richard King Mellon Foundation account for over 21 percent of acquisition costs for lands on the barrier island. Federal acquisition efforts account for about 8 percent of purchases to date.

About 61 percent of the available beachfront acquisitions for the Refuge have been completed. Of the original 15 km of beachfront identified for acquisition, approximately 8 km have been acquired and 5 km are awaiting purchase. The remaining lands have been purchased for private development and are no longer available. Escalating coastal development in Brevard and Indian River counties threatens the remaining parcels identified for acquisition. Ongoing development continues to fragment the remaining habitat and could result in increased lighting and beach armoring, which negatively impact sea turtles. A narrow window of opportunity is left to acquire the last remaining lands required for the refuge.

H1.4.2. **Evaluate the status of the high-density nesting beaches on Hutchinson Island, Florida, and develop a plan to ensure its long-term protection.** Approximately 10 percent of green sea turtle nesting in the United States occurs along this 32 km beach. Development is degrading nesting habitat, and public use is causing significant disturbance to nesting activities. DEP and FWS should evaluate the threats and take appropriate measures, including acquisition, to ensure long-term protection.

H1.4.3. **Evaluate status of other undeveloped beaches that provide important habitat for maintaining historic nesting distribution and develop a plan for long-term protection.** DEP and FWS should evaluate other nesting beaches in the Southeast that contribute significantly to the historic nesting distribution to ensure long-term protection.

H2. **Restore areas to suitable habitat.**

H2.1. **Reestablish dunes and native vegetation.** Dune restoration and revegetation with native plants should be a required component of all renourishment projects. This will enhance beach stability and nesting habitat and may result in the need for less frequent renourishment activities.

H2.2. **Remove exotic vegetation and prevent spread to nesting beaches.** Australian pine trees shade nests and can alter natural hatchling sex ratios. Australian pines also aggressively replace native dune and beach vegetation through shading and chemical inhibition and consequently exacerbate erosion and loss of nesting habitat. Erosion can topple trees and leave exposed roots that can entrap nesting females. Removal of exotics, such as is ongoing at St. Lucie Inlet SP, Hobe Sound NWR, and Dry Tortugas NP, Florida, should continue. DEP, FWS, and NPS should identify other important nesting beaches where exotic vegetation is degrading nesting habitat and work with responsible parties to restore natural vegetation.

H3. **Conduct research to evaluate the relationship of sand characteristics (including aragonite) and female nesting behavior, nesting success, hatching success, hatchling emerging success, hatchling fitness, and sex ratios.** Beach nourishment may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content if the placed sand is dissimilar from the original beach sand. These changes could result in adverse impacts on nest site selection, digging behavior, clutch viability, and emergence by hatchlings. Gas diffusion of nests could be affected by sand grain shape, size, and compaction and variations may alter hatching success. Sand color and moisture influence nest incubation temperature and can affect hatchling sex determination. The effect of importing non-native materials, such as aragonite, to U.S. beaches for beach nourishment adds additional unknowns that could conceivably affect female nesting behavior, nesting success, hatching success, hatchling emerging success, hatchling fitness, and sex ratios and should be fully evaluated before large-scale use.

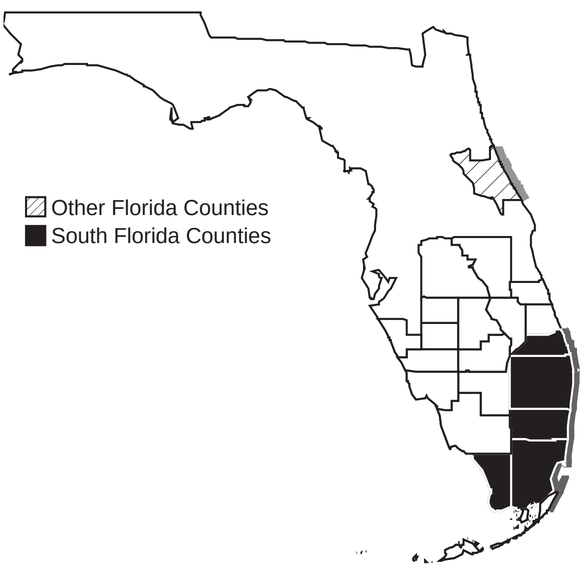
Studies of alternative sand sources for beach renourishment and their suitability for sea turtles are needed. After years of beach renourishment, Miami-Dade County is running out of suitable sand material for future renourishment projects. Broward and Palm Beach counties will also be running out of sand sources in the near future. COE is exploring the potential use of sand from upland sand sources and the importation of sand from the Bahamas and the Turks and Caicos Islands. Concerns have been raised about the long-term consequences to nesting and incubating sea turtles using these alternative beach renourishing materials. In order to adequately address these concerns in section 7 consultations, studies must be conducted on the suitability of these materials prior to receiving a proposal for large-scale nourishment of Florida beaches with these alternative sand sources.

Hawksbill Sea Turtle

Eretmochelys imbricata

Federal Status:	**Endangered (June 2, 1970)**
Critical Habitat:	**Designated (June 1982 and September 1998): Selected beaches and/or waters of Mona, Monito, Culebrita, and Culebra Islands, Puerto Rico**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. Florida nesting distribution of the hawksbill sea turtle.



Nesting by the hawksbill sea turtle is rare in Florida. During 1979 to 1992 only 11 nests were reported statewide, and of these, 10 were in South Florida (Meylan *et al*. 1995). Surveys for this species are difficult because of the similarities with loggerhead crawls and hatchlings, and because the nesting season for the hawksbill extends beyond the normal timeframe for the statewide survey. This account provides an overview of the biology of the hawksbill turtle throughout its range. The discussion of environmental threats and management activities, however, pertains only to the species in Florida and the U.S. Caribbean. Serious threats to the hawksbill turtle on its nesting beaches include artificial lighting, beach nourishment, increased human presence and exotic beach and dune vegetation.

This account is modified from the 1993 Recovery Plan for the Hawksbill Turtle in the U.S. Caribbean, Atlantic and Gulf of Mexico and represents South Florida's contribution to the range-wide recovery plan for this species (NMFS and FWS 1993).

Description

The following combination of characters distinguishes the hawksbill from other sea turtles: two pairs of prefrontal scales; thick, posteriorly overlapping scutes on the carapace; four pairs of costal scutes (the anteriormost not in contact with the nuchal scute); two claws on each flipper; and a beak-like mouth. In addition, when on land the hawksbill has an alternating gait, unlike the leatherback (*Dermochelys coriacea*) and green (*Chelonia mydas*) sea turtles.

The carapace is heart-shaped in very young turtles and becomes more elongate or subovate with maturity. The lateral and posterior carapace margins are sharply serrated in all but very old individuals. The epidermal scutes that overlay the bones of the shell are unusually thick and overlap posteriorly on the carapace in all but hatchlings and very old individuals. Carapacial scutes are often richly patterned with irregularly radiating streaks of brown and black on an amber background. The scutes of the plastron of Atlantic hawksbills are usually clear yellow, with little or no dark pigmentation. The soft skin on the hawksbill's venter is cream or yellow and may be pinkish-orange in mature individuals. There are typically four pairs of inframarginal scales. The head is elongate and tapers sharply to a point. The lower jaw is V-shaped. The scales of the head and forelimbs are dark brown or black and have yellow borders.

The hawksbill is a small to medium-sized marine turtle. Nesting females average about 87 cm in curved carapace length (Eckert 1992) and weight may be to 80 kg in the Caribbean (Pritchard *et al.* 1983), with a record weight of 127 kg (Carr 1952). Hatchlings in the U.S. Caribbean average about 42 mm in straight carapace length and range in weight from 13.5 to 19.5 g (Hillis and Mackay 1989, Van Dam and Sarti 1989, Eckert 1992).

Hawksbill crawls are difficult to distinguish from those of the loggerhead turtle (*Caretta caretta*), and hatchlings of the two species are also very similar, making identification of nests and estimates of productivity very difficult.

Taxonomy

The hawksbill turtle was originally named *Testudo imbricata* by Linnaeus (1766). A specimen at the University of Uppsala in Sweden, bearing Linnaeus' No. 130, is probably the type (Smith and Smith 1979). Taxonomic reviews appear in Smith and Smith (1979), Witzell (1983), and Pritchard and Trebbau (1984). Two subspecies *(Eretmochelys imbricata imbricata* in the Atlantic Ocean and *E. i. bissa* in the Indian and Pacific oceans) are recognized by Smith and Smith (1979). However, criteria for distinguishing the two forms are unreliable (Pritchard and Trebbau 1984) and subspecific designations are rarely used. A complex pattern of phenotypic variation exists. Some widely separated populations appear highly similar in color and pattern, whereas other populations that occupy the same ocean basin show marked differences (Pritchard and Trebbau 1984). Common names for the hawksbill turtle include tortoise-shell turtle, carey, caret, and tortue imbriquee.

Distribution

The hawksbill occurs in tropical and subtropical seas of the Atlantic, Pacific, and Indian oceans. Detailed descriptions of its worldwide distribution are given by Groombridge (1982), Witzell (1983), and Groombridge and Luxmoore (1989). The species is widely distributed in the Caribbean Sea and western Atlantic Ocean. Representatives of at least some life history stages regularly occur in southern Florida, northern Gulf of Mexico, Texas, in the Greater and Lesser Antilles, and along the Central American mainland south to Brazil. In U.S. Caribbean Sea waters, hawksbills are most common in Puerto Rico and its associated islands (particularly Mona, Culebra, and Vieques) and in the U.S. Virgin Islands. In the continental U.S., the hawksbill occurs along all of the Gulf states and along the eastern seaboard as far north as Massachusetts, but sightings north of Florida are rare.

Hawksbills are observed in Florida with some regularity in the waters near the Florida Keys and on the reefs off Palm Beach County (Lund 1985), where

Hawksbill sea turtle.
Original photograph courtesy of U.S. Fish and Wildlife Service.

the warm Gulf Stream current passes close to shore. According to DeSola (1932), before their numbers were reduced by overfishing, the Florida Keys were once considered the world's finest fishing grounds for hawksbill turtles.

Texas is the only other state where hawksbills are sighted with any regularity. A total of 77 observations, most involving posthatchlings and juveniles, have been recorded there between 1972 and 1984 (Amos 1989). These small turtles are believed to originate from nesting beaches in Mexico (Hildebrand 1987, Amos 1989).

Within U.S. jurisdiction in the Caribbean Sea, nesting occurs on beaches in Puerto Rico and the U.S. Virgin Islands. The most important sites are Mona Island (Puerto Rico) and Buck Island (St. Croix, U.S. Virgin Islands). Nesting also occurs on other beaches of St. Croix, Culebra Island, Vieques Island, mainland Puerto Rico, St. John, and St. Thomas.

Within the continental U.S., nesting is restricted to the southeastern coast of Florida, and has been reported from Broward, Miami-Dade, Martin, Monroe, Palm Beach, and Volusia counties (Figure 1) (Meylan 1992, Meylan *et al*. 1995). Nesting by hawksbills has been recorded several times on Soldier Key, a small, mangrove-fringed islet in Biscayne Bay (DeSola 1932, Dalrymple *et al.* 1985). The only reported nesting in Manatee County on the west coast of Florida (Conley and Hoffman 1987) was not adequately documented. Low levels of nesting are suspected to occur in the Marquesas and Dry Tortugas.

Throughout their range, hawksbills typically nest at low densities; aggregations consist of a few dozen, at most a few hundred individuals. This is in contrast to green turtles and loggerhead turtles, which nest by the thousands or tens of thousands at concentrated sites. The largest known nesting concentrations in the Caribbean are in the Yucatan Peninsula of Mexico (Meylan 1989), where approximately 800 to 1,000 nests are made each year between Isla Holbox (Quintana Roo) and Isla Carmen (Campeche) (NMFS and FWS 1993, cited in Eckert 1992). This corresponds to approximately 178 to 222 turtles, given an estimated average of 4.5 nests per female per season (Corliss *et al.* 1989). Other important (but relatively small) nesting beaches in the Caribbean region are located in Belize, Nicaragua, Panama, Venezuela, Antigua, and the Grenadines. Hawksbills are also known to nest in Cuba, possibly in significant numbers, but population estimates are not available. With few exceptions, all of the countries in the Caribbean report fewer than 100 females nesting annually (Meylan 1989).

Habitat

Hawksbill sea turtles use different habitats at different stages of their life cycle. Sightings (Hornell 1927, Gunter 1981), strandings (Vargo *et al.* 1986, Carr 1987, Amos 1989) and gut-content analyses (Meylan 1984b) suggest that posthatchling hawksbills occupy the pelagic environment, taking shelter in weed lines that accumulate at convergence zones. *Sargassum* and floating debris such as styrofoam, tar droplets, and plastic bits—common components of weed lines—are consistently found in the stomachs of posthatchling hawksbills that strand in Texas (Plotkin and Amos 1988). Thus, it seems likely that weed lines in the Gulf of Mexico serve as habitat for hawksbills that enter U.S. waters from nesting beaches in Mexico and Central America. Posthatchlings from beaches in the U.S. are presumed to occupy weed lines in the Atlantic Ocean.

Hawksbills reenter coastal waters when they reach approximately 20 to 25 cm carapace length. Coral reefs are widely recognized as the resident foraging habitat of juveniles, subadults, and adults. This habitat association is undoubtedly related to their diet of sponges, organisms that need solid substrate for attachment. The ledges and caves of the reef provide shelter for resting both during the day and night. Hawksbills are found around rocky outcrops and high-energy shoals, which are optimum sites for sponge growth. Hawksbills are known to inhabit mangrove-fringed bays and estuaries, particularly along the eastern shore of continents where coral reefs are absent (Carr 1952). In Texas, juvenile hawksbills are associated with stone jetties (Hildebrand 1987, Amos 1989).

Hawksbills nest on low- and high-energy beaches in tropical oceans of the world, frequently sharing the high-energy beaches with green turtles. Both insular and mainland nesting sites are known. Hawksbills will nest on small pocket beaches and, because of their small body size and great agility, can traverse fringing reefs that limit access by other species. They exhibit a wide tolerance for nesting substrate type.

Critical Habitat

Critical habitat was designated for the hawksbill sea turtle in June 1982 and September 1998. Although the designation did not include Florida, is does include selected beaches and/or waters of Mona, Monito, Culebrita, and Culebra Island, Puerto Rico. Critical habitat for hawksbill sea turtles identifies specific areas which have those physical or biological features essential to the conservation of the hawksbill sea turtle and/or may require special management considerations.

Behavior

The biology of the hawksbill has been extensively reviewed (Carr *et al.* 1966, Witzell 1983, Meylan 1984a, Pritchard and Trebbau 1984, and Eckert 1992). Only a brief overview is presented here.

Reproduction and Demography

The 6-month nesting season of the hawksbill is longer than that of other sea turtles. Most nests on Buck Island Reef NM are made from July to October (Hillis 1990). The peak season on Mona Island is from August to October (Richardson 1990). Courtship and mating apparently begin somewhat earlier, and may occur either along the migratory route or off the nesting beach. Nesting in the Caribbean is principally nocturnal, although rare daytime nesting is known. Nesting behavior, described by Carr *et al.* (1966), follows the general sequence of that of other species of sea turtles: emergence from the sea, site selection, site clearing and body pit construction, egg chamber construction, egg laying, filling in the egg chamber, disguising the nest site, and returning to sea. The entire process takes approximately 1 to 3 hours.

Hawksbills nest an average of 4.5 times per season (Corliss *et al.* 1989, Van Dam and Sarti 1990) at intervals of approximately 14 days. Earlier estimates of two to three nests per season reported at various projects around the world probably resulted from incomplete beach coverage. As many as 12 clutches may be produced by a single female in one season (Melucci *et al.* 1992). Not all emergences or nesting attempts result in eggs being laid. On Mona Island, an average of two emergences per successful nest was calculated; one female was observed making as many as 11 digging attempts on a single emergence (Kontos 1988). The ratio of crawls to nests varies geographically depending on local conditions, making site-specific information necessary for accurate interpretation of aerial survey data. On the basis of limited information, 2- and 3-year re-migration intervals appear to predominate; annual nesting by the hawksbill has not been recorded in the Caribbean.

Hawksbills have strong philopatry for their nesting beaches (Bjorndal *et al.* 1985, NMFS and FWS 1993), and are capable of returning to specific beach areas (Carr and Stancyk 1975, Diamond 1976, Lund 1985, Melucci *et al.* 1992). The extent to which site fixity is expressed among and within populations, or even by individuals over time, remains to be quantified.

Clutch size is directly correlated with carapace length (Hirth 1980) and varies markedly throughout the range of the species. In Florida and the U.S. Caribbean, clutch size is approximately 140 eggs, and several records exist of over 200 eggs per nest. Eggs are approximately 40 mm in diameter and take about 60 days to hatch. Hatching success at nesting beaches in the U.S. is approximately 80 percent (Van Dam and Sarti 1990, Hillis 1990).

Few data are available on the growth rates of wild hawksbill turtles. Most information has come from a study involving recaptures of 32 turtles (size range: 39.5 to 87.5 cm curved carapace length) on the Great Barrier Reef

(Limpus 1992). Mean growth rates ranged from 0.06 cm/yr for two adults, to 2.17 cm/yr for immature turtles ranging in size from 50 to 60 cm initial curved carapace length. The study concluded that hawksbills recruiting onto the reef at 35 cm in length would begin breeding 31 years later. Because the time required for these turtles to reach 35 cm is unknown, the actual age at sexual maturity is not known.

Boulon (1983) reported an average growth rate of 0.28 cm straight carapace length per month (3.36 cm/yr) for hawksbills ranging in size from 27.4 to 60.7 cm in St. Thomas (U.S. Virgin Islands). In the southern Bahamas, growth rates of four wild juvenile hawksbills ranged from 2.4 to 5.9 cm/yr (Bjorndal and Bolten 1988). Growth rates of adult females on the nesting beach in Costa Rica averaged 0.3 cm/yr (Bjorndal *et al.* 1985).

The few data available suggest slow growth and an advanced age at sexual maturity, as has been demonstrated for several other species of sea turtles. Rates of growth vary among different size classes (Limpus 1992) and seem to decrease considerably after sexual maturity is reached.

Migration

Very little is known of the movement patterns of posthatchling hawksbills, although their occupation of the pelagic environment is relatively well documented. Posthatchlings in Texas waters are presumed to have been passively transported there by currents that pass along Mexico. The movement patterns of hatchlings entering the sea from U.S. beaches are unknown.

Immature hawksbills show evidence of residency on specific feeding grounds (Nietschmann 1981, Limpus 1992), but developmental migrations may occur with changes in habitat occupation (Limpus 1992). Immature hawksbills tagged in the U.S. Virgin Islands have been recovered in eastern Puerto Rico, the British West Indies, St. Martin, and St. Lucia, representing travel distances of 95 km, 46 km, 185 km, and 650 km, respectively (Boulon 1989). Other recaptures of immature hawksbills have documented the long-distance travel of an 11 kg hawksbill from Great Inagua, Bahamas, to the Turks and Caicos Islands (Bjorndal *et al.* 1985) and the migration of a subadult hawksbill from Brazil to Dakar, Senegal, a distance of 3,680 km (Marcovaldi and Filippini 1991). The purpose and regularity of migrations by immature hawksbills deserve further study.

Recoveries of tagged adult hawksbills suggest that some populations or groups within a population undertake reproductive migrations (Meylan 1982, 1984a, Bjorndal *et al.* 1985). Migrations have been documented of adult females from beaches in Costa Rica to feeding grounds in Nicaragua, and from Nicaragua feeding grounds to a beach in Jamaica. An adult male tagged on the foraging grounds in Nicaragua was recovered in Panama (Meylan 1982). NMFS and FWS (1993) reported the travel of a hawksbill from Isla Mujeres, Mexico, to Bani, Dominican Republic, a distance of 2,925 km. Indirect evidence of migration by hawksbills was provided by Limpus (1992), who described a population of immature hawksbills in the Great Barrier Reef that reside at least 1,400 km from any regular hawksbill nesting site.

Foraging

Very little is known about the diet of posthatchling hawksbills in the pelagic environment. Eggs of pelagic fish, pelagic species of *Sargassum,* and various floating debris such as tar droplets, styrofoam, and plastic have been identified (Meylan 1984b).

Although a wide variety of benthic organisms have been recorded from digestive tracts, sponges are the principal diet of hawksbills once they enter shallow coastal waters and begin feeding on the bottom (Meylan 1988). Quantitative studies have focused on the Caribbean, but there is evidence that spongivory is a worldwide feeding habit. It is unquestionably a highly unusual one, being shared by only about a dozen other vertebrates. A high degree of feeding selectivity is indicated by the consumption of a limited number of sponge species. Sponge predation by hawksbills may influence reef succession and diversity by freeing up space on the reef for settlement by benthic organisms. The hawksbill's highly specific diet, and its dependence on filter-feeding, hard-bottom communities make it vulnerable to deteriorating conditions on coral reefs.

Relationship to Other Species

Although the hawksbill turtle is rare in South Florida, it shares nesting beaches with the threatened loggerhead turtle, and the endangered green and leatherback turtles. Other federally listed species that occur in coastal dune and coastal strand habitat, and that need to be considered when managing nesting beaches, are the southeastern beach mouse (*Peromyscus polionotus niveiventris*) and the beach jacquemontia (*Jacquemontia reclinata*). Beach nourishment projects, in particular, could affect these species as well as the turtles. The range of the beach mouse in South Florida is estimated to include Indian River County south to Broward County. The beach jacquemontia is found in Palm Beach County south to Miami, Miami-Dade County.

Some hawksbill nests have been discovered that are believed to be the result of hybrid crosses. Preliminary genetic testing in some of these cases has revealed the female parent was a loggerhead; tests are pending to reveal the identities of the male parent as a hawksbill or a hybrid (Meylan *et al*. 1995).

A variety of natural and introduced predators prey on hawksbill eggs and hatchlings. Until eradicated in 1987, mongooses were destroying up to 55 percent of all nests on Buck Island Reef NM (Small 1982). Prior to extensive live trapping, mongooses were destroying an estimated 24 percent of all turtle eggs in 1980 and 1981 on St. John, U.S. Virgin Islands. Feral hogs destroyed 44 to 100 percent of all hawksbill nests deposited outside of fenced areas on Mona Island, Puerto Rico, during 1985 to 1987 (Kontos 1985, 1987, 1988).

Status and Trends

The hawksbill is listed as endangered by the International Union for the Conservation of Nature and Natural Resources (IUCN) and is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Groombridge 1982). It was also listed as endangered throughout its range on June 2, 1970 (35 FR 8495) under the Endangered Species Act of 1973, as amended (FWS 1989). Groombridge and

Luxmoore (1989) carried out an exhaustive review of the worldwide conservation status of the hawksbill turtle and concluded that the species is suspected or known to be declining in 38 of the 65 geopolitical units for which nesting density estimates are available. They noted severe declines in the western Atlantic Ocean and Caribbean region, as did Meylan (1989), who reported that current nesting levels may be far lower than previously estimated. Despite protective legislation, international trade in tortoiseshell and subsistence use of meat and eggs continue unabated in many countries and pose a significant threat to the survival of the species in this region.

In the U.S. Caribbean, there is evidence that hawksbill nesting populations have been severely reduced during the 20th century (Eckert 1992). At present, they are not believed to be declining, but neither are there signs of recovery, despite over a decade of protection. The most recent status review of the species in the U.S. recognized that numerous threats still exist for U.S. populations and recommended that the hawksbill remain listed as endangered throughout its range (Eckert 1992).

Estimates of the size of nesting populations are available for only a few localities. Richardson (1990) reported that an average of 160 nests were made annually on Mona Island, Puerto Rico, during seven years of monitoring (1974, 1984 to 1989). This corresponds to approximately 36 nesting females per year. A total of 196 nests were recorded on the island in 1990 (Van Dam *et al.* 1991). Approximately 65 to 125 nests are made annually on Buck Island Reef NM, St. Croix, U.S. Virgin Islands (Eckert 1992). Since research began in 1988, between 15 to 30 female hawksbills have been recorded nesting on Buck Island Reef NM each year.

The hawksbill sea turtle does not nest frequently or commonly in Florida. Since 1989, nesting has been reported from Broward, Miami-Dade, Martin, Monroe, Palm Beach and Volusia counties, and the number of known nests each year through 1996 varied from zero to two. Results of surveys, however, undoubtedly underestimate the actual number of nests in Florida, and it appears that hawksbills are using the more remote islands and cays of the Florida Keys, where surveys are not conducted regularly (Meylan *et al.* 1995).

Environmental Threats

A number of threats exist to sea turtles in the marine environment, including: oil and gas exploration, development, and transportation; pollution; trawl, purse seine, hook and line, gill net, pound net, long line, and trap fisheries; underwater explosions; dredging; offshore artificial lighting; power plant entrapment; entanglement in debris; ingestion of marine debris; marina and dock development; boat collisions; and poaching. These threats and protective measures are discussed in detail in the Recovery Plan for the Hawksbill Turtle in the U.S. Caribbean, Atlantic and Gulf of Mexico (NMFS and FWS 1993). In South Florida, and for this Recovery Plan, we are focusing on the threats to nesting beaches, including: beach erosion, armoring and nourishment; artificial lighting; beach cleaning; increased human presence; and recreational beach equipment.

Beach Erosion: Hawksbill nesting beaches are usually small and the sand builds up over long periods of time. Storms periodically remove the sand, but it is usually replaced by wind and wave action. Storms may cause trees to fall that hinder the hawksbills from reaching nesting habitat. Buck Island Reef NM's nesting beaches were severely degraded in this manner by Hurricane Hugo in 1989. Buck Island Reef NM staff selectively removed fallen trees and debris and constructed sand ramps in the steep berms to provide access to high-density nesting areas. Normal, periodic erosion cycles may remove and replace large areas of a nesting beach, such as occurs at Sandy Point NWR, St. Croix. The overall effect is to clean and renourish the nesting beach. Occasionally, vulnerable nests may need to be relocated in such areas. Hawksbill nests are regularly relocated at Humacao, Pinones, Mona Island, and Caja de Muertos, Puerto Rico. Natural processes of beach erosion are not generally a significant threat to hawksbills.

Beach Armoring: Problems are caused by humans placing immovable structures on ephemeral shorelines. Beaches naturally recede and replenish but real estate boundaries are fixed. Where beachfront development occurs, the site is often fortified to protect the property from erosion. The purpose of virtually all shoreline engineering is to save structures, not dry sandy beaches, and it ultimately causes environmental damage. Beach armoring includes sea walls, rock revetments, riprap, sandbag installations, groins, and jetties. Approximately 21 percent (234 km) of Florida's beaches are armored (NMFS and FWS 1991). Although not quantified, beach armoring is extensive in some regions of Puerto Rico but rare in the U.S. Virgin Islands.

Beach armoring, may result in the permanent loss of a dry nesting beach by accelerating erosion and preventing natural beach or dune accretion. It may prevent or hamper nesting females from reaching suitable nesting sites. Clutches deposited seaward of these structures may be inundated at high tide or may be washed out entirely by increased wave action near the base of these structures.

As these structures fail and break apart, they spread debris on the beach trapping both adults and hatchlings, thus impeding access to suitable nesting areas and causing higher incidences of false crawls (non-nesting emergences). Sandbags are particularly susceptible to rapid failure and result in extensive debris on nesting beaches. Rock revetments, riprap, and sandbags can cause nesting turtles to abandon nesting attempts. When inadequate amounts of sand cover these structures, turtles attempting to nest may construct improperly sized and shaped egg cavities.

Groins and jetties are designed to trap sand during transport in longshore currents. Jetties keep sand from flowing into channels. These structures prevent normal sand transport and accrete beaches on one side of the structure while starving beaches on the other side. Severe beach erosion (Pilkey *et al.* 1984) and corrresponding degradation of suitable nesting habitat may result (S. MacPherson, FWS, personal communication 1998).

Drift fences, also commonly called sand fences, are erected to build and stabilize dunes by trapping sand moving along the beach and preventing excessive sand loss. Additionally, these fences can serve to protect dune systems by deterring public access. Constructed of narrowly spaced wooden or plastic slats or plastic fabric, drift fences when improperly placed, can impede nesting attempts and/or trap emergent hatchlings and nesting females.

Beach Nourishment: Beach nourishment entails pumping, trucking, or scraping sand onto the beach to rebuild what has been lost to erosion. It is a common practice in Florida but is much less common in Puerto Rico and the U.S. Virgin Islands. Although beach nourishment may increase the potential nesting area, significant adverse effects to sea turtles may result if protective measures are not taken. Placement of sand on an eroded section of beach or an existing beach in and of itself may not provide suitable nesting habitat for sea turtles. Beach nourishment can impact turtles through direct burial of nests and by disturbance to nesting turtles if conducted during the nesting season. Beach nourishment may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content, if the placed sand is dissimilar from the original beach sand (Nelson and Dickerson 1988a). These changes can affect nest site selection, digging behavior, incubation temperature (and hence sex ratios), gas exchange parameters within incubating nests, hydric environment of the nest, hatching success and hatchling emerging success (Mann 1977, Ackerman 1980, Mortimer 1982, Raymond 1984a).

Beach compaction and unnatural beach profiles that may result from beach nourishment activities could adversely affect sea turtles regardless of the timing of the projects. Very fine sand and/or the use of heavy machinery can cause sand compaction on nourished beaches (Nelson *et al*. 1987, Nelson and Dickerson 1988a). Significant reductions in nesting success have been documented on severely compacted nourished beaches (Raymond 1984a). Increased false crawls result in increased physiological stress to nesting females. Sand compaction may increase the length of time required for female sea turtles to excavate nests, also causing increased physiological stress to the animals (Nelson and Dickerson 1988c).

Nelson and Dickerson (1988b) evaluated compaction levels at 10 renourished east coast Florida beaches and concluded that 50 percent were hard enough to inhibit nest digging, 30 percent were questionable as to whether their hardness affected nest digging, and 20 percent were probably not hard enough to affect nest digging. They further concluded that, in general, beaches nourished from offshore borrow sites are harder than natural beaches, and, while some may soften over time through erosion and accretion of sand, others may remain hard for 10 years or more.

On nourished beaches, steep escarpments may develop along their water line interface as they adjust from an unnatural construction profile to a more natural beach profile (Coastal Engineering Research Center 1984, Nelson *et al*. 1987). These escarpments can hamper or prevent access to nesting sites. Female turtles coming ashore to nest can be discouraged by the formation of an escarpment, leading to situations where they choose marginal or unsuitable nesting areas to deposit eggs (e.g., in front of the escarpments, which often results in failure of nests due to repeated tidal inundation). This effect can be minimized by leveling the beach prior to the nesting season.

A change in sediment color due to beach nourishment could change the natural incubation temperatures of nests. This, in turn, could alter natural sex ratios. To provide the most suitable sediment for nesting sea turtles, the color of the nourished sediments must resemble the natural beach sand in the area. Natural reworking of sediments and bleaching from exposure to the sun would help to lighten dark nourishment sediments; however, the time frame for sediment mixing and bleaching to occur could be critical to a successful sea turtle nesting season.

Nourishment projects result in heavy machinery, pipelines, increased human activity, and artificial lighting on the project beach. These activities are normally conducted on a 24-hour basis and can adversely affect nesting and hatching activities. Pipelines and heavy machinery can create barriers to nesting females emerging from the surf and crawling up the beach, causing a higher incidence of false crawls (non-nesting emergences) and an unnecessary energy expenditure. Increased human activity on the project beach at night may cause further disturbance to nesting females. Artificial lights along the project beach and in the nearshore area of the borrow site may deter nesting females and disorient or misorient emergent hatchlings from adjacent non-project beaches.

Beach nourishment projects require continual maintenance (subsequent nourishment) as beaches erode, therefore their negative impacts to turtles are repeated on a regular basis. Nourishment of highly eroded beaches (especially those with a complete absence of dry beach) can be beneficial to nesting turtles if conducted properly. Careful consideration and advance planning and coordination must be carried out to ensure that timing, methodology, and sand sources are compatible with nesting and hatching requirements.

Artificial Lighting: Extensive research has demonstrated that the principal component of the sea finding behavior of emergent hatchlings is a visual response to light (Daniel and Smith 1947, Hendrickson 1958, Carr and Ogren 1960, Ehrenfeld and Carr 1967, Mrosovsky 1978, Dickerson and Nelson 1989, Witherington and Bjorndal 1991). Artificial beachfront lighting from buildings, streetlights, dune crossovers, vehicles, and other sources has been documented as causing the disorientation (loss of bearings) and misorientation (incorrect orientation) of hatchling turtles, including hawksbills (McFarlane 1963, Philibosian 1976, Mann 1977, Ehrhart 1983). In Florida, many lighting ordinance requirements do not become effective until 11 p.m., whereas over 30 percent of hatchling emergence occurs prior to this time (Witherington *et al*. 1990). On Sandy Point NWR, hawksbill and leatherback hatchlings are strongly attracted, especially on moonless nights, to the lights of Frederiksted (several km to the northeast). Another example is the Hotel Palmas del Mar parking lot lights at Humacao, Puerto Rico. These lights regularly disorient or misorient hawksbill hatchlings.

The results of disorientation or misorientation are often fatal. As hatchlings head toward lights or meander along the beach, their exposure to predators and the likelihood of desiccation are greatly increased. Misoriented hatchlings can become entrapped in vegetation or debris, and in Florida loggerhead hatchlings are frequently found dead on nearby roadways and in parking lots after being struck by vehicles. Hatchlings that successfully find the water may be misoriented after entering the surf zone or while in nearshore waters. Intense artificial lighting can even draw hatchlings back out of the surf (Daniel and Smith 1947, Carr and Ogren 1960).

The problem of artificial beachfront lighting is not restricted to hatchlings. Nesting turtles can also be misoriented by lights. Witherington (1992) determined that broad-spectrum artificial lights significantly reduced loggerhead and green turtle nesting activity. In addition to the lights on or near the nesting beaches, the background glow associated with intensive inland lighting, such as that emanating from nearby large metropolitan areas, may deter nesting females and disorient or misorient hatchlings navigating the nearshore waters. Cumulatively, along the heavily developed beaches of the southeastern continental U.S., Puerto Rico, and U.S. Virgin Islands, the adverse effects from artificial lights may be profound.

Beach Cleaning: Beach cleaning refers to the removal of both abiotic and biotic debris from developed beaches. There are several methods employed, including mechanical raking, hand raking, and picking up debris by hand. Large expanses of open sand may be cleaned with mechanical devices to a depth of several inches. The top of a clutch of hawksbill eggs is often no more than 10.1 to 15.2 cm below the surface of the sand and hawksbill nests on resort beaches are often subject to damage from raking and cleaning. This raking can result in heavy machinery repeatedly traversing nests and potentially compacting sand above nests. Resulting tire ruts along the beach may hinder or trap emergent hatchlings. Mann (1977) suggested that mortality within nests may increase when externally applied pressure from beach cleaning machinery is common on soft beaches with large grain sand. Mechanically pulled rakes and hand rakes can penetrate the surface and disturb the sealed nest or may actually uncover pre-emergent hatchlings near the surface of the nest. In some areas, collected debris is buried directly on the beach, and this can lead to excavation and destruction of incubating egg clutches. Disposal of debris near the dune line or on the high beach can cover incubating egg clutches and subsequently hinder and entrap emergent hatchlings and may alter natural nest temperatures.

Wind erosion is another threat exacerbated by beach cleaning. The complete removal of leaf litter and herbaceous vegetation on a beach allows prevailing winds to move sand to areas outside of the prime nesting area, and the vegetated nearshore berm may be lowered by 0.9 m or more. On a cleaned beach in Antigua, the wind has moved the sand more than 30 m back from the shoreline. Today, limestone bedrock is too close to the surface to permit turtle nesting on several historic nesting areas.

Increased Human Presence: Residential and tourist use of developed (and developing) nesting beaches can negatively affect nesting turtles, incubating egg clutches, and hatchlings. The most serious threat caused by increased human presence on the beach is the disturbance of nesting females. Nighttime human activity can cause nesting females to abort nesting attempts at any stage of the process. Murphy (1985) reported that disturbance has caused turtles to shift to other nesting beaches, delay egg laying, and select poor nesting sites. Female hawksbills ascending a beach to nest are easily deterred by the presence of people, noise, and flashlights. Turtles frightened from a protected public beach may go to an adjacent beach, where they may be more vulnerable to poaching. Pedestrian traffic in the nesting area can also break and destroy vegetation and crush eggs. Pedestrian tracks can hinder hatchlings, efforts to reach the ocean (Hosier *et al.* 1981). Campfires and the use of flashlights on nesting beaches misorient hatchlings and can deter nesting females (Mortimer 1979). Hatchlings have been drawn into campfires. A campfire placed over a hawksbill nest will kill the developing embryos or pre-emergent hatchlings.

Recreational Beach Equipment: The placement of physical obstacles (e.g., lounge chairs, cabanas, umbrellas, Hobie cats, canoes, small boats, and beach cycles) on nesting beaches can hamper or deter nesting attempts and interfere with incubating egg clutches and the seaward movement of hatchlings. The placement of recreational beach equipment directly above incubating egg clutches may hamper hatchlings during their emergence and can destroy eggs through direct invasion of the nest. Nesting females gravitate to dark horizons when seeking a nest site, whether the horizon be a beach forest or a cabana. Hawksbills may nest in the shadow of a chair or umbrella on the open beach. If the structure is removed, the nest is no longer protected from direct sunlight and the nest may get too hot.

Predation: Predators, particularly exotics, such as fire ants (*Solenopsis invicta*); and human-associated ones including racoons *(Procyon lotor)* and opossums (*Didelphis virginiana*) are becoming increasingly detrimental to nesting beaches.

Poaching: In the U.S., killing of female turtles is infrequent. However, in a number of areas, egg poaching and clandestine markets for eggs are not uncommon. From 1983 to 1989, the Florida Marine Patrol, DEP, made 29 arrests for illegal possession of turtle eggs.

The greatest threat to hawksbills on nesting beaches in Puerto Rico (Matos 1987), St. Thomas, and St. Croix (NMFS and FWS 1993) is poaching. While on the beaches, adult females are killed for their shell. Better surveillance by law enforcement and volunteer groups is believed to be reducing the levels of take. Hawksbills that use the remote beaches on Mona and Culebra islands are vulnerable to poaching. Hawksbills that use Pinones (a beach close to San Juan, Puerto Rico) are taken, in spite of the fact that Pinones has been given one of the largest Puerto Rico DNR ranger contingents deployed on any Puerto Rican beach. Although the rate of poaching may be limited on any given beach, the overall effect is an enormous drain on hawksbill populations.

Other Threats: In nearshore waters, hawksbills are periodically captured in the cooling water intakes of industrial facilities, such as Florida Power and Light Company's St. Lucie Power Plant on Hutchinson Island. Between March 1976 (when the St. Lucie Plant opened) and November 1988, six hawksbills were captured (Ernest *et al.* 1989). As of June 1, 1992, three more had been captured. All were released unharmed (NMFS and FWS 1993).

Management

Because the hawksbill is rare in South Florida, there is no specific management ongoing for this species. Conservation measures to protect nesting beaches for sea turtles in general, however, will also benefit the hawksbill. The following discussion taken from the Recovery Plan for the Hawksbill Turtle in the U.S. Caribbean, Atlantic and Gulf of Mexico (NMFS and FWS 1993) provides specific management and conservation measures being implemented for the species in the U.S. Caribbean.

The most important hawksbill conservation achievement in recent years was Japan's decision to end import of hawksbill shell by 1993 and to drop its CITES reservations on sea turtles by July 1, 1994. Because Japan is the largest importer of stuffed hawksbills and hawksbill shells in the world, this decision should significantly diminish the future demand for the species.

The two most important hawksbill nesting beaches in the U.S. Caribbean are now fully protected. Buck Island Reef NM, St. Croix, U.S. Virgin Islands, became part of the NPS in 1962. Mona Island, Puerto Rico, was established as a natural reserve under the protection of the Puerto Rico Department of Natural Resources in 1980. In addition, Isla Culebrita was transferred to Culebra NWR in 1982. Sandy Point NWR (a 2.4-km beach at Sandy Point, St. Croix) was established in 1984.

Conservation of sea turtle nesting habitat is continuing on several NWRs in South Florida, including Archie Carr, Hobe Sound, Ten Thousand Islands, and the complex of satellite refuges in the Florida Keys. Acquisition of high-density nesting beaches between Melbourne Beach and Wabasso Beach, Florida, is continuing to complete the Archie Carr NWR. The State of Florida purchased the first parcel specifically for the refuge in July 1990. Federal acquisition began in 1991. When completed, the refuge will protect up to 16 km of nesting beach. Since the initial acquisition, Brevard County and the Richard King Mellon Foundation have joined in as acquisition partners. Hobe Sound NWR, located north of West Palm Beach in Martin County, contains 5.25 km of Atlantic coast shoreline for nesting habitat. In addition to providing some of the most productive sea turtle nesting habitat in the U.S., the refuge is also home to Florida scrub-jays (*Aphelocoma coerulescens*) and gopher tortoises *(Gopherus polyphemus*). The most longstanding beach management program has been to reduce destruction of nests by natural predators, such as raccoons. Control of numerous exotic plants such as Australian pine (*Casuarina equisetifolia*) and Brazilian pepper (*Schinus terebinthifolius*) are also major issues in managing the refuge.

One of the most difficult habitat protection efforts throughout South Florida is trying to minimize or eliminate the construction of seawalls, riprap, groins, sandbags, and improperly placed drift or sand fences. State and Federal laws designed to protect the beach and dune habitat in South Florida include the Coastal Barrier Resources Act of 1982 and the Coastal Zone Protection Act of 1985. These have had varying degrees of success at maintaining suitable nesting sites for sea turtles. Prior to 1995, DEP permits were required for all coastal armoring projects prior to construction. When issuing these permits, DEP incorporated sea turtle protection measures, and sea turtle concerns were generally well addressed.

However, in 1995, the Florida Legislature passed a law giving coastal counties and municipalities the authority to approve construction of coastal armoring during certain emergency situations. (All non-emergency armoring situations must still receive a DEP permit prior to construction.) Although the new law weakened prior regulations on armoring, it does require that emergency armoring structures approved by a coastal county or municipality be temporary and that the structure be removed or a permit application submitted to DEP for a permanent rigid coastal structure within 60 days after the emergency installation of the structure.

In addition, to implement this new law, DEP finalized a formal agency rule on coastal armoring on September 12, 1996. The new rule recommends that local governments obtain the necessary approval from the FWS prior to authorizing armoring projects. The new rule also requires that several measures be undertaken to address sea turtle concerns for non-emergency armoring and for placement of permanent rigid coastal structures subsequent to an emergency (temporary) armoring event. For example, the new regulations require that (1) special conditions be placed on permitted activities to limit the nature, timing, and sequence of construction, as well as address lighting concerns; (2) structures not be used where the construction would result in a significant adverse impact, and (3) armoring be removed if it is determined to not be effective or to be causing a significant adverse impact to the beach and dune system.

Beach nourishment is a better alternative for sea turtles than seawalls and jetties. When beach nourishment was done mostly in the summer, all nests had to be moved from the beach prior to nourishment. Now FWS and State natural resource agencies review beach nourishment projects to ensure appropriate timing of nourishment during the nesting and hatching season. In southeast Florida, the hawksbill nesting and hatching season is from June 1 through December 31. Any management decisions regarding beach nourishment, beach armoring and other coastal construction, marina and dock development, and artificial lighting should consider these dates. Beaches where compaction after nourishment is a problem are plowed to a depth of 92 cm to soften the sand so that it is useable for nesting turtles (Nelson and Dickerson 1987). Progress is being made toward better timing of projects and sand quality.

Progress is being made by counties and cities to prevent disorientation and misorientation of hatchlings due to artificial lighting (Ernest *et al.* 1987, Shoup and Wolf 1987). In South Florida, lighting ordinances have been passed by Indian River, St. Lucie, Martin, Palm Beach, Broward, Monroe, Collier, Charlotte, Sarasota and Lee counties, as well as numerous municipalities. Most recently, Witherington and Martin (1996) provide a thorough discussion of the effects of light pollution on sea turtle nesting beaches and on juvenile and adult turtles, and offer a variety of effective management solutions for ameliorating this problem.

In the U.S. Virgin Islands, the coastal zone management commissions have imposed lighting and monitoring restrictions on projects being built adjacent to nesting beaches (NMFS and FWS 1993). In 1986, it became illegal to drive vehicles or ride horses on beaches in the U.S. Virgin Islands.

In 1988, the NPS initiated a study of the hawksbill nesting population at Buck Island Reef NM to monitor long-term trends. In 1991, the FWS collaborated with the NPS in a study of hawksbill postnesting migrations and movements at Buck Island Reef NM. In 1991, the NPS also used radio and sonic telemetry to study internesting movements, and the NPS initiated nesting surveys of hawksbill beaches on St. John, U.S. Virgin Islands.

Since 1986, a nesting-behavior study has been conducted at Humacao under the auspices of Puerto Rico DNR. A similar study has been initiated on Caja del Muertos. Since 1990, with U.S. Navy support, Puerto Rico Department of Natural Resources has been tagging hawksbills on Vieques.

Mortality of hawksbill turtles has been monitored since 1980 through the implementation of a regional data collection effort. This voluntary stranding network from Maine to Texas is coordinated by the NMFS and serves to document the geographic and seasonal distribution of sea turtle mortality (Schroeder and Warner 1988). Since 1987, four index zones have been systematically surveyed. It is clear that strandings represent an absolute minimum mortality. However, they can be used as an annual index to mortality and are an indication of the size and distribution of turtles being killed. They can also provide valuable biological information on food habits, reproductive condition, and sex ratios.

A substantial effort is being made by government and non-government agencies and private individuals to increase public awareness of sea turtle conservation issues. Federal and State agencies and private conservation organizations, such as the Center for Marine Conservation, Caribbean Conservation Corporation, Greenpeace, and National Audubon Society, have produced and distributed a variety of audio-visual aids and printed materials about sea turtles. These include a booklet on various types of light fixtures and ways of screening lights to lessen their effects on hatchlings (Raymond 1984b), the brochure “Attention Beach Users,” “Lights Out” bumper stickers and decals, a coloring book, video tapes, slide and tape programs, full-color identification posters of the eight species of sea turtles, and a hawksbill poster. Florida Power and Light Company has also produced a booklet (Van Meter 1992) and two leaflets containing general information on sea turtles, as well as a coastal roadway lighting manual.

Literature Cited

Ackerman, R.A. 1980. Physiological and ecological aspects of gas exchange by sea turtle eggs. American Zoologist 20:575-583.

Amos, A.F. 1989. The occurrence of hawksbills *Eretmochelys imbricata* along the Texas coast. Pages 9-11 *in* S.A. Eckert, K.L. Eckert, and T.H. Richardson, compilers. Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA technical memorandum NMFS/SEFC-232. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Bjorndal, K.A. and A.B. Bolten. 1988. Growth rates of immature green turtles, *Chelonia mydas,* on feeding grounds in the southern Bahamas. Copeia 1988:555-564.

Bjorndal, K.A., A. Carr, A.B. Meylan, and J.A. Mortimer. 1985. Reproductive biology of the hawksbill *Eretmochelys imbricata* at Tortuguero, Costa Rica, with notes on the ecology of the species in the Caribbean. Biological Conservation 34:353-368.

Boulon, R., Jr. 1983. Some notes on the population biology of green *Chelonia mydas* and hawksbill *Eretmochelys imbricata* turtles in the northern U.S. Virgin Islands: 1981-83. Report to NMFS, grant no. NA82-GA-A-00044. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Boulon, R., Jr. 1989. Virgin Islands turtle tag recoveries outside of the U.S. Virgin Islands. Pages 207-209 *in* S.A. Eckert, K.L. Eckert, and T.H. Richardson compilers. Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA Technical Memorandum NMFS/SEFC-232. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Carr, A. 1952. Handbook of turtles. Cornell University Press; Ithaca, NY.

Carr, A. 1987. New perspectives on the pelagic stage of sea turtle development. Conservation Biology 1:103-121.

Carr, A., H. Hirth, and L. Ogren. 1966. The ecology and migrations of sea turtles, 6. The hawksbill turtle in the Caribbean Sea. American Museum Novitiates 2248:1-29.

Carr, A.F., Jr., and L.H. Ogren. 1960. The ecology and migrations of sea turtles, 4. The green turtle in the Caribbean Sea. Bulletin American Museum Natural History 121:1-48.

Carr, A., and S. Stancyk. 1975. Observations on the ecology and survival outlook of the hawksbill turtle. Biological Conservation 8:161-172.

Coastal Engineering Research Center. 1984. Shore protection manual, volumes I and II. U.S. Army Corps of Engineers Waterways Experiment Station; Vicksburg, Mississippi.

Conley, W.J. and B.A. Hoffman. 1987. Nesting activity of sea turtles in Florida, 1979-1985. Florida Scientist 50:201-210.

Corliss, L.A., J.I. Richardson, C. Ryder, and R. Bell. 1989. The hawksbills of Jumby Bay, Antigua, West Indies. Pages 33-36 *in* S.A. Eckert, K.L. Eckert, and T.H. Richardson, compilers. Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA technical memorandum NMFS/SEFC-232. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Dalrymple, G.H., J.C. Hampp, and D.J. Wellins. 1985. Male-biased sex ratio in a cold nest of a hawksbill sea turtle *Eretmochelys imbricata*. Journal of Herpetology 19:158-159.

Daniel, R.S. and K.U. Smith. 1947. The sea-approach behavior of the neonate loggerhead turtle. Journal of Comparative Physiology and Psychology 40:413-420.

DeSola, C.R. 1932. The turtles of the northeastern states. Bulletin of the New York Zoological Society 34:131-160.

Diamond, W. 1976. Breeding biology and conservation of hawksbill turtles, *Eretmochelys imbricata L.*, on Cousin Island, Seychelles. Biological Conservation 9:199-215.

Dickerson, D.D. and D.A. Nelson. 1989. Recent results on hatchling orientation responses to light wavelengths and intensities. Page 41 *in* S.A. Eckert, K.L. Eckert, and T. H. Richardson, compilers. Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA technical memorandum NMFS/SEFC-232. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Eckert, K.A. 1992. Five year status reviews of sea turtles listed under the Endangered Species Act of 1973: hawksbill sea turtle *Eretmochelys imbricata.* U.S. Fish and Wildlife Service P.O. No. 20181-1-0060.

Ehrenfeld, D.W. and A. Carr. 1967. The role of vision in the sea-finding orientation of the green turtle *Chelonia mydas.* Animal Behavior 15:25-36.

Ehrhart, L.M. 1983. A survey of nesting by the green turtle, *Chelonia mydas,* and loggerhead turtle, *Caretta caretta,* in south Brevard County, Florida. Unpublished Report to World Wildlife Fund-U.S.; Washington, D.C.

Ernest, R.G., R. Erick, and C.J. Bove. 1987. Development of a comprehensive sea turtle protection ordinance for St. Lucie County, Florida. (Abstract). seventh annual workshop on sea turtle biology and conservation. February 1987. Wekiva Springs State Park, Florida.

Ernest, R.G., R.E. Martin, N. William-Walls, and J.R. Wilcox. 1989. Population dynamics of sea turtles utilizing shallow coastal waters off Hutchinson Island, Florida. Pages 57-59 *in* S.A. Eckert, K.L. Eckert, and T. H. Richardson, compilers. Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA technical memorandum NMFS/SEFC-232. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Groombridge, B. 1982. The IUCN amphibia-reptilia red data book, Part 1. Testudines, Crocodylia, Rhynchocephalia. IUCN; Gland, Switzerland.

Groombridge, B., and R. Luxmoore. 1989. The green turtle and hawksbill (Reptilia: Cheloniidae): world status, exploitation and trade. CITES Secretariat; Lausanne, Switzerland.

Gunter, G. 1981. Status of turtles on the Mississippi coast. Gulf Research Reports 7:89-92.

Hendrickson, J.R. 1958. The green sea turtle, *Chelonia mydas* (Linn.) in Malaya and Sarawak. Proceedings of the Zoological Society, London 130:455-535.

Hildebrand, H. 1987. A reconnaissance of beaches and coastal waters from the border of Belize to the Mississippi River as habitats for marine turtles. Report to NOAA/NMFS/SEFC Panama City Laboratory, purchase order NA-84-CF-A-134. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Hillis, Z. 1990. Buck Island Reef National Sea Turtle Research Program: 1989-the year of hawksbills and hurricanes. Pages 15-17 *in* T.H. Richardson, J.I. Richardson, and M. Donnelly, compilers. Proceedings of the tenth annual workshop on sea turtle biology and conservation. NOAA Technical Memorandum NMFS/SEFC-278. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Hillis, Z. and A.L. Mackay. 1989. Research report on nesting and tagging of hawksbill sea turtles *Eretmochelys imbricata* at Buck Island Reef National Monument, U.S. Virgin Islands, 1987-88. National Park Service, purchase order PX 5380-8-0090.

Hirth, H.F. 1980. Some aspects of the nesting behavior and reproductive biology of sea turtles. American Zoologist 20:507-523.

Hornell, J. 1927. The turtle fisheries of the Seychelles islands. H.M. Stationery Office; London, England.

Hosier, P.E., M. Kochhar, and V. Thayer. 1981. Off-road vehicle and pedestrian track effects on the sea-approach of hatchling loggerhead turtles. Environmental Conservation 8:158-161.

Kontos, A.R. 1985. Sea turtle research report, 1985, Mona Island, Puerto Rico. Annual report to U.S. Fish and Wildlife Service. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Kontos, A.R. 1987. 1986 annual summary: Estimation of sea turtle abundance and nesting success on Mona Island, Puerto Rico. Annual Report to the U.S. Fish and Wildlife Service, Unit Coop. Agreement No. 14-16-009-1551, Work Order #10. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Kontos, A. 1988. 1987 annual summary: Estimation of sea turtle abundance on Mona Island, Puerto Rico. Annual report to the U.S. Fish and Wildlife Service, Agreement 14-16-009-1551. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Limpus, C.J. 1992. The hawksbill turtle, *Eretmochelys imbricata,* in Queensland: population structure within a southern Great Barrier Reef feeding ground. Wildlife Research 19:489-506

Linnaeus, *C. Systemae naturae per regna tria. Editio duodecima reformata.* Vol. 1. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Lund, P. F. 1985. Hawksbill turtle *Eretmochelys imbricata* nesting on the east coast of Florida. Journal of Herpetology 19:164-166.

MacPherson, S. 1998. Comments on technical agency/draft multi-species recovery plan for South Florida. September 30, 1998.

Mann, T.M. 1977. Impact of developed coastline on nesting and hatchling sea turtles in southeastern Florida. Unpublished M.S. Thesis. Florida Atlantic University; Boca Raton, Florida.

Marcovaldi, M.A. and A. Filippini. 1991. Trans-Atlantic movement by a juvenile hawksbill turtle. Marine Turtle Newsletter 52:3.

Matos, R. 1987. Sea turtle hatchery project with specific reference to the leatherback *Dermochelys coriacea* and hawksbill *Eretmochelys imbricata* sea turtle, Humacao, Puerto Rico, 1987. Annual Report, Puerto Rico Department of Natural Resources. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

McFarlane, R. W. 1963. Disorientation of loggerhead hatchlings by artificial road lighting. Copeia 1963:153.

Melucci, C., J.I. Richardson, R. Bell, and L.A. Corliss. 1992. Nest site preference and site fixity of hawksbills on Long Island, Antigua. Pages 171-174 *in* M. Salmon and J. Wyneken, compilers. Proceedings of the eleventh annual workshop on sea turtle biology and conservation. NOAA Technical Memorandum NMFS/SEFC-302.

Meylan, A. 1982. Sea turtle migration—evidence from tag returns. Pages 91-100 *in* K.A. Bjorndal, ed. Biology and Conservation of Sea Turtles. Smithsonian Institution Press; Washington, D.C.

Meylan, A. 1984a. Biological synopsis of the hawksbill turtle *Eretmochelys imbricata.* Pages 112 - 117 *in* P. Bacon, F. Berry, K. Bjorndal, H. Hirth, L. Ogren, and M. Weber, eds. Proceedings of the western Atlantic turtle symposium. volume 1. Rosenstiel School of Marine and Atmospheric Sciences Printing; Miami, Florida.

Meylan, A. 1984b. Feeding ecology of the hawksbill turtle *Eretmochetys imbricata:* Spongivory as a feeding niche in the coral reef community. Unpublished Ph.D. Dissertation. University of Florida; Gainesville, Florida.

Meylan, A. 1988. Spongivory in hawksbill turtles: a diet of glass. Science 239:393-395.

Meylan, A. 1989. Status report of the hawksbill turtle, Pages 101-115 *in* L. Ogren, F. Berry, K. Bjorndal, H. Kumpf, R. Mast, G. Medina, H. Reichart, and R. Witham, eds. Proceedings of the second western Atlantic turtle symposium. NOAA Technical Memorandum NMFS/SEFC-226. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Meylan, A. 1992. Hawksbill Turtle *Eretmochelys imbricata.* Pages 95-99 *in* P. Moler, ed. Rare and endangered biota of Florida. University Presses of Florida; Gainesville, Florida.

Meylan, A., B. Schroeder, and A. Mosier. 1995. Sea turtle nesting activity in the State of Florida 1979-1992. Florida Marine Research Publications Number 52; St. Petersburg, Florida.

Mortimer, J.A. 1979. Ascension Island: British jeopardize 45 years of conservation. Marine Turtle Newsletter 10:7-8.

Mortimer, J.A. 1982. Factors influencing beach selection by nesting sea turtles. Pages 45-51 *in* K.A. Bjorndal , ed. Biology and conservation of sea turtles. Smithsonian Institution Press; Washington, D.C.

Mrosovsky, N. 1978. Orientation of marine turtles. Pages 413-419 *in* K. Schmidt-Koenig and W.T. Keeton, eds. Animal migration, navigation and homing. Springer Verlag; New York, New York.

Murphy, T. M. 1985. Telemetric monitoring of nesting loggerhead sea turtles subjected to disturbance on the beach. Paper presented at fifth annual workshop on sea turtle biology and conservation, 13-16 March 1985; Waverly, Georgia.

National Marine Fisheries Service [NMFS] and U.S. Fish and Wildlife Service [FWS]. 1993. Recovery plan for the hawksbill turtle in the Carribean, Atlantic and Gulf of Mexico. National Marine Fisheries Service; St. Petersburg, Florida.

National Marine Fisheries Service [NMFS] and U.S. Fish and Wildlife Service [FWS]. 1991. Recovery plan for U.S. population of loggerhead turtle. National Marine Fisheries Service; Washington D.C.

Nelson, D.A., and D.D. Dickerson. 1987. Correlation of loggerhead turtle nesting digging with beach sand consistency. (Abstract). Seventh annual workshop on sea turtle biology and conservation, February 1987; Wekiva Springs State Park, Florida. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Nelson, D.A., and D.D. Dickerson. 1988a. Effects of beach nourishment on sea turtles. *in* L.S. Tait, ed. Proceedings of the beach preservation technology conference '88. Florida Shore & Beach Preservation Association, Incorporated; Tallahassee, Florida.

Nelson, D.A., and D.D. Dickerson. 1988b. Hardness of nourished and natural sea turtle nesting beaches on the east coast of Florida. Unpublished report. U.S. Army Engineer Waterways Experiment Station; Vicksburg, Mississippi.

Nelson, D.A. and D.D. Dickerson. 1988c. Response of nesting sea turtles to tilling of compacted beaches, Jupiter Island, Florida. Unpublished report. U.S. Army Corps of Engineers Waterways Experiment Station; Vicksburg, Mississippi.

Nelson, D.A., K. Mauck, and J. Fletemeyer. 1987. Physical effects of beach nourishment on sea turtle nesting, Delray Beach, Florida. Technical report EL-87-15. U.S. Army Corps of Engineer Waterways Experiment Station; Vicksburg, Mississippi.

Nietschmann, B. 1981. Following the trail of a vanishing species—the hawksbill turtle. National Geographic Society Research Report 13:459-480.

Philibosian, R. 1976. Disorientation of hawksbill turtle hatchlings, *Eretmochelys imbricata,* by stadium lights. Copeia 1976:824.

Pilkey, O.H., Jr., D.C. Sharma, H.R. Wanless, L.J. Doyle, O.H. Pilkey, Sr., W.J. Neal, and B.L. Gruver. 1984. Living with the east Florida shore. Duke University Press; Durham, North Carolina.

Plotkin, P. and A.F. Amos. 1988. Entanglement in and ingestion of marine turtles stranded along the south Texas coast. Pages 79-82 *in* B.A. Schroeder, compiler. Proceedings of the eighth annual workshop on sea turtle conservation and biology. NOAA Technical Memorandum NMFS/SEFC-214. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Pritchard, P.C.H. and P. Trebbau. 1984. The turtles of Venezuela. Society for the Study of Amphibians and Reptiles, Contributions to Herpetology, 2. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Pritchard, P.C,.H. P. Bacon, F. Berry, A. Carr, J. Fletemeyer, R. Gallagher, S. Hopkins, R. Lankford, R. Marquez M., L. Ogren, W. Pringle, Jr., H. Reichart, and R. Witham. 1983. Manual of sea turtle research and conservation techniques, 2nd ed. K.A. Bjorndal and G.H. Balazs, eds. Prepared for the western atlantic sea turtle symposium, Center for Environmental Education; Washington, D.C.

Raymond, P.W. 1984a. The effects of beach restoration on marine turtles nesting in south Brevard County, Florida. Unpublished M.S. Thesis. University of Central Florida; Orlando, Florida.

Raymond, P.W. 1984b. Sea turtle hatchling disorientation and artificial beachfront lighting. Center for Environmental Education; Washington, D.C.

Richardson, J.I. 1990. Estimation of sea turtle abundance and nesting success on Mona Island, Puerto Rico. Final report, U.S. Fish and Wildlife Service, Unit Cooperative Agreement 14-16-0009-1551. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Schroeder, B.A. and A.A. Warner. 1988. 1987 annual report of the sea turtle stranding and salvage network, Atlantic and Gulf coasts of the United States. NMFS/SEFC, Miami laboratory, Coastal Resource Division contribution no. CRD-87/88-28.

Shoup, L.P., and R.E. Wolf. 1987. Boca Raton beach area outdoor lighting restrictions for the protection of sea turtles. (Abstract). Seventh annual workshop on sea turtle biology and conservation, February 1987; Wekiva Springs State Park, Florida.

Small, V. 1982. Sea Turtle Nesting at Virgin Islands National Park and Buck Island Reef National Monument, 1980 and 1981. Department of the Interior, National Park Service, Research Resource Management Report SER-61. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Smith, H.M., and R.B. Smith. 1979. Synopsis of the herpetology of Mexico. Vol. VI. Guide to Mexican Turtles. John Johnson; North Bennington, Vermont.

U.S. Fish and Wildlife Service [FWS]. 1989. Endangered and threatened wildlife and plants. 50 CFR 17. 11 & 17.12. U.S. Fish and Wildlife Service, Department of the Interior; Washington, D.C.

Van Dam, R. and L. Sarti. 1989. Sea turtle biology and conservation on Mona Island, Puerto Rico. Report for 1989. Chelonia, Sociedad Herpetologica de Puerto Rico.

Van Dam, R. and L. Sarti. 1990. The hawksbills of Mona Island, Puerto Rico. Report for 1990. Chelonia, Sociedad Herpetologica de Puerto Rico. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Van Dam, R. and L. Sarti, and D. Pares. 1991. The hawksbills of Mona Island, Puerto Rico. Page 187 *in* M. Salmon and J. Wyneken, compilers. Proceedings of the eleventh annual workshop on sea turtle biology and conservation. NOAA Technical Memorandum NMFS/SEFC-302. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Van Meter, V.B. 1992. Florida's sea turtles. Florida Power and Light Company; Miami, Florida.

Vargo, S., P. Lutz, D. Odell, E. Van Vleet, and G. Bossart. 1986. The effects of oil on marine turtles. Final report, vol. 2. Prepared for Minerals Management Service, U.S. Department of the Interior. OCS Study MMS 86-0070. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Witherington, B.E. 1992. Behavioral responses of nesting sea turtles to artificial lighting. Herpetologica 48:31-39.

Witherington, B.E., K.A. Bjorndal, and C.M. McCabe. 1990. Temporal pattern of nocturnal emergence of loggerhead turtle hatchlings from natural nests. Copeia 1990:1165-1168.

Witherington, B.E., and K.A. Bjorndal. 1991. Influences of artificial lighting on the seaward orientation of hatchling loggerhead turtles *Caretta caretta.* Biological Conservation 55:139-149.

Witherington, B.E., and R.E. Martin. 1996. Understanding, assessing, and resolving light pollution problems on sea turtle nesting beaches. FMRI Technical Report TR-2. Florida Marine Research Institute; St. Petersburg, Florida.

Witzell, W.N. 1983. Synopsis of biological data on the Hawksbill Turtle, *Eretmochelys imbricata* (Linnaeus, 1766). FAO Fisheries Synopsis No. 137.

Recovery for the Hawksbill Sea Turtle

Eretmochelys imbricata

Recovery Objective: DELIST the species once recovery criteria are met.

South Florida Contribution: SUPPORT delisting actions.

Recovery Criteria

The South Florida recovery contribution parallels the existing recovery plans for the sea turtles. South Florida's objective for the loggerhead, green, leatherback, and hawksbill sea turtle, will be achieved when: the level of nesting for each species is continuously monitored and increases to the species-specific recovery goal; beaches supporting greater than 50 percent of the nesting activity are in public ownership; all important nesting beaches are protected and appropriately managed to prevent further degradation; non-native nuisance species have been controlled or eliminated on public lands; at least 60 percent hatch success is documented on major nesting beaches; effective lighting ordinances or lighting plans are implemented; and beaches are restored or rehabilitated to be suitable for nesting where appropriate.

Species-level Recovery Actions

S1. **Continue standardized surveys of nesting beaches.** Nesting surveys are undertaken on the majority of nesting beaches. In the past, beach coverage varied from year to year, as did the frequency of surveys, experience and training of surveyors and data reporting. Consequently, no determination of nesting population trends had been possible with any degree of certainty. However, in 1989, to better assess trends in nesting, DEP, in cooperation with FWS, initiated an Index Nesting Beach Survey (INBS) program to collect nesting data that can be used to statistically and scientifically analyze population trends. The INBS program should continue to gather a long-term data base on nesting activities in Florida that can be used as an index of nesting population trends.

S2. **Protect and manage populations on nesting beaches.** Predators, poaching, tidal inundation, artificial lighting, and human activities on nesting beaches diminish reproductive success. Monitoring of nesting activity is necessary to implement and evaluate appropriate nest protection measures and determine trends in the nesting population.

S2.1. **Evaluate nest success and implement appropriate nest protection measures.** Nesting and hatching success and hatchling emerging success on beaches occurring on State or Federal lands and all other important local or regional nesting beaches should be evaluated. Appropriate nest protection measures should be implemented by FWS and DEP, and appropriate local governments or organizations, to ensure greater than 60 percent hatch rate. Until recovery is ensured, however, projects on all Federal and State lands and key nesting beaches, such as those in Brevard, Indian River, St. Lucie, Martin, and Palm Beach counties, should strive for a higher rate of hatching success. In all cases, the least manipulative method should be employed to avoid interfering with known or unknown natural biological processes. Artificial incubation should be avoided. Where beach hatcheries are necessary, they should be located and constructed to allow self release, and hatch rates approaching 90 percent should be attained. Nest protection measures should always enable hatchling release the same night of hatching.

S2.2. **Determine influence of factors such as tidal inundation and foot traffic on hatching success.** Tidal inundation can diminish hatching success, depending on frequency, duration, and developmental stage of embryos. Some nests are relocated due to the perceived threat from tides. The extent to which eggs can tolerate tidal inundation needs to be quantified to enable development of guidelines for nest relocation relative to tidal threats. The effect of foot traffic on hatching success is unknown, although many beaches with significant nesting also have high public use. FWS should support research and, in conjunction with DEP, develop recommendations for nest protection from tidal threat and foot traffic.

S2.3. **Reduce effects of artificial lighting on hatchlings and nesting females.** Studies have shown that light pollution can deter female sea turtles from coming onto the beach to nest; in fact, brightly lit beaches have been determined to be used less frequently for nesting. Also, females attempting to return to sea after nesting can be disoriented by beach lighting and have difficulties making it back to the ocean. In some cases, nesting females have ended up on coastal highways and been struck by vehicles. Artificial beach lighting is even more detrimental to hatchling sea turtles, which emerge from nests at night. Under natural conditions, hatchlings move toward the brightest, most open horizon, which is over the ocean. However, when bright light sources are present on the beach, they become the brightest spot on the horizon and attract hatchlings in the wrong direction, making them more vulnerable to predators, desiccation, exhaustion, and vehicles.

S2.3.1. **Implement and enforce lighting ordinances and resolve lighting problems in areas where lighting ordinances have not been adopted.** FWS and DEP should identify and resolve artificial lighting impacts to sea turtles in South Florida. Since 1987, hatchling disorientation incidents observed by DEP marine turtle permit holders and park personnel have been reported through standardized reporting forms. Report forms serve as documentation for lighting problems on nesting beaches and allow the identification of specific problem light sources. FWS and DEP should use these report forms to locate and resolve lighting problems, with the help of local governments, through public education efforts, and by directly contacting the owners of the problem lights and making recommendations for their modification. FWS and DEP should also proactively conduct pre-season lighting inspections to identify and make recommendations for correcting problem light sources before they result in disorientation events.

Where lighting ordinances have been adopted and enforced, hatchling disorientation and misorientation have been drastically reduced. All coastal counties and communities with nesting beaches should adopt ordinances (March through October on the Atlantic Coast and May through October on the Gulf Coast). Many incorporated communities within Broward and Palm Beach counties, Florida, are particularly problematic because of the high-density nesting beaches and the lack of effective lighting regulations. DEP should ensure appropriate lighting on new construction projects.

S2.3.2. **Evaluate extent of hatchling disorientation and misorientation on all important nesting beaches.** FWS, DEP, and counties should continue to evaluate hatchling disorientation and misorientation problems on all important nesting beaches. Many lighting ordinance requirements do not become effective until 11 p.m., whereas over 30 percent of hatchling emergence occurs prior to this time (Witherington et al. 1990). FWS, DEP, and county governments should also support research to gather additional quantitative data on hatchling emergence times and nesting times on representative beaches throughout South Florida to support the most effective time requirements for lighting ordinances.

S2.3.3. **Prosecute individuals or entities responsible for hatchling disorientation and misorientation under the Endangered Species Act or appropriate State laws.** Hatchling disorientation and misorientation from artificial lights can cause high mortality and be the major source of hatchling mortality on some nesting beaches if not controlled. Law enforcement efforts should be focused where lighting ordinances are not being implemented or enforced on major nesting beaches and where repeated violations are not corrected.

S2.4. **Ensure beach nourishment and coastal construction activities are planned to avoid disruption of nesting and hatching activities.** These activities can cause significant disruption of nesting activities during the nesting season when viewed cumulatively over the nesting range. Nest relocation can involve manipulation of large numbers of nests, which can result in lowered hatch success and altered hatchling sex ratios, and therefore is not an acceptable alternative to altering the timing of projects during the peak nesting period. COE, FWS, and DEP should ensure beach nourishment and other beach construction activities are not permitted during the nesting season on important nesting beaches.

S2.5. **Ensure law enforcement activities eliminate poaching and harassment.** Poaching, while not a significant cause of nest loss regionally, is occasionally a local problem. Poaching has been repeatedly reported around the Ten Thousand Islands NWR and adjacent islands in southwest Florida. In addition, intentional and unintentional disturbance and harassment of nesting turtles is an increasing problem on many beaches. FWS should work closely with DEP to identify problem areas and focus intensive law enforcement efforts to eliminate poaching and deter harassment of nesting turtles.

S3. Continue to gather information on species and population biology.

S3.1. **Determine etiology of fibropapillomatosis. Research on the hawksbill sea turtle fibropapilloma disease should be continued and expanded.** Fibropapillomatosis (FP) is a disease of sea turtles characterized by the development of multiple tumors on the skin and also internal organs, most frequently the lungs and kidneys. The tumors interfere with swimming, eating, breathing, seeing, and reproduction, and turtles with heavy tumor burdens become severely debilitated and die. FP has seriously impacted green turtle populations in Florida (about 50 percent of juvenile green turtles in Indian River Lagoon and Florida Bay have fibropapillomas) and is now emerging as a significant threat to the loggerhead as well. FP is a transmissible disease caused by a virus, and, while both a unique herpesvirus and retroviruses have been identified in FP tumors, neither has yet been proven to be the cause of the disease. Researchers are concerned that there may be environmental (contaminant) cofactors for this disease in nearshore areas. Continuation and expansion of research on the disease is essential to developing an approach to remedying the problem.

S3.2. Maintain the Sea Turtle Stranding and Salvage Network. Most accessible U. S. beaches in the Atlantic and Gulf of Mexico are surveyed for stranded sea turtles by volunteer or contract personnel. Through the Sea Turtle Stranding and Salvage Network, stranding data are archived and summarized by the individual states and the NMFS Miami Laboratory. These data provide an index of sea turtle mortality, and are thought to be a cost-effective means of evaluating the effectiveness of the TED regulations. These data also provide basic biological information on sea turtles and are useful in determining other sources of mortality. The systematic stranding surveys of index areas need to be continued in South Florida. Periodic review of the efficacy of surveys should also be conducted.

S3.3. Centralize administration and coordination of tagging programs. Sea turtle researchers commonly tag turtles encountered during their research projects and usually maintain independent tagging data bases. The lack of centralization for administering these tagging data bases often results in confusion when tagged turtles are recaptured, and delays in reporting of recaptures to the person originally tagging the turtle. NMFS and FWS should investigate the possibilities of establishing a centralized tagging data base, including PIT tags.

S3.3.1. Centralize tag series records. A centralized tag series data base is needed to ensure that recaptured tagged turtles can be promptly reported to persons who initially tagged the animal. The tag series data base would include listings of all tag series that have been placed on sea turtles in the wild, including the name and address of the researcher. This would eliminate problems in determining which researcher is using which tag series or types of tags, and would preclude unnecessary delays in reporting of tag returns. NMFS and/or FWS should establish and maintain this data base.

S3.3.2. Centralize turtle tagging records. In addition to the need for a centralization of tag series records, there are advantages in developing a centralized turtle tagging data base. Such a data base would allow all turtle researchers to trace unfamiliar tag series or types to their source, and also to have immediate access to important biological information collected at the time of original capture. The major disadvantage is that this data base would require frequent editing and updating, and would be costly and somewhat time consuming to maintain. It would also make it possible for unethical researchers to exploit the work of others, while providing no guarantees that such contributions would be acknowledged. NMFS and FWS should determine whether such a data base can be established and is feasible to maintain.

S3.4. **Develop requirements for care and maintenance of turtles in captivity, including diet, water quality, tank size, and treatment of injury and disease.** Sea turtles are maintained in captivity for rehabilitation, research or educational display. Proper care will ensure the maximum number of rehabilitated turtles can be returned to the wild and a minimum number removed from the wild for research or education purposes. None of these requirements has been scientifically evaluated to determine the best possible captive conditions for sea turtles. FWS and NMFS should support the necessary research to develop these criteria, particularly relating to diet and the treatment of injury and disease. These criteria should be published and required for any permit to hold sea turtles in captivity. FWS, NMFS and/or DEP should inspect permitted facilities at least annually for compliance with permit requirements.

S4. **Monitor trends in nesting activity.** DEP and FWS should continue to refine standardized nest survey criteria, identify additional index survey beaches to be monitored, and continue to conduct training workshops for surveyors. Surveys in Florida do not routinely cover the end of the hawksbill nesting season. Consequently, DEP and FWS should ensure that routine monitoring of nesting beaches is done on at least a weekly basis during the time period that hawksbill turtles nest, including any period of nesting that occurred outside of the regular survey period.

S5. **Continue information and education activities.** Sea turtle conservation requires long-term public support over a large geographic area. The public must be factually informed of the issues, particularly when conservation measures conflict with human activities, such as commercial fisheries, beach development, and public use of nesting beaches. Public education is the foundation upon which a long-term conservation program will succeed or fail.

S5.1. **Update existing slide programs and information leaflets on sea turtle conservation for the general public.** FWS has developed a bilingual slide tape program on sea turtle conservation and should keep the program current and available for all public institutions and conservation organizations. FWS and DEP should continually update and supply the public with informational brochures on sea turtle ecology and conservation needs.

S5.2. **Disseminate information from brochures and reports on recommended lighting modifications or measures to reduce hatchling disorientation and misorientation.** Recently published literature contains information on the types of light, screening, or shading that is best for turtles (e.g., Witherington and Martin 1996).

S5.3. **Develop public service announcements (PSA) regarding the sea turtle artificial lighting conflict and disturbance of nesting activities by public nighttime beach activities.** A professionally produced public service announcement for radio and TV would provide tremendous support and reinforcement of the many coastal lighting ordinances. It would generate greater support through understanding. FWS should develop a high-quality PSA that could be used throughout the Southeast during the nesting season.

S5.4. **Ensure facilities permitted to hold and display captive sea turtles have appropriate informational displays.** Over 50 facilities are permitted to hold sea turtles for rehabilitation, research, and public education. Many are on public display and afford opportunities for public education. Display of accurate information on the basic biology and conservation problems of sea turtles should be a requirement of all permittees. All facilities should be visited by FWS, NMFS and/or DEP to ensure captive sea turtles are being displayed in a way to meet these criteria.

S5.5. Post informational signs at public access points on nesting beaches. Public access points to nesting beaches provide excellent opportunities to inform the public of necessary precautions for compatible public use on the nesting beach and to develop public support through informational and educational signs. FWS, NPS, DEP and other appropriate organizations should post such educational and informational signs on nesting beaches as appropriate.

Habitat-level Recovery Actions

H1. Protect and manage nesting habitat. Coastal development has already destroyed or degraded many miles of nesting habitat in South Florida. Although sea turtle nesting occurs on over 2,240 km of beaches within the southeast United States, development pressures are so great that cumulative impacts could result in increased degradation or destruction of nesting habitat and eventually lead to a significant population decline if not properly managed.

H1.1. Ensure beach nourishment projects are compatible with maintaining good quality nesting habitat. Beach nourishment can improve nesting habitat in areas of severe erosion and is a preferred alternative to beach armoring. However, placement of sand on an eroded section of beach or an existing beach in and of itself may not provide suitable nesting habitat for sea turtles. Although beach nourishment may increase the potential nesting area, significant negative impacts to sea turtles may result if protective measures are not incorporated during construction.

H1.1.2. Evaluate sand transfer systems as an alternative to beach nourishment. Sand transfer systems can diminish the necessity for frequent beach renourishment and thereby reduce disruption of nesting activities and eliminate sand compaction. The construction and operation of these systems must be carefully evaluated to ensure important nearshore habitats are not degraded or sea turtles injured or destroyed.

H1.1.3. Refine a sand budget formulation methodology for Sebastian Inlet. Inlets interrupt the natural flow of longshore sediment transport along the shoreline. The interrupted flow of sand is diverted either offshore in ebb tide shoals, into bays or lagoons in flood tide shoals, or in navigation channels (National Research Council 1990). As a result, erosion occurs downdrift of the interrupted shoreline. There are six man-made inlets on the Atlantic coast from Indian River County to Broward County. In Indian River County, for example, erosion has been nearly 2 m per year at Sebastian Inlet SRA (just south of Sebastian Inlet), when the average erosion rate for the county is just under .3 m per year (J. Tabar, Indian River County, personal communication 1996). DEP, Sebastian Inlet Tax District, and Indian River County should conduct engineering studies to refine a sand budget formulation methodology for the Sebastian Inlet. Other needs include: annually bypassing sand to downdrift beaches, conducting further studies of the long-term effects of the flood shoal on the inlet-related sediment budget, identifying the long-term impacts of impoundment of sand and sediment volume deficit to downdrift areas, and determining the area of inlet influence.

H1.2. Prevent degradation of nesting habitat from seawalls, revetments, sand bags, sand fences, or other erosion control measures. One of the most difficult habitat protection efforts throughout South Florida is trying to minimize or eliminate the construction of seawalls, riprap, groins, sandbags, and improperly placed drift or sand fences. In 1995, the Florida Legislature passed a law giving coastal counties and municipalities the authority to approve construction of coastal armoring during certain emergency situations. (All non-emergency armoring situations must still receive an DEP permit prior to construction.) Although the new law weakened prior regulations on armoring, it does require that emergency armoring structures approved by a coastal county or municipality be temporary and that the structure be removed, or a permit application submitted to DEP for a permanent rigid coastal structure, within 60 days after the emergency installation of the structure. In addition, to implement this new law, DEP finalized a formal agency rule on coastal armoring on September 12, 1996.

H1.2.1. Ensure laws regulating coastal construction and beach armoring are enforced. The 1996 DEP rule recommends that local governments obtain an incidental take permit from FWS under section 10 of the Endangered Species Act and develop a sea turtle habitat conservation plan prior to authorizing armoring projects. The new rule also requires that several measures be undertaken to address sea turtle concerns for non-emergency armoring and for placement of permanent rigid coastal structures subsequent to an emergency (temporary) armoring event. For example, the new regulations require that (1) special conditions be placed on permitted activities to limit the nature, timing, and sequence of construction, as well as address lighting concerns; (2) structures not be used where the construction would result in a significant adverse impact; and (3) armoring be removed if it is determined to not be effective or to be causing a significant adverse impact to the beach and dune system.

H1.2.2. Ensure failed erosion control structures are removed. Failed erosion control structures such as uncovered plastic bags or tubes and fragmented concrete or wooden structures degrade nesting habitat and deter nesting activities. DEP should ensure failed structures are removed from nesting beaches.

H1.2.3. Develop standard requirements for sand fence construction. Sand fences can effectively build dune systems and improve nesting habitat; however, improperly designed sand fences can trap nesting females or hatchlings and prevent access to suitable nesting habitat. DEP and FWS should develop and evaluate sand fencing designs and establish standard requirements for sand fence construction.

H1.3. Identify important nesting beaches experiencing greater than 40 percent nest loss from erosion and implement appropriate habitat restoration measures (without relocation). Some important nesting beaches now suffer severe erosion as a result of inlet maintenance or jetty construction. In some situations, limited safe locations for relocating nests place constraints on nest relocation programs. Nest relocation programs should be considered as a short-term measure, at best, to protect nests in these situations, with primary efforts directed toward habitat restoration.

DEP and FWS should review all important nesting beaches and identify those with 40 percent or more nest loss due to erosion or tidal inundation. Habitat restoration plans should be developed and implemented for identified nesting beaches.

H1.4. **Acquire or otherwise ensure the long-term protection of important nesting beaches.** Acquisition of important sea turtle nesting beaches would ensure long-term protection of nesting habitat for sea turtles nesting in the United States. Acquisition and protection of undisturbed nesting habitat would enhance sea turtle nesting and hatching success.

H1.4.1. **Continue to acquire in fee title all undeveloped beaches between Melbourne Beach and Wabasso Beach, Florida, for the Archie Carr National Wildlife Refuge.** The Archie Carr NWR was designated by Congress in 1989 in recognition of the need for long stretches of quiet, undisturbed sandy beaches, with little or no artificial lighting, to ensure the reproductive success and survival of sea turtles. The refuge is located within a 33-km stretch of beach on the barrier islands of Brevard and Indian River counties on the Atlantic coast of Florida. The proposed acquisition plan for the refuge set a goal for purchase of 15 km within four sections of this 33-km stretch. Three of the sections are located in Brevard County and one in Indian River County.

Partners in the land acquisition effort for the refuge and adjacent buffer areas on the barrier island include FWS, DEP, Brevard County, Indian River County, Richard King Mellon Foundation, The Conservation Fund, and The Nature Conservancy. To date, contributions from the State of Florida and local county partnerships account for over 70 percent of land acquisition expenditures, while contributions from the Richard King Mellon Foundation account for over 21 percent of acquisition costs for lands on the barrier island. Federal acquisition efforts account for about 8 percent of purchases to date.

About 61 percent of the available beachfront acquisitions for the Refuge have been completed. Of the original 15 km of beachfront identified for acquisition, approximately 8 km have been acquired and 5 km are awaiting purchase. The remaining lands have been purchased for private development and are no longer available. Escalating coastal development in Brevard and Indian River counties threatens the remaining parcels identified for acquisition. Ongoing development continues to fragment the remaining habitat and could result in increased lighting and beach armoring, which negatively impact sea turtles. A narrow window of opportunity is left to acquire the last remaining lands required for the refuge.

H1.4.2. **Evaluate status of other undeveloped beaches that provide important habitat for maintaining the historic nesting distribution and develop a plan for long-term protection.** DEP and FWS should evaluate other nesting beaches in the Southeast that contribute significantly to the historic nesting distribution to ensure long-term protection.

H2 **Restore areas to suitable habitat.**

H2.1. **Reestablish dunes and native vegetation.** Dune restoration and revegetation with native plants should be a required component of all renourishment projects. This will enhance beach stability and nesting habitat and may result in the need for less frequent renourishment activities.

H2.2. Remove exotic vegetation and prevent spread to nesting beaches. Australian pine trees shade nests and can alter natural hatchling sex ratios. Australian pines also aggressively replace native dune and beach vegetation through shading and chemical inhibition and consequently exacerbate erosion and loss of nesting habitat. Erosion can topple trees and leave exposed roots that can entrap nesting females. Removal of exotics, such as is ongoing at St. Lucie Inlet SP, Hobe Sound NWR, and Dry Tortugas NP, Florida, should continue. DEP, FWS, and NPS should identify other important nesting beaches where exotic vegetation is degrading nesting habitat and work with responsible parties to restore natural vegetation.

H3. Conduct research to evaluate the relationship of sand characteristics (including aragonite) and female nesting behavior, nesting success, hatching success, hatchling emerging success, hatchling fitness, and sex ratios. Beach nourishment may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content if the placed sand is dissimilar from the original beach sand. These changes could result in adverse impacts on nest site selection, digging behavior, clutch viability, and emergence by hatchlings. Gas diffusion of nests could be affected by sand grain shape, size, and compaction and variations could alter hatching success. Sand color and moisture influence nest incubation temperature and can affect hatchling sex determination. The effect of importing non-native materials, such as aragonite, to U. S. beaches for beach nourishment adds additional unknowns that could conceivably affect female nesting behavior, nesting success, hatching success, hatchling emerging success, hatchling fitness, and sex ratios and should be fully evaluated before large-scale use.

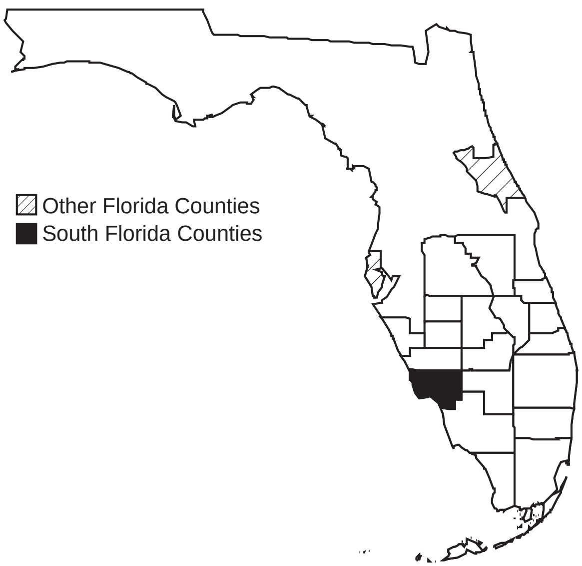
Studies of alternative sand sources for beach renourishment and their suitability for sea turtles are needed. After years of beach renourishment, Miami-Dade County is running out of suitable sand material for future renourishment projects. Broward and Palm Beach counties will also be running out of sand sources in the near future. COE is exploring the potential use of sand from upland sand sources and the importation of sand from the Bahamas and the Turks and Caicos Islands. Concerns have been raised about the long-term consequences to nesting sea turtles and incubating nests of renourishing beaches with these altrnative materials. In order to adequately address these concerns in section 7 consultations, studies must be conducted on the suitability of these materials prior to receiving a proposal for large-scale nourishment of Florida beaches with these alternative sand sources.

Kemp's Ridley Sea Turtle

Lepidochelys kempii

Federal Status:	**Endangered (December 2, 1970)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. Florida nesting occurrences of the Kemp's ridley sea turtle.



Nesting emergences by the Kemp's ridley sea turtle are extremely rare in Florida; only five nests have been reported since 1989. (Two in Pinellas County, one in Lee County, and two in Volusia County.) In addition, four false crawls were reported from Palm Beach County in 1989 (Meylan *et al*. 1995)

This account was taken from the 1992 Recovery Plan for the Kemp's Ridley Sea Turtle (FWS and NMFS 1992).

Description

The Kemp's ridley and its congener, the olive ridley, are the smallest of all extant sea turtles, the weight of an adult generally being less than 45 kg and the straight carapace length around 65 cm. Adult Kemp's ridleys' shells are as wide as they are long. The coloration changes significantly during development from the grey-black dorsum and venter of hatchlings to the lighter grey-olive carapace and cream-white or yellowish plastron of adults. There are two pairs of prefrontal scales on the head, five vertebral scutes, five pairs of costal scutes and generally 12 pairs of marginals on the carapace. In each bridge adjoining the plastron to the carapace, there are four scutes, each of which is perforated by a pore. This is the external opening of Rathke's gland which secretes a substance of unknown (possibly pheromonal) function. Males are not well described but resemble the females in size and coloration. Secondary sexual characteristics, typical of males of sea turtle species, are present in *L. kempii; i.e.*, the longer tail, more distal vent, recurved claws and, during breeding, a softened, mid-plastron. The eggs are between 34 and 45 mm in diameter and 24 to 40 g in weight (Chavez *et al.* 1968a,b; Marquez 1970, 1990; Pritchard and Marquez 1973). Hatchlings generally range from 42 to 48 mm in straight line carapace length, 32 to 44 mm in width and 15 to 20g in weight (Chavez *et al.* 1967; Marquez 1972, 1990; Fontaine and Caillouet 1985). In 1984 and 1985, the NPS Service (1985) reported hatchlings with mean carapace lengths of 43.5 and 43.25 mm, respectively. For 1984, hatchlings had a mean weight of 16.37 g and in 1985, the mean was 15.74 g.

Taxonomy

Kemp's ridley was first described by Samuel Garman in 1880, as *Thalassochelys kempii* (or *Colpochelys kempii*). The sea turtle was named for Richard M. Kemp, a fisherman interested in natural history who submitted the type specimen from Key West, Florida. Later *L. kempii* was allocated to the genus, *Lepidochelys*, Fitzinger 1843, by Baur (1890) when it was realized that Kemp's ridley and the Indo-Pacific olive ridley, *Lepidochelys olivacea*, were congeneric. Several others subsequently considered *L. kempii* to be a subspecies of *L. olivacea*, but currently it is recognized as a full species (see below) clearly distinct from *Lepidochelys olivacea* (Bowen *et al.* 1991). The latter species is distributed in the Pacific and Indian oceans and in the southern Atlantic, and individuals occasionally reach the southeastern Caribbean (Trinidad, Isla Margarita, Guadeloupe) but are nowhere sympatric with *L. kempii*, a more northern species in the Atlantic. A taxonomic review of the genus was made by Pritchard (1969) including a detailed morphological description of the two species, establishing that they have enough morphological differentiation to justify designation as separate species (Pritchard 1989). This status is accepted by most authors *(e.g.*, Marquez 1970, 1990; Brongersma 1972, Marquez *et al*. 1982, Smith and Smith 1979, Frair 1982, Pritchard and Trebbau 1984, Marquez and Bauchot 1987, Bowen *et al*. 1991).

Distribution

Movements of the adult females away from the nesting beach have been recorded by Chavez (1969), Pritchard and Marquez (1973), Marquez *et al*.(1990), and Byles (1988). Byles (1988) also found that post-nesting adult females stayed nearshore in water of 50 m or less during their movements away from the beach. During the nesting season, Mendonca and Pritchard (1986) found post-nesting females made slow and seemingly random movements offshore near the nesting beach for 1 to 2 days, then more rapid, longshore movements at least 10 km (and up to 100 km) north or south of their last nesting site before returning to lay eggs again or leaving the area entirely. They deduced that *L. kempii* exhibits extensive inter-nesting movements and that there may be some factors grouping turtles nesting on the same day together until the subsequent nesting emergence. Although they postulated that preferred inter-nesting aggregation sites existed adjacent to the nesting beach, small sample size and imprecise positioning did not allow them to clearly map these sites.

Juvenile/subadult *L. kempii* have been found along the eastern seaboard of the U.S. and in the Gulf of Mexico. Atlantic juveniles/subadults travel northward with vernal warming to feed in the productive, coastal waters of Georgia through New England, returning southward with the onset of winter to escape the cold (Lutcavage and Musick 1985, Henwood and Ogren 1987, Ogren 1989). In the Gulf, juvenile/subadult ridleys occupy shallow, coastal regions. Ogren (1989) suggested that in the northern Gulf they move offshore to deeper, warmer water during winter. Little is known of the movements of the post-hatching, planktonic stage within the Gulf.

Kemp's ridley sea turtle.
Original photograph courtesy of U.S. Fish and Wildlife Service.

Kemp's ridley nesting is extremely rare in Florida. However, two nests have been reported from Pinellas County (one in 1989, and one in 1994), one from Lee County in 1996, and two from Volusia County in 1996 (Figure 1).

Habitat

The major nesting beach where *L. kempii* emerges in any concentration to lay eggs is on the northeastern coast of Mexico. This location is near Rancho Nuevo in southern Tamaulipas. *L. kempii* (together with the flatback turtle, *Natator depressus*, of Australia) has the most restricted distribution of any sea turtle. The species occurs mainly in coastal areas of the Gulf of Mexico and the northwestern Atlantic Ocean. Occasional individuals reach European waters (Brongersma 1972). There is a single record from Malta in the Mediterranean (Brongersma and Carr 1983), a few from Madeira and the Moroccan coast (Fontaine *et al*. 1989), and a record from Bermuda (Mowbray and Caldwell 1958). Recently, a juvenile ridley was found in the Azores (Bolten and Martins 1990).

Adults of this species are usually confined to the Gulf of Mexico, although adult-sized individuals sometimes are found on the eastern seaboard of the United States. The post-pelagic stages are commonly found dwelling over crab-rich sandy or muddy bottoms. Juveniles frequent bays, coastal lagoons, and river mouths. Adults are present seasonally near the Mississippi River mouth and the Campeche Banks, converging annually on the Rancho Nuevo nesting grounds (Carr 1963, Pritchard 1969, Pritchard and Marquez 1973). What appeared to be winter dormancy was observed in Canaveral Channel during seasonally low temperatures (Carr *et al.* 1980).

Behavior

Reproduction and Demography

Principal courtship and mating areas for *L. kempii* are not well known. Anecdotal information supplied by fishermen revealed that mating presumably occurs at or before the nesting season in the vicinity of the nesting beach (Chavez *et al*. 1967, Pritchard 1969, Marquez 1970). Shaver (1991b) reported a mating pair of ridleys in Mansfield Channel at the southern boundary of Padre Island National Seashore (PAIS). Reproduction for the majority of the extant population appears to be annual (Marquez *et al*. 1982). Nesting occurs from April into July, and is essentially limited to the beaches of the western Gulf of Mexico, primarily in the Mexican state of Tamaulipas. The mean clutch size between 1978 and 1991 was 100.8 eggs. The hatchlings emerge after 45 to 58 days, depending upon the incubation conditions, especially temperature. See Pritchard and Marquez (1973) for a complete description of the nesting process.

Although growth data for wild *L. kempii* are sparse, it is unlikely that most adults grow very much after maturity. Recent work by Zug 1989, suggests juveniles may grow rapidly and that 20 cm ridleys are about two years old. Standora *et al*. (1989) found that five juvenile *L. kempii* (mean initial size = 31.6 cm) from Long Island, New York, waters had a mean increase in carapace length of about 0.8 cm per month from spring to summer after release following a fall hypothermic event. Head-started ridleys and captive juveniles of the species apparently grow rapidly, as do other sea turtles maintained in captivity (Fontaine *et al*. 1985). Two individuals of *L. kempii* at Cayman Turtle Farm fed high protein diets began to lay eggs at 5 years old and at a much smaller size than seen in the wild. These two examples Wood and Wood (1984) gave were 20 and 24.5 kg with curved carapace lengths (CCL) of 48.3 and 53.3 cm, respectively. Marquez (1970) states the minimum and maximum nesting sizes are 58 cm and 68.5 cm CCL, respectively. Marquez (1972) calculated the age to maturity based on captive growth, recapture data and minimum nesting size as 6 to 7 years. The recovery team for the Kemp's ridley feels that this estimate may be too low based on growth rates for other carnivorous cheloniids, namely loggerheads (*Caretta caretta*). Frazer and Ehrhart (1985) estimated the age of maturity for loggerheads as 12 to 30 years.

Foraging

Neonatal *L. kempii* presumably feed on the available sargassum and associated infauna or other epipelagic species found in the Gulf of Mexico. In the post-pelagic stages, the ridley is largely cancrivorous (crab eating), with a preference for portunid crabs. From studies of stomach contents, usually of stranded dead turtles, *L. kempii* appears to be a shallow water, benthic feeder (De Sola and Abrams 1933; Carr 1942, 1952; Smith and List 1950; Liner 1954; Dobie *et al*. 1961; Hardy, Jr. 1962; Montoya 1966; Marquez 1970; Ernst and Barbour 1972; Pritchard and Marquez 1973; Hendrickson 1980; Hildebrand 1982; Mortimer 1982; Lutcavage and Musick 1985). Shaver (1991a) gives a good review of the dietary items consumed by *L. kempii* (taken from specimens stranded along the Texas coast) in her comparison of the stomach contents of wild and head-started turtles.

Relationship to Other Species

Although Kemp's ridley nesting is extremely rare in South Florida, it shares nesting beaches with the threatened loggerhead turtle, and the endangered green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) turtles. Other federally listed species that occur in coastal dune and coastal strand habitat, and that need to be considered when managing nesting beaches, are the southeastern beach mouse (*Peromyscus polionotus niveiventris*) and the beach jacquemontia (*Jacquemontia reclinata*). Beach nourishment projects, in particular, could affect these species as well as the turtles. The range of the beach mouse in South Florida is estimated to include Indian River County south to Broward County. The beach jacquemontia is found in Palm Beach County south to Miami, Miami-Dade County.

Status and Trends

The Kemp's ridley was listed as endangered on December 2, 1970 (35 FR 18320). The endangered status was continued with the status review performed by NMFS in 1985 (NOAA 1985). Internationally, *L. kempii* is considered the most endangered sea turtle (Zwinenberg 1977, Groombridge 1982, Magnuson *et al.* 1990). It is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Less than 50 years ago the Kemp's ridley was an abundant sea turtle in the Gulf of Mexico. Populations were able to generate a synchronized reproductive effort that resulted in an estimated 40,000 females nesting in one day on the single known nesting beach on the northeastern coast of Mexico (Carr 1963, Hildebrand 1963). Such former aggregations could only have been produced by a very large adult population. *L. kempii* has experienced one of the most dramatic declines in population numbers recorded for an animal. Dr. Archie Carr and others sought the nesting areas of Kemp's ridleys throughout the Gulf of Mexico, the Caribbean and southeast U.S. over many years (Carr 1963). When the Mexican nesting beach was first discovered by scientists in 1961, the population was already severely depleted. By the mid-1980s, nesting numbers had declined from the estimated 40,000 to about 700 nests per year (Turtle Expert Working Group 1998). However, due to the recovery efforts of a joint U.S.-Mexico partnership, the Kemp's ridley population now appears to be in the early stages of an exponential expansion. In 1998, more than 3,600 nests were recorded (FWS news release 1998).

Because nearly the entire adult female population nests at a single locality (about 60 km of beach on the east coast of Mexico), it is possible to estimate the female reproductive population by counting all the nests laid at this site. Marquez *et al*. (1982) previously calculated from tag recapture data that females average 1.5 nests/per season. However, recently Pritchard (1990) deduced 2.31 nests/season/female were likely at the nesting beach. Recent work using ovarian ultrasonography and endocrinology of female Kemp's at Rancho Nuevo led Rostal (1991) to estimate 3.075 nests/female for the 1990 season. The number of nests/female/season has a profound effect on the estimated number of females in the population. Using the older 1.5 figure yields an estimate of 770 females (1155 nests/1.5 nests/female) for the 1991 season. The difference in calculated number of females in the breeding population using an average of Pritchard's and Rostal's figures (about 2.7) results in a 45 percent reduction compared to using 1.5 nests/season/female. Using 2.7 nests/season/female yields a considerably lower estimate of 428 females in the population that oviposited in 1991. If only 58 percent of the turtles nest every year (Marquez *et al*. 1982), the total female population would be about 738 individuals. If the number of turtles nesting annually (58 percent) is underestimated because of unknown tag loss in the population, the number in the nesting population will be overestimated even more and will be less than 738 females. The estimate excludes males, immature turtles, and the small breeding groups or solitary nesters dispersed between Padre Island, Texas and Isla Aguada, Campeche. These small nesting groups, solitary females, and the number of males (or sex ratio), need to be evaluated quantitatively so that the estimate of total population can be refined to obtain a better assessment of the total adult population in the Gulf of Mexico. Until such data are available, an index of adult female population trends is generated by comparing the number of nests/season laid at the Rancho Nuevo nesting beach.

Environmental Threats

A number of threats exist to sea turtles in the marine environment, including: oil and gas exploration, development, and transportation; pollution; trawl, purse seine, hook and line, gill net, pound net, longline, and trap fisheries; underwater explosions; dredging; offshore artificial lighting; power plant entrapment; entanglement in debris; ingestion of marine debris; marina and dock development; boat collisions; and poaching. For this recovery plan, we discuss the threats to the Kemp's ridley on its nesting beach in Mexico; some of these same threats, as well as others, are present in South Florida (refer to the loggerhead account as an example of additional threats in South Florida).

Threats to the nesting beach for Kemp's ridley in Mexico are presently few, but potentially serious. Human population growth and increasing developmental pressure will ultimately result in escalating threats to the nesting beach. Only the central part of the prime nesting area is protected by Mexican presidential decree, and legislation has never been enacted to fully implement the decree. A primary concern is human encroachment and access along the entire nesting area. The wording of the Mexican decree is so vague that construction of commercial fishing facilities proceeded in 1987 immediately adjacent to the main turtle camp at Rancho Nuevo. Occasionally, plans for massive expansion of La Pesca (just to the north of the nesting area) as a fishing center, or dredging the Gulf Intercoastal Waterway from Brownsville, Texas, to Barra del Tordo (in the south part of the nesting beach) are reported. These projects would result in detrimental and possibly disastrous effects on the nesting environment if they were to be completed.

Other nesting environment threats such as armoring, nourishment, or cleaning of the beach; motorized equipment; and non-native dune vegetation do not currently exist. Erosion, nest depredation, and other nest loss agents are not considered problems at present because every nest possible is moved to protected central corrals. At a future date, when increasing numbers of nests necessitate a change in management from corral protection to leaving the nests *in situ*, these factors will have to be addressed.

A threat that comes about due to management practices at Rancho Nuevo is the problem of concentrating all of the collected nests in corrals. This concentration makes the eggs more susceptible to reduced viability from manipulation, disease vectors and inundation. The former two do not seem to have been factors over the time of the binational project, but inundation was a severe problem in 1980 and 1983, drowning nests and reducing the overall percentage hatch by significant margins.

Direct exploitation of Kemp's ridley eggs occurred at the Rancho Nuevo nesting beach in the 1940s through the early 1960s prior to the initiation of protection of the beach in 1966 (Chavez *et al*. 1967). Prior to the late 1960s, the eggs were taken out in mule trains, by truck and by horseback (Hildebrand 1963). Hildebrand felt that continued exploitation could lead to the demise of the species, and he listed anecdotal information as to the disappearance of other arribada beaches to the south of Rancho Nuevo from heavy fishing and egg harvest pressures.

Dredging operations affect *L. kempii* through incidental take and by degrading the habitat. Incidental take of ridleys by hopper dredges has been documented. NMFS consulted with the COE in November 1991 and issued a biological opinion under Section 7 of the ESA finding that the unrestricted operation of hopper dredges from North Carolina to Cape Canaveral, Florida, jeopardized the continued existence of sea turtles, particularly Kemp's ridley. In addition to direct take, channelization of the inshore and nearshore areas can degrade foraging and migratory habitat through spoil dumping, degraded water quality/clarity and altered current flow.

Management

Because the presence of the Kemp's ridley is occasional throughout South Florida, there is no specific management ongoing for this species. Conservation measures to protect nesting beaches for sea turtles in general, however, will also benefit the Kemp's ridley. The following discussion is taken from the 1992 Recovery Plan for the Kemp's Ridley Sea Turtle (FWS and NMFS 1992), as examples of specific management and conservation measures being implemented for the species in Mexico.

The Kemp's ridley has been protected under U.S. law since its Federal listing as an endangered species on December 2, 1970. Protection from international trade has been afforded by CITES under which Kemp's is listed on Appendix 1. The species has been afforded some legal protection by Mexico since the 1960s. In 1977, a refuge was established at the only known nesting beach (Anon. 1977) and a Mexican presidential decree included the Rancho Nuevo nesting beach natural reserve as part of a system of reserves for sea turtles (Anon. 1986). On May 28, 1990 a complete ban on the taking of sea turtles was effected by Mexican presidential decree (Anon. 1990). In addition, the Mexican government Secretaria de Desarrollo Urbano y Ecologia and Secretaria de Pesca has proposed a national plan *"Programa Nacional de*

Proteccion y Conservation de Tortugas Marinas (Propuesta)" which could be a major force, if adopted and implemented, in the protection of all of the remaining sea turtle resources of Mexico (Anon. 1991).

Nesting beach protection in the vicinity of Rancho Nuevo has been significantly increased over the past two decades. The collaboration of Mexican and U. S. conservationists under Instituto Nacional de Pesca (INP) and FWS is now used as a model for an international multi-agency effort. Protection efforts on the Rancho Nuevo nesting beach were initiated in 1966 by the Mexican Government. From 1966 to 1977, an average of 23,000 hatchlings were released annually (FWS and NMFS 1992). From 1978 to 1991, under a cooperative beach patrol effort involving both FWS and INP, the number of released hatchlings was increased to a yearly average of 54,676 individuals. For adult females, a downward trend in population numbers continued through 1985, in spite of the efforts since 1966 to stop the egg poaching and harm to the nesting females on the beach. There has been an increase in the number of nests documented at Rancho Nuevo since 1985. The increase is in part due to wider coverage of the nesting beach by the binational protection team and in part due to increased numbers of nests laid. How much of the increase is attributable to new recruits to the nesting population versus increased efforts to patrol north and south of the reserve (after a dispersion of nesting females since Hurricane Gilbert altered large expanses of the primary nesting area) is difficult to say (Burchfield *et al*. 1990). Regardless of the recent apparent increase in nests laid, the view is quite different when all known nests are plotted over time since 1947. In this perspective, the recent increase is overwhelmed by the decline since 1947, and the numbers of nests seen since 1978 form little more than a horizontal line on the graph.

As far as we know, no adult turtle has suffered non-human predation on the beach since 1966 when the Mexican program began. Because of the intensive vigilance of the binational protection team, adequate motorized beach patrols ,and the presence of armed marines, poaching of adult turtles on the nesting beach has not been documented since 1980, and only occasionally is a clutch of eggs taken by humans.

Nearly all nests laid on the beach are moved the same day to fenced and guarded corrals near the camps. Hatching success has been improved in the corrals since the binational project began. The mean from 1987 to 1991 was 72 percent, nearly that of undepredated *in situ* nests. Almost all of the nests left *in situ* suffer predation, primarily by coyotes, skunks, and raccoons. The few missed nests that are discovered a day or more after being laid and are too old for safe transport to a corral are preferentially protected with plastic mesh *in situ* and monitored for hatching. Alternatively, if those older nests cannot be protected *in situ*, they are carefully transferred to a sandpacked styrofoam box for incubation at one of the camps.

Habitat research now underway promises to provide us with a much improved picture of the biology of this species. Netting studies in the northern Gulf of Mexico (Ogren 1989), east coast habitat use and tracking studies (Byles 1989, Standora *et al*. 1990), and adult migratory and wintering studies

(Byles 1988) are continuing. These studies will contribute considerably to our understanding of Kemp's ridley habitat use and requirements and thus to our ability to protect foraging and migratory habitats.

"Head-start" is the term used to describe the process whereby sea turtles are maintained in captivity for a period following hatching, so that the (presumably) very high neonatal mortality may be circumvented. The animals are released when they have outgrown threats from avian and the majority of non-avian predatory species. The Kemp's ridley head-start experiment began in 1978 as part of a complex, binational agreement to undertake several conservation and research measures at Rancho Nuevo, PAIS and at the NMFS Galveston Lab (Magnuson *et al.* 1990). The head-start experiment was undertaken as a last-ditch effort in the face of the alarming decline in turtles nesting at the Rancho Nuevo nesting beach. In 1977, when the project was conceived, protection of the beach lacked manpower and funds, and whether protection would continue was unclear. In fact, the major cause of mortality resulting from man's activity, shrimping, was just becoming established and no turtle excluder devices (TED) were available to eliminate this type of mortality. Currently, protection of the nesting beach is reasonably secure and TED regulations are in place and being expanded in the U.S. shrimp fleets, while Mexico is embarking on a program of TED placement in their shrimp fleets. Between 1978 and 1992, about 18,000 head-started Kemp's were released. In 1992, the program was ended.

Literature Cited

Anon. 1977. "Acuerdo que establece la zona de refugio y veda para la proteccion de la tortuga lora". Departamento de Pesca. Diario Oficial de la Federacion, julio 4 de 1977.

Anon. 1986. "Decreto de zonas de reservas y sitio de refucrio para la proteccion, conservacion, repoblacion, desarrollo y control de las diversas especies de tortugas marinas." Diario Oficial de la Federacion, 29 Octubre 1986.

Anon. 1988. Regulations implementing the pollution prevention requirements of annex V of Marpol 73/78. Federal Register 53(122):23884-23895.

Anon. 1990. Policy and guidelines for planning and coordinating recovery of endangered and threatened species. U.S. Department of the Interior, Fish and Wildlife Service, May 1990.

Anon. 1991 (Unpublished). Programa nacional de proteccion y conservation de tortugas marinas (Propuesta). Secretaria de Pesca and Secretaria de Desarrollo Urbano y Ecologia, Mexico.

Baur, G. 1890. The genera of the Cheloniidae. American Naturalist 24:486-487.

Bolten, A.B. and H.R. Martins. 1990. Kemp's ridley captured in the Azores. Marine Turtle Newsletter 48:23.

Bowen, B., A. Meylan and J. Avise. 1991. Evolutionary distinctiveness of the endangered Kemp's ridley sea turtle. Nature 352:709-711.

Brongersma, L. 1972. European Atlantic turtles. Zoologische Verhandelingen, Leiden.

Brongersma, L., and A. Carr. 1983. *Lepidochelys kempii* (Garman) from Malta. Proceedings of the Koninklljk Nederlandse Akademie van Wetenschappen, Amsterdam C 86(4):445-454.

Burchfield, P. M., R.Byles, J.V. Mongrell, D. Rostal and M. Bartlett. 1990 (Unpublished). Report on the Republic of Mexico/ United States of America Conservation effort on behalf of Kemp's ridley sea turtle at Playa de Rancho Nuevo, Tamaulipas, Mexico, 1989. Annual report to U.S. Fish & Wildlife Service.

Byles, R.A. 1988 (Unpublished). Satellite telemetry of Kemp's ridley sea turtle, *Lepidochelys kempii,* in the Gulf of Mexico. Report to the National Fish and Wildlife Foundation. December, 1988.

Byles, R.A. 1989. Distribution and abundance of Kemp's ridley sea turtle, *Lepidochelys kempii* in Chesapeake Bay and nearby coastal waters. Page 145 *in* C. W. Caillouet and A.M. Landry, eds. First international symposium on Kemp's ridley sea turtle biology, conservation and management. Texas A&M University; Galveston, Texas, October 1-4, 1985. TAMU-SG-89-105.

Carr, A.F. 1942. Notes on sea turtles. Proceedings of the New England Zoology Club 21:1-16.

Carr, A.F. 1952. Handbook of turtles. Cornell University Press; Ithaca, New York.

Carr, A.F. 1963. Panspecific reproductive convergence in *Lepidochelys kempii.* Ergebn. Biol., 26:298-303.

Carr, A., L. Ogren and C. McVea. 1980. Apparent hibernation by the Atlantic loggerhead turtle *Caretta caretta* off Cape Canaveral, Florida. Biological Conservation 19:7-14.

Chávez, H., M. Contreras y E. Hernandez D. 1967. Aspectos biologicos y proteccion de la tortuga lora, *Lepidochelys kempii* (Garman), en la costa de Tamaulipas, Mexico., I.N.I.B.P., Pub. 17.

Chávez, H., M. Contreras and E. Hernandez D. 1968a. On the coast of Tamaulipas. Part one. International Turtle and Tortoise Society Journal 2(4):20-29,37.

Chávez, H., M. Contreras and E. Hernandez D. 1968b. On the coast of Tamaulipas. Part two. International Turtle and Tortoise Society Journal, 2(5):16-19, 27-314.

Chávez, H. 1969. Tagging and recapture of the lora turtle *(Lepidochelys kempii*). International Turtle and Tortoise Society Journal 3:14-19, 32-36.

De Sola, C.R., and F. Aabrams. 1933. Testudinata from southeastern Georgia, including Okefenokee Swamp. Copeia 1933:1:10-12.

Dobie, James L., Larry H. Ogren and J. F. Fitzpatrick, Jr. 1961. Food notes and records of the Atlantic ridley turtle *(Lepidochelys kempii)* from Louisiana. Copeia 1961:109-110.

Ernst, C, H. and R. W. Barbour. 1972. Turtles of the United States. The University Press of Kentucky; Lexington, Kentucky.

Fontaine, C.T. and C.W. Caillouet. 1985. The Kemp's ridley sea turtle headstart research project: An annual report for fiscal year 1984. NOAA Technical Memorandum, NMFS-SEFC 152.

Fontaine, C.T., K. Marvin, T. Williams, W. Browning, R. Harris, K. Indelicato, G. Shattuck and R. Sadler. 1985. The husbandry of hatchling to yearling Kemp's ridley sea turtles *(Lepidochelys kempii).* NOAA, Technical Memorandum, NMFS-SEFC-158:iii.

Fontaine, C.T., T.D. Williams, S.A. Manzelia, and C. Caillouet. 1989. Kemp's ridley sea turtle head start operations of the NMFS SEFC Galveston Laboratory. Pages 96-110 *in:* Caillouet, C.W. and A.M. Landry eds., First International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management. Texas A&M University; Galveston, Texas, October 1-4, 1985. TAMU-SG-89-105:96-110.

Frair, W. 1982. Serum electrophoresis and sea turtle classification. Comparative Biochemistry and Physiology 72B:1-4.

Frazer, N.B. and L.M. Ehrhart. 1985. Preliminary growth models for green, *Chelonia mydas*, and loggerhead, *Caretta caretta*, turtles in the wild. Copeia 1985:73-79.

Garman, S. 1880. On certain species of Cheloniidae. Bulletin Museum of Comparative Zoology 6(6):123-126.

Groombridge, B. 1982. The IUCN Amphibia-reptilia red data book. part 1. Testudines, Crocodylia, Rhynchocephalia. International Union for Conservation of Nature and Natural Resources.

Hardy, J.D. Jr. 1962. Comments on the Atlantic ridley turtle, *Lepidochelys olivacea kempii*, in the Chesapeake Bay. Ches. Sci. 3:217-220.

Hendrickson, J.R. 1980. The ecological strategies of sea turtles. American Zoologist 20:597-608.

Henwood, T.A., and L.H. Ogren. 1987. Distribution and migrations of immature Kemp's ridley turtles *(Lepidochelys kempii)* and green turtles *(Chelonia mydas)* off Florida, Georgia, and South Carolina. Northeast Gulf Science 9(2):153-160.

Hildebrand, H. 1963. Hallazgo del area de anidacion de la tortuga "lora" *Lepidochelys kempii* (Garman), en la costa occidental del Golfo de Mexico (Rept., Chel.). Ciencia Mexicana 22(4):105112.

Hildebrand, H. 1982. A historical review of the status of sea turtle populations in the western Gulf of Mexico. Pages 447-453 *in* K. Bjorndal, ed. Biology and conservation of sea turtles. Proceedings world conference of sea turtle conservation. Smithsonian Institution Press; Washington, D.C.

Liner, E. A. 1954. The herpetofauna of Lafayette, Terrebone and Vermillion parishes, Louisiana. Louisiana Academy of Science 17:65-85.

Lutcavage, M., and J.A. Musick. 1985. Aspects of the biology of sea turtles in Virginia. Copeia 1985(2):449-456.

Magnuson, J.J., K.A. Bjorndal, W.D. DuPaul, G.L. Graham, D.W. Owens, P.C.H. Pritchard, J.I. Richardson, G.E. Saul and C.W. West. 1990. Decline of the Sea Turtles: Causes and Prevention. National Academy Press; Washington, D.C.

Márquez M., R. 1970 (Unpublished). Las tortugas marinas de Mexico. I.P.N., Escuela Nacional de Ciencias Biologias (Thesis).

Márquez M., R. 1972. Resultados preliminares sobre edad y crecimiento de la tortuga lora, *Lepidochelys kempii* (Garman). Mem. IV Concr. Nac. Ocean. 1969. Mexico. pp. 419-427.

Márquez M., R. 1990. FAO Species Catalogue. Sea turtles of the world. An annotated and illustrated catalogue of sea turtle species known to date. FAO Fisheries Synopsis. 125(l1). FAO, Rome.

Márquez, R. and M. Bauchot. 1987. Tortues. Pages 1423-1438 *in* W. Fischer, M. Schneider & M. Bauchot, eds. Mediterranee et Mer Noire, Zone de peche 37. Bol. 11 Vertebres. Fiches FAO D'identification des Especes pour les Besoins de la Peche.

Márquez, R., A. Villanueva and M. Sanchez. 1982. The population of Kemp's ridley sea turtle in the Gulf of Mexico, *Lepidochelys kempii*. Pages 159-164 *in* K. Bjorndal, ed. Biology and conservation of sea turtles. Proceedings world conference of sea turtle conservation. Smithsonian Institution Press; Washington, D.C.

Mendonca, M.T. and P.C.H. Pritchard. 1986. Offshore movements of post-nesting Kemp's ridley sea turtles *(Lepidochelys kempii)*. Herpetologica 42(3):373-380.

Meylan, A., B. Schroeder, and A. Mosier. 1995. Sea turtle nesting activity in the state of Florida 1979-1992. Florida Marine Research Publications Number 52; St. Petersburg, Florida.

Mowbray, L.S. and D.K. Caldwell. 1958. First record of the ridley turtle from Bermuda, with notes on other sea turtles and the turtle fishery in the islands. Copeia 1958, 2:147-148.

Montoya, E.A. 1966. Programa Nacional de Marcado de Tortugas Marinas. SIC, Inst. Nal. de Inv. Biologico Pesqueras-Mexico Pub.

Mortimer, J.A. 1982. Feeding ecology of sea turtles. Pages 103-109 *in:* Bjorndal, K. ed. Biology and conservation of sea turtles. Proceedings world conference of sea turtle conservation. Smithsonian Institution Press; Washington, D.C.

National Oceanographic and Atmospheric Administration [NOAA]. 1987. Final environmental impact statement listing and protecting the green sea turtle, loggerhead sea turtle, and Pacific ridley sea turtle under the Endangered Species Act of 1973. U.S. Department of Commerce, NOAA, NMFS. June 1987.

National Park Service [NPS]. 1985. Kemp's ridley sea turtle restoration and enhancement project, incubation and imprinting phase, 1985 report. Department of the Interior, National Park Service; Padre Island National Seashore.

Ogren, L.H. 1989. Distribution of juvenile and sub-adult Kemp's ridley sea turtle: Preliminary results from 1984-1987 surveys. Pages 116-123 *in* C. W. Caillouet, and A.M. Landry, eds. First International symposium on Kemp's ridley sea turtle biology, conservation and management. Texas A&M University; Galveston, Texas, October 1-4, 1985. TAMU-SG-89-105.

Pritchard, P.C.H. 1969. Studies of the systematics and reproductive cycles of the genus *Lepidochelys.* Ph.D, dissertation, University of Florida.

Pritchard, P. 1989. Evolutionary relationships, osteology, morphology, and zoogeography of Kemp's ridley sea turtle, Pages 157-164 *in:* Caillouet, C.W. and A.M. Landry eds. First international symposium on Kemp's Ridley sea turtle biology, conservation and management. Texas A&M University; Galveston, Texas, October 1-4, 1985., TAMU-SG-89-105.

Pritchard, P. 1990. Kemp's ridleys are rarer than we thought. Marine Turtle Newsletter 49:1-3.

Pritchard, P.C.H., and R. Marquez. 1973. Kemp's ridley or Atlantic ridley, *Lepidochelys kempii.* IUCN Monograph No. 2. (Marine Turtle Ser.).

Pritchard, P.C.H. and P. Trebbau. 1984. The turtles of Venezuela: Society for the Study of Amphibians and Reptiles. Contributions to Herpetology. No. 2.

Rostal, D.C. 1991 (Unpublished). The reproductive behavior and physiology of the Kemp's ridley sea turtle, *Lepidochelys kempii* (Garman, 1880). Ph.D. Dissertation, Texas A&M University; College Station, Texas.

Shaver, D.J. 1991a. Feeding ecology of wild and head-started Kemp's ridley sea turtles in south Texas waters. Journal of Herpetology 25(3):327-334.

Shaver, D.J. 1991b (Unpublished). Padre Island National Seashore Kemp's ridley sea turtle project 1991 report. Department of the Interior, National Park Service; Padre Island National Seashore, September 1991.

Smith, P.W., and J.C. List. 1950. Notes on Mississippi amphibians and reptiles. American Midland Naturalist 53(l):115-125.

Smith, H.M., and R.B. Smith. 1979. Synopsis of the herpetofauna of Mexico. VI. Guide to Mexican turtles. J. Johnson; North Bennington, Vermont.

Standora, E.A., S.J. Morreale, R. Estes, R. Thompson and M. Hilburger. 1989. Growth rates of juvenile ridleys and their movements in New York waters. Pages 175-178 *in* S. A. Eckert, K.L. Eckert and T.H. Richardson, compilers. Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA Technical Memorandum. NMFS-SEFC-232.

Standora, E.A., S.J. Morreale, R.D. Thompson and V.J. Burke. 1990. Telemetric monitoring of diving behavior and movements of juvenile Kemp's ridleys. Page 133 *in* T. H. Richardson, J.I. Richardson and M. Donnelly, compilers. Proceedings of the tenth annual workshop on sea turtle conservation and biology. NOAA Technical Memorandum. NMFS-SEFC-278.

Turtle Expert Working Group. 1998. An assessment of the Kemp's ridley *(Lepidochelys kempii)* and loggerhead *(Caretta caretta)* sea turtle populations in the Western North Atlantic. NOAA Technical Memorandum NMFS-SEFSC-409. 96 pp.

U.S. Fish and Wildllife Service [FWS]. June 30, 1998, News Release.

U.S. Fish and Wildlife Service [FWS] and National Marine Fisheries Service [NMFS]. 1992. Recovery plan for the Kemp's ridley sea turtle *Lepidochelys kempii.* National Marine Fisheries Service; St. Petersburg, Florida.

Wood, J.R., and F.E. Wood. 1984. Captive breeding in Kemp's ridley. Marine Turtle Newsletter 29:12.

Zug, G.R., and H.J. Kalb. 1989. Skeletochronological age estimates for juvenile *Lepidochelys kempii* from the Atlantic coast of North America. Pages 271-272 *in* Proceedings of the ninth annual workshop on sea turtle conservation and biology, 7-11 February 1989; Jekyll Island, Georgia.

Zwinenberg. A.J. 1977. Kemp's ridley, *Lepidochelys kempii* (Garman, 1880), undoubtedly the most endangered marine turtle today (with notes on the current status of (*Lepidochelys olivacea).* Bulletin of Maryland Herpetological Society 13(3):170-192.

Recovery for the Kemp's Ridley Sea Turtle

Lepidochelys kempii

Recovery Objective: DELIST the species once recovery criteria are met.

South Florida Contribution: SUPPORT delisting actions..

Recovery Criteria

The best scientific information available raises questions about whether the Kemp's ridley sea turtle utilizes nesting beaches within the coastal counties of South Florida. Unless new information demonstrates that this species occurs in South Florida, no recovery criteria will be developed or proposed as part of this recovery plan.

Species-level Recovery Actions

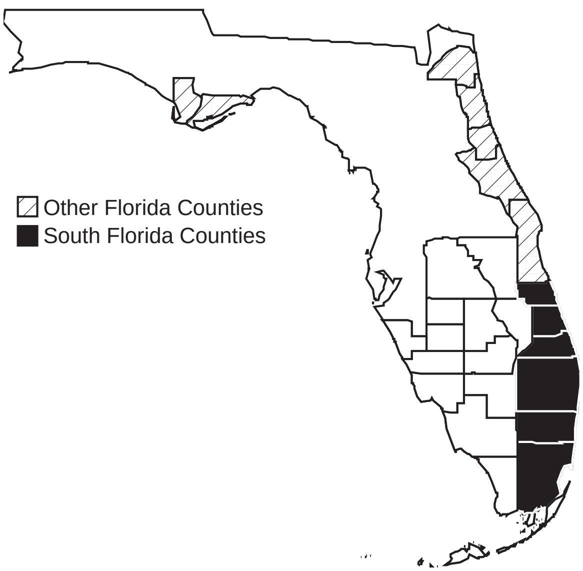
S1. Continue standardized surveys of nesting beaches to determine if Kemp's ridley sea turtles nest in South Florida. Nesting surveys are undertaken on the majority of nesting beaches. In the past, beach coverage varied from year to year, as did the frequency of surveys, experience and training of surveyors, and data reporting. Consequently, no determination of nesting population trends had been possible with any degree of certainty. However, in 1989, to better assess trends in nesting, DEP, in cooperation with FWS, initiated an Index Nesting Beach Survey (INBS) program to collect nesting data that can be used to statistically and scientifically analyze population trends. The INBS program should continue to gather a long-term data base on nesting activities in Florida that can be used as an index of nesting population trends.

Leatherback Sea Turtle

Dermochelys coriacea

Federal Status:	**Endangered (June 2, 1970)**
Critical Habitat:	**Designated (September 1978 and March 1979): Sandy Point, St. Croix, U.S.Virgin Islands, and surrounding waters.**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. Florida nesting distribution of the leatherback sea turtle.



The leatherback sea turtle is the largest of all the sea turtles. It is also unique among sea turtles, because instead of a bony carapace, it has leather-like outer skin in which is embedded a mosaic of small bones. The leatherback nests regularly in small numbers on the east coast of Florida. The nesting and hatching season extends from mid-February through mid-November. Sea turtles, in general, are susceptible to human changes to the marine environment, as well as to their nesting beaches. This account provides an overview of the biology of the leatherback sea turtle throughout its range. The discussion of environmental threats and management activities, however, pertains only to Florida and the U.S. Caribbean. Serious threats to the leatherback turtle on its nesting beaches include: artificial lighting, beach nourishment, increased human presence, and exotic beach and dune vegetation.

This account is from the 1992 Recovery Plan for Leatherback Turtles in the U.S. Caribbean, Atlantic, and Gulf of Mexico (NMFS and FWS 1992). Updated information is included only for South Florida.

Description

The leatherback sea turtle is the largest of the sea turtles and is so distinctive that it is placed in a separate family, Dermochelyidae. The leatherback sea turtle possesses a skeletal morphology unique among turtles (Rhodin *et al*. 1981) and recent karyological studies with this species (Medrano *et al*. 1987) support classifications which segregate extant sea turtle species into two distinct families (Gaffney 1975, 1984, Bickham and Carr 1983). All other extant sea turtles are in the family Cheloniidae.

The carapace of the leatherback sea turtle is also different from that of other sea turtles. Other sea turtles have bony plates covered with horny scutes on the carapace, while the slightly flexible carapace of the leatherback is distinguished by a rubber-like texture. The carapace of the leatherback is about 4 cm thick and is made primarily of tough, oil-saturated connective tissue raised into seven prominent longitudinal ridges and tapered to a blunt point posteriorly. A nearly continuous layer of small dermal bones lies just below the leathery outer skin of the carapace. No sharp angle is formed between the carapace and the plastron, resulting in a barrel-shaped appearance. The front flippers are proportionally longer than in other sea turtles and may span 270 cm in an adult. The leatherback's mean curved carapace length for adult females nesting in the U.S. Caribbean is 155 cm (range 137 to 176). On Sandy Point NWR, weights of 262 kg to 506 kg have been recorded (Eckert and Eckert 1985, Basford *et al*. 1986, Brandner *et al*. 1987). Adults and near adults captured in Virginia waters have ranged from 137 to 183 cm curved carapace length (NMFS and FWS 1992). Size and weight relationships calculated from adult females in St. Croix suggest the Virginia leatherbacks range in weight from 204 to 696 kg. The largest leatherback on record (a male stranded on the coast of Wales in 1988) weighed 916 kg (Morgan 1989).

Leatherback hatchlings are dorsally mostly black and covered with tiny polygonal or bead-like scales; the flippers are margined in white and rows of white scales appear as stripes along the length of the back. In the U.S. Virgin Islands hatchlings average 61.3 mm in straightline carapace length and 45.8 g in weight (Eckert *et al*. 1984). Both front and rear flippers lack claws. In the adult the epidermis is black (with varying degrees of pale spotting) and scaleless. This scaleless condition is unique among sea turtles. The undersurface is mottled, pinkish-white and black, the proportion of light to dark pigment being highly variable. In both adults and hatchlings, the upper jaw bears two tooth-like projections, each flanked by deep cusps, at the premaxillary-maxillary sutures (Pritchard 1971).

The crawl of the nesting leatherback is very deep and broad, with symmetrical diagonal marks left by the front flippers usually with a deep incised median groove formed by dragging of the relatively long tail (Pritchard *et al.* 1983).

The internal anatomy and physiology of the leatherback is also distinctive. The core body temperature, at least for adults in cold water, has been shown to be several degrees C above the ambient temperature (Frair *et al*. 1972). This may be due to several features, including the thermal inertia of a large body mass, an insulating layer of subepidermal fat, countercurrent heat exchangers in the flippers, potentially heat-generating brown adipose tissue, and a relatively low freezing point for lipids (Mrosovsky and Pritchard 1971, Friar *et al*. 1972, Greer *et al*. 1973, Neill and Stevens 1974, Goff and Stenson 1988, Davenport *et al*. 1990, Paladino *et al*. 1990). The skeleton of the leatherback remains extensively cartilaginous, even in adult animals, and the species is unique among turtles in showing an extensive cartilage canal vascular system in the epiphyseal regions (Rhodin *et al.* 1981).

Taxonomy

The generic name *Dermochelys* was introduced by Blainville (1816). The binomial refers to the distinctive leathery, scaleless skin of the adult turtle. The specific name *coriacea* was first used by Vandelli (1761) and adopted by Linneaus (1766) (see Rhodin and Smith 1982). Refer to Pritchard and Trebbau (1984) for a more detailed discussion of taxonomy and synonymy.

Juvenile leatherback sea turtle.
Original photograph courtesy of U.S. Fish and Wildlife Service.

Distribution

The wide-ranging leatherback sea turtle nests on shores of the Atlantic, Pacific and Indian Oceans. Non-breeding animals have been recorded as far north as the British Isles and the maritime Provinces of Canada and as far south as Argentina and the Cape of Good Hope (Pritchard 1992).

Efforts to determine the distribution and numbers of leatherback sea turtles in the marine environment have met with varying degrees of success. A 1987 aerial survey of shallow Gulf of Mexico waters (Perdido Bay, Alabama to Cape San Blas, Florida) described leatherbacks as “uncommon” in all study areas (though relatively more common in autumn than in spring), the highest density being 0.027 leatherbacks/100 km^2 offshore Louisiana in October (Lohoefener *et al*. 1988). Earlier surveys (April 1982 to February 1983) in the Atlantic revealed leatherbacks in the study area (Key West, Florida to Cape Hatteras, North Carolina, out to the western boundary of the Gulf Stream) year-round, but no density estimates were given (Thompson 1984). Thompson (1984) reported a significant negative correlation between leatherbacks and water temperature in the spring, fall and winter, suggesting that the species is not dependent upon warm temperatures and is likely to be associated with cooler, perhaps more productive waters. The same study reported that leatherbacks appeared to prefer water about 20°C (± 5°) and were rarely sighted in the Gulf Stream sampling areas. Summarizing incidental catch and interview data (1897 to 1980), as well as at-sea observations recorded during shore to Gulf Stream summer transects, Lee and Palmer (1981) also concluded that (at least off North Carolina) leatherbacks were rarely seen in the Gulf Stream and were most often seen in waters < 915 m in depth.

A survey conducted during March 1982 to August 1984, but restricted to the Cape Canaveral area, reported that 94.5 percent of all leatherback sightings (n=128 total) occurred east of the 20 m isobath, and 90.6 percent occurred during the summer (Schroeder and Thompson 1987). In contrast, New England Aquarium surveys of Florida and Georgia (1984 to 1988) reported few leatherbacks prior to 1988, but in mid-February of that year 168 leatherbacks were sighted along the northeast coast of Florida, with peak densities reported along 80 km of coastline between Daytona Beach and Cape Canaveral (Knowlton and Weigle 1989). The impetus for this sudden winter abundance in Florida nearshore waters is unknown; by the following survey (16 March) the animals had disappeared (Knowlton and Weigle 1989). The extent to which distribution and abundance are defined by transient phenomena is presently unclear.

A 1979 aerial survey of the mid- and north-Atlantic areas of the U.S. Outer Continental Shelf (shoreline to the surface projection of the 2,000 m isobath) between Cape Hatteras, North Carolina and Cape Sable, Nova Scotia, showed leatherbacks to be present April to November throughout the study area (but most likely to be observed from the Gulf of Maine south to Long Island); peak estimates of relative abundances during the summer were in the hundreds (Shoop *et al*. 1981). The same study concluded that leatherbacks were observed more frequently in colder waters at higher latitudes during the summer than were other sea turtle species.

Nesting grounds for the leatherback are distributed circumglobally (ca. 40°N to 35°S; Sternberg 1981), with the Pacific coast of Mexico supporting the world's largest known concentration of nesting turtles. Pritchard (1982) estimates that 115,000 adult female leatherbacks remain worldwide and that some 50 percent of them may nest in western Mexico. The largest nesting colony in the wider Caribbean region is found at Ya:lima:po-Les Hattes, French Guiana, where the total number of adult females is estimated to be 14,700 to 15,300 (Fretey and Girondot 1989). Lower density Caribbean nesting is also reported from Surinam (Pritchard 1973, Schulz 1975), Guyana (Pritchard 1988a,b), Colombia and Venezuela (Pritchard and Trebbau 1984), Panama (Meylan *et al*. 1985, Garcia 1987), and Costa Rica (e.g., Carr and Ogren 1959, Hirth and Ogren 1987).

On the islands of the eastern Caribbean, Bacon (1970) estimated that 150 to 200 leatherbacks nested annually in Trinidad, primarily at Matura and Paria bays. Shortly thereafter, Bacon and Maliphant (1971) indicated that perhaps 200 to 250 leatherbacks nested annually in Trinidad; recent population estimates are not available. Nesting north of Trinidad in the Lesser and Greater Antilles is predictable, but occurs nowhere in large numbers (Caldwell and Rathjen 1969, Carr *et al*. 1982, Meylan 1983). The largest sub-regional nesting colony is in the Dominican Republic, where an estimated 300 leatherbacks nest annually (Ross and Ottenwalder 1983). The U.S. Caribbean supports relatively minor nesting colonies (probably 150-200 adult females per annum, combined) but represents the most significant nesting activity within the U.S.

Leatherback nesting in the U.S. Caribbean is reported from the Virgin Islands (St. Croix, St. Thomas, St. John) and Puerto Rico, including Islas Culebra, Vieques, and Mona. The total number of nests deposited annually on Sandy Point NWR has ranged from 82 (1986) to 355 (1994) (Eckert and Eckert 1985, Basford *et al*. 1986, 1988, McDonald *et al*. 1991, 1992, 1993, 1994). On

Isla Culebra, the colony is smaller (88 to 271 nests per year 1984 to 1995, Tallevast *et al*. 1990, FWS unpublished reports). Playas Resaca and Brava receive 91 to 100 percent of all leatherback nesting on Culebra (Tucker 1988).

Throughout the southeastern U.S. the geography of beach coverage is more or less complete, but the timing is often inadequate to gain a complete picture of leatherback nesting. Beach patrols generally commence in May and are designed to maximize observations of leatherback sea turtle nests. However, leatherbacks have been known to start nesting as early as late February or March, thus, current data may slightly underestimate the actual nesting activity. Leatherback nests reported from Florida and Georgia are probably deposited by 10 to 25 females annually. Leatherback turtles have been known to nest in Georgia and South Carolina, but only on rare occasions. Hildebrand (1963) was informed by a resident of Padre Island, Texas that a few nesting individuals had been seen on the island in the 1930s, but none in recent years.

Leatherback nesting in Florida was once considered extremely rare (Carr 1952, Caldwell *et al*. 1956, Allen and Neill 1957). However, the leatherback is now known to nest regularly in small numbers on Florida's east coast (Meylan *et al*. 1995). Leatherback nesting has also been reported on the west coast of Florida on St. Vincent NWR (LeBuff 1990), St. Joseph Peninsula State Park and St. George Island (S. MacPherson, FWS, personal communication 1997). In South Florida, leatherbacks have been observed on nesting beaches in Indian River, St. Lucie, Martin, Palm Beach, Broward and Miami-Dade counties on the east coast (Figure 1).

Virtually nothing is known of the pelagic distribution of hatchling or juvenile leatherback turtles. The paths taken by hatchlings leaving their natal beaches are uncharted. Discussions of the "lost year" (the early pelagic stage of sea turtle development) which include tabulated summaries of neonate and juvenile sea turtles associated with *Sargassum* weed or taken from pelagic habitats (e.g., Carr 1987) have not mentioned sightings of young *Dermochelys.* Our knowledge of juvenile distribution rests on a handful of chance observations, and includes sightings in waters within (Caldwell 1959, Johnson 1989) and outside (e.g., Brongersma 1970, Hughes 1974, Pritchard 1977, Horrocks 1987) the U.S.

Strandings

Leatherbacks stranding on U.S. shores are generally of adult or near adult size, demonstrating the importance of pelagic habitat under U.S. jurisdiction to turtles breeding in tropical and subtropical latitudes. Direct evidence of this is available from Caribbean and South American tagged turtles stranding on U.S. shores. Nesters tagged in French Guiana subsequently stranded in Georgia (NMFS and FWS 1992), as well as in New York (NMFS and FWS 1992), New Jersey, South Carolina, and Texas (Pritchard 1976). Nesters tagged in Trinidad and St. Croix subsequently stranded in New York (Lambie 1983) and New Jersey (Boulon *et al*. 1988), respectively. Conversely, an individual tagged in Virginia waters in 1985 was killed a year later in Cuba (Barnard *et al*. 1989). Additional evidence of the importance of U.S. coastal waters for leatherbacks is provided by the Sea Turtle Stranding and Salvage Network. During the period 1980 to 1991, 816 leatherback strandings were recorded along the continental U.S. coastline. During this same period, 161 leatherbacks were recovered dead along Florida's coast. Curved carapace lengths for the Florida strandings ranged from 110 to 195 cm. Eighty-four percent of all leatherback strandings in Florida occurred between January to April and October to December. Strandings were lowest (16 percent) during summer months, May to September.

Habitat

Adult leatherback sea turtles are highly migratory and believed to be the most pelagic of all sea turtles. Habitat requirements for juvenile and post-hatchling leatherbacks, however, are virtually unknown. Nesting females prefer high-energy beaches with deep, unobstructed access (Hirth 1980, Mrosovsky 1983), which occur most frequently along continental shorelines (Hendrickson 1980).

Critical Habitat

Critical habitat was designated for the leatherback sea turtle in September 1978 and March 1979. Although the designation did not include Florida, is does include nesting beach on Sandy Point, St. Croix and the surrounding waters. Critical habitat for leatherback sea turtles identify specific areas which have those physical or biological features essential to the conservation of the leatherback sea turtle and/or may require special management considerations.

Behavior

Reproduction and Demography

Mating behavior of the leatherback is described by Carr and Carr (1986) in waters off Puerto Rico, though there is some indirect evidence that mating typically occurs prior to (or during) migration to the nesting ground (Eckert and Eckert 1988). Nesting behavior (i.e., the basic sequence entailing beaching, ascent, selection of a suitable site, "body pitting", egg chamber excavation, oviposition, nest filling and camouflage, departure) is similar to that of other marine turtle species (detailed descriptions in Deraniyagala 1936, Carr and Ogren 1959). Gravid females emerge from the sea nocturnally; diurnal nesting occurs only occasionally. Because of a proclivity for nesting in high-energy and thus frequently unpredictable environments, it is not uncommon that large numbers of eggs are lost to erosion (Bacon 1970, Pritchard 1971, Hughes 1974, Mrosovsky 1983, Eckert 1987), though this is not always the case (Tucker 1989). While the majority of females return to the same nesting beach repeatedly throughout the nesting season, some females are known to nest on separate beaches > 100 km apart within a season.

In the U.S. Caribbean, nesting commences in March (a very few nests are laid in February) and continues into July. The most systematic data available on reproductive output has been gathered at Sandy Point NWR and Isla Culebra. Data from these projects reveal that females arrive at the nesting beach asynchronously, renest an average of every 9 to 10 days, deposit 5 to 7 nests per annum (observed maximum = 11), and remigrate predominantly at 2 to 3 year intervals. The annual nest : false crawl ratio on Culebra (all beaches) is 4:1 to

6.2:1 (1984 to 1987; Tucker 1988); 1.2:1 to 3:1 on Sandy Point (1982-1988; NMFS and FWS 1992). Clutch size averages 116 eggs, including 80 yolked eggs, on Sandy Point NWR, 103 eggs, including 70 yolked eggs, on Culebra. Clutch size averages 101 eggs, including 76 yolked, on Hutchinson Island, Florida (NMFS and FWS 1992). Similar clutch sizes are reported elsewhere on St. Croix (Adams 1988) and Puerto Rico (Matos 1986, 1987), as well as in Georgia (Ruckdeschel *et al*. 1982) and Florida (Carr 1952, Caldwell 1959, Broward County Erosion Prevention District/Environmental Quality Control Board--now Department of Natural Resource Protection--1987). Eggs incubate for 55 to 75 days, consistently averaging 63 days on both Sandy Point and Culebra and 64 days on Hutchinson Island, Florida. *In situ* hatch success for nests surviving to term is about 55 percent on Manchenil Bay, St. Croix (Adams 1988), about 65 percent on Sandy Point NWR (Eckert and Eckert 1985, Brandner *et al*. 1987, 1990), and about 66 percent on Hutchison Island, Florida (NMFS and FWS 1992). Higher success (about 75 percent) is reported on Culebra (Tucker 1988, 1989).

No data on the growth rate of juvenile leatherback turtles in the wild are available. This situation arises from the unfortunate fact that the distribution of juvenile leatherback turtles is unknown, and thus specimens are unavailable for capture-recapture methodologies designed to measure growth. The problem is exacerbated by poor survivability in captivity, which further limits opportunities for study. Nonetheless, some investigators have been successful in raising leatherbacks and publishing data on captive growth rates (Deraniyagala 1936, Glusing 1967, Frair 1970, Spoczynska 1970, Phillips 1977, Witham 1977, Bels *et al*. 1988). With the exception of Bels *et al*. (1988), turtles did not survive beyond 2 years.

Captive growth data are widely disparate, but the very rapid growth reported by some investigators (coupled with evidence of chondro-osseous development conducive to rapid growth) has led to speculations that leatherbacks may reach sexual maturity in 2 to 3 years (Rhodin 1985). Bels *et al*. (1988) challenge this hypothesis in their report of a healthy captive leatherback 1,200 days of age weighing 28.5 kg, with a carapace 82 cm in length. While leatherbacks may grow to sexual maturity at an earlier age than other sea turtles, it is clear that more data are needed before growth rates can be accurately calculated.

Migration

The leatherback migrates farther (Pritchard 1976) and ventures into colder water than does any other marine reptile (e.g., Threlfall 1978, Goff and Lien 1988). The evidence currently available from tag returns and strandings in the western Atlantic suggests that adults engage in routine migrations between boreal, temperate and tropical waters, presumably to optimize both foraging and nesting opportunities (Bleakney 1965, Pritchard 1976, Lazell 1980, Rhodin and Schoelkopf 1982, Boulon *et al*. 1988). The composition of epibiotic barnacle communities on Caribbean-nesting leatherbacks provides indirect evidence that gravid females embark from and subsequently return to temperate latitudes (Eckert and Eckert 1988).

Direct evidence of long-distance movement is scarce, but is available from leatherbacks tagged while nesting in the Caribbean and subsequently stranding in northern latitudes (Pritchard 1973, 1976, Lambie 1983, Boulon *et al*. 1988); and also from a turtle tagged in Chesapeake Bay in 1985 and killed in Cuba in 1986 (Barnard *et al*. 1989). In addition, a nester tagged at Jupiter Beach, Florida, was recaptured near Cayo Arcas, Gulf of Campeche (Hildebrand 1987), and a nester tagged at Sandy Point NWR, St. Croix, was recaptured near Cayos Triangulos, also in the Gulf of Campeche, 2 years later and some 3,000 km from the tagging site (Boulon 1989). The longest known movement is that of an adult female who traveled 5,900 km to Ghana, West Africa, after nesting in Surinam (Pritchard 1973). An adult female tagged with a satellite transmitter while nesting in French Guiana in 1986 traveled 820 km in three weeks (an average speed of 40 km/day, Duron-DuFrenne 1987). A nester tagged with a satellite transmitter on Sandy Point NWR, St. Croix in 1989 travelled 515 km (and ventured some 200 km south of St. Croix) before the transmitter was removed 18 days later when the turtle emerged to nest on Isla Culebra (NMFS and FWS 1992).

Foraging

Food habits are known primarily from the stomach samples of slaughtered animals (Brongersma 1969, Hartog 1980, Hartog and Van Nierop 1984). Leatherbacks feed on pelagic medusae (jellyfish), siphonophores, and salpae in temperate and boreal latitudes (e.g., Bleakney 1965, Brongersma 1969, Duron 1978, Eisenberg and Frazier 1983, Musick 1988). Aerial surveys document leatherbacks in Virginia waters, especially May to July during peak jellyfish *(Chrysaora* spp*., Aurelia* spp.*)* abundance (Musick 1988, NMFS and FWS 1992). Further south, foraging on the cabbage head jellyfish *(Stomolophus meleagris)* has been observed in waters off North Carolina (NMFS and FWS 1992). In February 1989, an adult female leatherback (originally tagged in French Guiana) stranded on the Georgia coast and stomach contents revealed unidentified medusae and *Libinia* sp., a small crab commensal on *Stomolophus* (NMFS and FWS 1992). Captain Joe Webster has observed leatherbacks feeding on “jellyballs” *(Stomolophus)* in Georgia waters and notes that the turtles are seen in water as shallow as 5.6 m where jellyballs are abundant (NMFS and FWS 1992). In the Gulf of Mexico, aerial survey data often show leatherbacks associated with *Stomolophus* (Leary 1957, Lohoefener *et al*. 1988). Other observers have also reported a “co-incidence” of leatherbacks and maximum jellyfish abundance, especially *Aurelia,* in the Gulf (NMFS and FWS 1992).

Foraging has most often been observed at the surface, but Hartog (1980) after finding nematocysts from deep water siphonophores in leatherback stomach samples, speculated that foraging may occur at depth. Limpus (1984) reported a leatherback feeding on octopus bait on a handline at 50 m depth off western Australia. Based on offshore studies of diving by adult females nesting on St. Croix, Eckert *et al*. (1989) proposed that the observed internesting dive behavior reflected nocturnal feeding within the deep scattering layer (strata comprised primarily of vertically migrating zooplankters, chiefly siphonophore and salp colonies in the Caribbean, (Michel and Foyo 1976). Eckert *et al*. (1989) calculate a maximum dive depth of 1,300 m, but report that 95 percent of all dives are < 20 minutes in length and < 200 m in depth.

Relationship to Other Species

In South Florida, the leatherback sea turtle shares nesting beaches with the threatened loggerhead turtle (*Caretta caretta*) and the endangered green sea turtle (*Chelonia mydas*) in several counties where it nests, most commonly in Martin and Palm Beach counties. Other federally listed species that occur in coastal dune and coastal strand habitat, and that need to be considered when managing nesting beaches, are the southeastern beach mouse (*Peromyscus polionotus niveiventris*) and the beach jacquemontia (*Jacquemontia reclinata*). Beach nourishment projects, in particular, could affect these species as well as the turtles. The range of the beach mouse in South Florida is estimated to include Indian River County south to Broward County. The beach jacquemontia is found in Palm Beach County south to Miami, Miami-Dade County.

A variety of natural and introduced predators such as raccoons (*Procyon lotor*), feral hogs, opossums (*Didelphis virginiana*), ghost crabs (*Ocypode quadratus*), and ants prey on incubating eggs and hatchlings. The principal predator of leatherback sea turtle eggs is the raccoon. Raccoons are particularly destructive and may take up to 96 percent of all nests deposited on a beach (Davis and Whiting 1977, Hopkins and Murphy 1980, Stancyk *et al.* 1980, Talbert *et al.* 1980, Schroeder 1981, Labisky *et al.* 1986). In 1996, Hobe Sound NWR experienced depredation in 23 percent of the nests enumerated. In addition to the destruction of eggs, certain predators may take considerable numbers of hatchlings just prior to or upon emergence from the sand.

Table 1. Average number of leatherback nests by

County	Average
Indian River*	3.3
St. Lucie	14
Martin	43
Palm Beach	66
Broward	10
Dade	3.2
Monroe**	-
Collier**	-
Lee**	-
Charlotte**	-
Sarasota**	-

*Nesting activity reported from 1993-1995 only
**Nesting activity not reported

Status and Trends

The leatherback sea turtle was listed as endangered under the Endangered Species Act on June 2, 1970 (35 FR 8495). Internationally, it is considered "endangered" by the International Union for Conservation of Nature and Natural Resources (IUCN). It is also included on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which the U.S. ratified in 1974. The nesting beach at Sandy Point NWR, St. Croix, became the first nesting beach of any marine turtle to be proposed as critical habitat (Federal Register, 23 March 1978; 43 FR 12050-12051) (Dodd 1978). In September 1978, the FWS designated the nesting beach on Sandy Point, St. Croix, as critical habitat; in March 1979, the NMFS determined the surrounding waters as critical habitat.

Declines in the number of nesting females have been documented in Malaysia (Brahim *et al*. 1987), India (Cameron 1923, Kar and Bhaskar 1982), Thailand (Polunin 1977), and the West Indies (Bacon 1970, Eckert and Lettsome 1988, Eckert 1989). It is not known whether leatherback populations within the U.S. are stable, increasing or declining, but there is no question that some nesting populations (*e.g.*, St. John, St. Thomas) have been virtually exterminated. The number of leatherbacks nesting in the past at what is now Sandy Point NWR is unknown, but studies of the population since 1981 show annual fluctuations which do not project a long-term decline.

Today, most beaches in Florida are monitored for sea turtle nesting. Here, leatherback nesting has fluctuated widely during the survey period between 1979 and 1994 (Meylan *et al.* 1995, DEP 1996). Between 1988 and 1992, annual reported leatherback sea turtle nests varied between 98 and 188 statewide. The distribution of these nests differs from the loggerhead and green sea turtle nests. Leatherback nests have a center of distribution at Palm Beach County which supports half of the total nests reported throughout Florida. Martin and St. Lucie county beaches have been the site of 27.7 percent and 13.2 percent of leatherback nests, respectively. South of Palm Beach County, the number of leatherback nests declines more sharply. Broward County supported 3.0 percent of leatherback nesting and Miami-Dade County supported 1.6 percent.

The average number of nests annually for leatherback turtles within South Florida is shown in Table 1. These data show that Palm Beach County is clearly the most important nesting location within the region for the endangered leatherback. Leatherback nests constitute 0.8 percent of the total in Palm Beach County but only 0.4 and 0.5 percent in Broward and Miami-Dade Counties, respectively. We chose to represent only the past 10 years of survey data in Table 1, because there was less beach surveyed and the data were not complete prior to 1985.

Environmental Threats

A number of threats exist to sea turtles in the marine environment, including: oil and gas exploration, development, and transportation; pollution; trawl, purse seine, hook and line, gill net, pound net, longline, and trap fisheries; underwater explosions; dredging; offshore artificial lighting; power plant entrapment; entanglement in debris; ingestion of marine debris; marina and dock development; boat collisions; and poaching. These threats and protective measures are discussed in detail in the Recovery Plan for Leatherback Turtles in the U.S. Caribbean, Atlantic and Gulf of Mexico (NMFS and FWS 1992). In South Florida, and for this Recovery Plan, we are focusing on the threats to nesting beaches, including: beach erosion, armoring and nourishment; artificial lighting; beach cleaning; increased human presence; recreational beach equipment; exotic dune and beach vegetation; nest loss to abiotic factors; and poaching.

Beach Erosion: Erosion of nesting beaches can result in partial or total loss of suitable nesting habitat. Erosion rates are influenced by dynamic coastal processes, including sea level rise. Man's interference with these natural processes through coastal development and associated activities has resulted in accelerated erosion rates and interruption of natural shoreline migration (National Research Council 1990).

Beach Armoring: Where beachfront development occurs, the site is often fortified to protect the property from erosion. Virtually all shoreline engineering is carried out to save structures, not dry sandy beaches, and ultimately results in environmental damage. One type of shoreline engineering, collectively referred to as beach armoring, includes sea walls, rock revetments, riprap, sandbag installations, groins and jetties. Beach armoring can result in permanent loss of a dry nesting beach through accelerated erosion and prevention of natural beach/dune accretion and can prevent or hamper nesting females from accessing suitable nesting sites. Clutches deposited seaward of these structures may be inundated at high tide or washed out entirely by increased wave action near the base of these structures.

As these structures fail and break apart, they spread debris on the beach trapping both adults and hatchlings, thus impeding access to suitable nesting areas and causing higher incidences of false crawls (non-nesting emergences). Sandbags are particularly susceptible to rapid failure and result in extensive debris on nesting beaches. Rock revetments, riprap, and sandbags can cause nesting turtles to abandon nesting attempts or to construct improperly sized and shaped egg cavities when inadequate amounts of sand cover these structures. Information obtained during preparation of the sea turtle recovery plans indicated that approximately 21 percent (234 km) of Florida's beaches were armored at that time (NMFS and FWS 1992).

Groins and jetties are designed to trap sand during transport in longshore currents or to keep sand from flowing into channels in the case of the latter. These structures prevent normal sand transport and accrete beaches on one side, of the structure while starving neighboring beaches on the other side thereby resulting in severe beach erosion (Pilkey *et al.* 1984) and corresponding degradation of suitable nesting habitat.

Drift fences, also commonly called sand fences, are erected to build and stabilize dunes by trapping sand moving along the beach and preventing excessive sand loss. Additionally, these fences can serve to protect dune systems by deterring public access. Constructed of narrowly spaced wooden or plastic slats or plastic fabric, drift fences when improperly placed can impede nesting attempts and/or trap emergent hatchlings and nesting females.

Beach Nourishment: Beach nourishment consists of pumping, trucking, or scraping sand onto the beach to rebuild what has been lost to erosion. Although beach nourishment may increase the potential nesting area, significant adverse effects to sea turtles may result if protective measures are not taken. Placement of sand on an eroded section of beach or an existing beach in and of itself may not provide suitable nesting habitat for sea turtles.

Beach nourishment can impact turtles through direct burial of nests and by disturbance to nesting turtles if conducted during the nesting season. Beach nourishment may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content, if the placed sand is dissimilar from the original beach sand (Nelson and Dickerson 1988a). These changes can affect nest site selection, digging behavior, incubation temperature (and hence sex ratios), gas exchange parameters within incubating nests, hydric environment of the nest, hatching success and hatchling emerging success (Mann 1977, Ackerman 1980, Mortimer 1982, Raymond 1984a).

Beach compaction and unnatural beach profiles that may result from beach nourishment activities could adversely affect sea turtles regardless of the timing of the projects. Very fine sand and/or the use of heavy machinery can cause sand compaction on nourished beaches (Nelson and Dickerson 1988a). Significant reductions in nesting success have been documented on severely compacted nourished beaches (Raymond 1984a). Increased false crawls result in increased physiological stress to nesting females. Sand compaction may increase the length of time required for female sea turtles to excavate nests, also causing increased physiological stress to the animals (Nelson and Dickerson 1988c). Nelson and Dickerson (1988b) evaluated compaction levels at 10 renourished east coast Florida beaches and concluded that 50 percent were hard enough to inhibit nest digging, 30 percent were questionable as to whether their hardness affected nest digging, and 20 percent were probably not hard enough to affect nest digging. They further concluded that, in general, beaches nourished from offshore borrow sites are harder than natural beaches, and, while some may soften over time through erosion and accretion of sand, others may remain hard for 10 years or more.

On nourished beaches, steep escarpments may develop along their water line interface as they adjust from an unnatural construction profile to a more natural beach profile (Coastal Engineering Research Center 1984, Nelson and Dickerson 1987). These escarpments can hamper or prevent access to nesting sites. Female turtles coming ashore to nest can be discouraged by the formation of an escarpment, leading to situations where they choose marginal or unsuitable nesting areas to deposit eggs (e.g., in front of the escarpments, which often results in failure of nests due to repeated tidal inundation). This effect can be minimized by leveling the beach prior to the nesting season.

A change in sediment color due to beach nourishment could change the natural incubation temperatures of nests. This, in turn, could alter natural sex ratios. To provide the most suitable sediment for nesting sea turtles, the color of the nourished sediments must resemble the natural beach sand in the area. Natural reworking of sediments and bleaching from exposure to the sun would help to lighten dark nourishment sediments; however, the time frame for sediment mixing and bleaching to occur could be critical to a successful sea turtle nesting season.

Nourishment projects result in heavy machinery, pipelines, increased human activity and artificial lighting on the project beach. These activities are normally conducted on a 24-hour basis and can adversely affect nesting and hatching activities. Pipelines and heavy machinery can create barriers to nesting females emerging from the surf and crawling up the beach, causing a higher incidence of false crawls (non-nesting emergences) and an unnecessary energy expenditure. Increased human activity on the project beach at night may cause further disturbance to nesting females. Artificial lights along the project beach and in the nearshore area of the borrow site may deter nesting females and disorient or misorient emergent hatchlings from adjacent non-project beaches.

Beach nourishment projects require continual maintenance (subsequent nourishment) as beaches erode; therefore their negative impacts to turtles are repeated on a regular basis. Nourishment of highly eroded beaches (especially those with a complete absence of dry beach) can be beneficial to nesting turtles if conducted properly. Careful consideration and advance planning and coordination must be carried out to ensure timing, methodology, and sand sources are compatible with nesting and hatching requirements.

Artificial Lighting: Extensive research has demonstrated that the principal component of the sea finding behavior of emergent hatchlings is a visual response to light (Daniel and Smith 1947, Hendrickson 1958, Carr and Ogren 1960, Ehrenfeld and Carr 1967, Dickerson and Nelson 1989, Witherington and Bjorndal 1991). Artificial beachfront lighting from buildings, streetlights, dune crossovers, vehicles and other types of beachfront lights have been documented in the disorientation (loss of bearings) and misorientation (incorrect orientation) of hatchling turtles (McFarlane 1963, Philibosian 1976, Mann 1977, Ehrhart 1983).

The results of disorientation or misorientation are often fatal. Many lighting ordinance requirements do not become effective until 11 p.m., whereas over 30 percent of hatchling emergence occurs prior to this time (Witherington *et al.* 1990). As hatchlings head toward lights or meander along the beach, their exposure to predators and likelihood of desiccation is greatly increased. Misoriented hatchlings can become entrapped in vegetation or debris, and many hatchlings are found dead on nearby roadways and in parking lots after being struck by vehicles. Hatchlings that successfully find the water may be misoriented after entering the surf zone or while in nearshore waters. Intense artificial lighting can even draw hatchlings back out of the surf (Daniel and Smith 1947, Carr and Ogren 1960). During the period 1989 to 1990, a total of 37,159 misoriented hatchlings were reported to the Florida Department of Natural Resources. Undoubtedly a large but unquantifiable number of additional misorientation events occurred but were not documented due to obliteration of observable sign, depredation, entrapment in thick vegetation, loss in storm drains, or obliteration of carcasses by vehicle tires.

The problem of artificial beachfront lighting is not restricted to hatchlings. Raymond (1984a) indicated that adult loggerhead emergence patterns were correlated with variations in beachfront lighting in south Brevard County, Florida, and that nesting females avoided areas where beachfront lights were the most intense. Witherington (1986) noted that loggerheads aborted nesting attempts at a greater frequency in lighted areas. Problem lights may not be restricted to those placed directly on or in close proximity to nesting beaches. The background glow associated with intensive inland lighting, such as that emanating from nearby large metropolitan areas, may deter nesting females and disorient or misorient hatchlings navigating the nearshore waters. Cumulatively, along the heavily developed beaches of the southeastern U.S., the negative effects of artificial lights are profound.

Beach Cleaning: Beach cleaning refers to the removal of both abiotic and biotic debris from developed beaches. There are several methods employed including mechanical raking, hand raking, and picking up debris by hand. Mechanical raking can result in heavy machinery repeatedly traversing nests and potentially compacting sand above nests and also results in tire ruts along the beach, which may hinder or trap emergent hatchlings. Mann (1977) suggested that mortality within nests may increase when externally applied pressure from beach cleaning machinery is exerted on soft beaches with large grain sand. Mechanically pulled rakes and hand rakes can penetrate the surface and disturb the sealed nest or may actually uncover pre-emergent hatchlings near the surface of the nest. In some areas, collected debris is buried directly on the beach, and this can lead to excavation and destruction of incubating egg clutches. Disposal of debris near the dune line or on the high beach can cover incubating egg clutches and subsequently hinder and entrap emergent hatchlings and may alter natural nest temperatures.

Increased Human Presence: Residential and tourist use of developed (and developing) nesting beaches can result in negative impacts to nesting turtles, incubating egg clutches, and hatchlings. The most serious threat caused by increased human presence on the beach is the disturbance to nesting females.

Nighttime human activity can cause nesting females to abort nesting attempts at all stages of the behavioral process. Murphy (1985) reported that disturbance can cause turtles to shift their nesting beaches, delay egg laying, and select poor nesting sites. Heavy utilization of nesting beaches by humans (pedestrian traffic) may result in lowered hatchling emerging success rates due to compaction of sand above nests (Mann 1977), and pedestrian tracks can interfere with the ability of hatchlings to reach the ocean (Hosier *et al.* 1981). Campfires and the use of flashlights on nesting beaches misorient hatchlings and can deter nesting females (Mortimer 1979).

Recreational Beach Equipment: The placement of physical obstacles (e.g., lounge chairs, cabanas, umbrellas, Hobie cats, canoes, small boats and beach cycles) on nesting beaches can hamper or deter nesting attempts and interfere with incubating egg clutches and the sea approach of hatchlings. The documentation of false crawls at these obstacles is becoming increasingly common as more recreational beach equipment is left in place nightly on nesting beaches. Additionally, there are documented reports of nesting females becoming entrapped under heavy wooden lounge chairs and cabanas on South Florida nesting beaches (NMFS and FWS 1992). The placement of recreational beach equipment directly above incubating egg clutches may hamper hatchlings during emergence and can destroy eggs through direct invasion of the nest (NMFS and FWS 1992).

Exotic Dune and Beach Vegetation: Non-native vegetation has invaded many coastal areas and often outcompetes native species such as sea oats, railroad vine, sea grape, dune panic grass and pennywort. The invasion of less stabilizing vegetation can lead to increased erosion and degradation of suitable nesting habitat. Exotic vegetation may also form impenetrable root mats which can prevent proper nest cavity excavation, invade and desiccate eggs, or trap hatchlings. The Australian pine *(Casuarina equisetifolia)* is particularly detrimental. Dense stands of this species have taken over many coastal strand areas throughout central and South Florida. Australian pines cause excessive shading of the beach that would not otherwise occur. Studies in Florida suggest that nests laid in shaded areas are subjected to lower incubation temperatures, which may alter the natural hatchling sex ratio. Fallen Australian pines limit access to suitable nest sites and can entrap nesting females. Davis and Whiting (1977) reported that nesting activity declined in Everglades National Park where dense stands of Australian pine took over native beach berm vegetation on a remote nesting beach. Conversely, along highly developed beaches, nesting may be concentrated in areas where dense stands of Australian pines create a barrier to intense beachfront and beach vicinity lighting.

Nest Loss to Abiotic Factors: Erosion or inundation and accretion of sand above incubating nests appear to be the principal abiotic factors that may negatively affect incubating egg clutches. While these factors are often widely perceived as contributing significantly to nest mortality or lowered hatching success, few quantitative studies have been conducted. Studies on a relatively undisturbed nesting beach by Witherington (1986) indicated that excepting a late season severe storm event, erosion and inundation played a relatively minor role in destruction of incubating nests. Inundation of nests and accretion of sand above incubating nests as a result of the late season storm played a major role in destroying nests from which hatchlings had not yet emerged. Severe storm events (e.g., tropical storms and hurricanes) may result in significant nest loss, but these events are typically aperiodic rather than annual occurrences. In the southeastern U.S., severe storm events are generally experienced after the peak of the hatching season and hence would not be expected to affect the majority of incubating nests. Erosion and inundation of nests are exacerbated through coastal development and shoreline engineering. These threats are discussed above under beach armoring.

Predation: Predators, particularly exotics such as fire ants (*Solenopsis invicta*), and human-associated ones including raccoons and opossums are becoming increasingly detrimental to nesting beaches.

Poaching: In the U.S., killing of female turtles is infrequent. However, in a number of areas, egg poaching and clandestine markets for eggs are not uncommon. From 1983 to 1989, the Florida Marine Patrol, DEP, made 29 arrests for illegal possession of turtle eggs.

Management

Conservation efforts for the leatherback have greatly improved since it was federally listed as endangered on June 2, 1970. During the 1970s, nest survey and protection efforts were generally sporadic and did little to reduce the widespread egg poaching on U.S. Caribbean beaches. Beginning in 1981, however, intensive nest survey and protection efforts were initiated on the single most important leatherback nesting beach in the U.S. Caribbean, Sandy Point, St. Croix. Prior to this, the majority of the 150 to 350 nests deposited annually were lost to poaching or erosion. Now overall hatch success exceeds 50 to 60 percent in most years. The FWS, in cooperation with Earthwatch, initiated similar measures on the other main U.S. Caribbean leatherback nesting beaches on Isla Culebra in 1984. Prior to the intensive nighttime patrolling, a high percentage of the nests on this island were poached. Overall hatch success is now greater than 75 percent in most years. Nest survey and protection efforts occur on several other U.S. Caribbean beaches of lesser but still significant importance such as Manchenil, St. Croix, and Pinones, Humacao, and Luquillo beaches in Puerto Rico.

In Florida, leatherback nesting data are collected in conjunction with loggerhead nesting surveys, which generally begin in early to mid-May. While a portion of the leatherback nesting season is missed by the systematic loggerhead and green sea turtle surveys, most nests are observed by someone and probably reported because of intensive public use of the main leatherback nesting beaches in Florida.

Along with the basic information on nest numbers, clutch size, and hatching success, the Sandy Point and Culebra projects have included additional studies of the nesting females and provided information on intra- and inter-nesting frequency, movements, survivorship, turtle size and weight, diving behavior, pre-reproductive migrations, nest temperature and expected hatchling sex ratio, depredation rates, nest site selection, and embryonic deformities.

In 1982, 310 ha of land on Isla Culebra, including Playas Resaca and Brava, were transferred to Culebra NWR. In 1984 the FWS purchased the 2.4 km long leatherback nesting beach at Sandy Point, St. Croix, establishing

Sandy Point NWR. These actions ensure the long-time protection of the most important leatherback nesting beaches in the U.S. Virgin Islands and Puerto Rico, although neither area is immune from external threats such as light pollution.

Recent reviews of sea turtle conservation efforts in the southeastern U.S. appear in Hopkins-Murphy (1988) and Possardt (1991). In addition to management of coastal habitats, NMFS and FWS (1992) discuss conservation measures for the leatherback turtle in the marine environment. In the South Florida Ecosystem, there are a number of management activities ongoing to benefit the leatherback sea turtle.

Conservation of sea turtle nesting habitat is continuing on several NWRs in South Florida, including Archie Carr, Hobe Sound, Ten Thousand Islands, and the complex of satellite refuges in the Florida Keys. Acquisition of high-density nesting beaches between Melbourne Beach and Wabasso Beach, Florida, is continuing to complete the Archie Carr NWR. The State of Florida purchased the first parcel specifically for the refuge in July 1990. Federal acquisition began in 1991. When completed, the refuge will protect up to 16 km of nesting beach. Since the initial acquisition, Brevard County and the Richard King Mellon Foundation have joined in as acquisition partners. Hobe Sound NWR, located north of West Palm Beach in Martin County, contains 5.25 km of Atlantic coast shoreline for nesting habitat. In addition to providing some of the most productive sea turtle nesting habitat in the U.S., the refuge is also home to Florida scrub-jays (*Aphelocoma coerulescens*) and gopher tortoises *(Gopherus polyphemus*). The most longstanding beach management program has been to reduce destruction of nests by natural predators, such as raccoons. Control of numerous exotic plants such as Australian pine and Brazilian pepper (*Schinus terebinthifolius*) are also major issues in managing the refuge.

One of the most difficult habitat protection efforts throughout South Florida is trying to minimize or eliminate the construction of seawalls, riprap, groins, sandbags, and improperly placed drift or sand fences. State and Federal laws designed to protect the beach and dune habitat in South Florida include the Coastal Barrier Resources Act of 1982 and the Coastal Zone Protection Act of 1985. These have had varying degrees of success at maintaining suitable nesting sites for sea turtles. Prior to 1995, DEP permits were required for all coastal armoring projects prior to construction. When issuing these permits, DEP incorporated sea turtle protection measures, and sea turtle concerns were generally well addressed.

However, in 1995, the Florida Legislature passed a law giving coastal counties and municipalities the authority to approve construction of coastal armoring during certain emergency situations. (All non-emergency armoring situations must still receive an DEP permit prior to construction.) Although the new law weakened prior regulations on armoring, it does require that emergency armoring structures approved by a coastal county or municipality be temporary and that the structure be removed or a permit application submitted to DEP for a permanent rigid coastal structure within 60 days after the emergency installation of the structure.

In addition, to implement this new law, DEP finalized a formal agency rule on coastal armoring on September 12, 1996. The new rule recommends that local governments obtain the necessary approval from the FWS prior to authorizing armoring projects. The new rule also requires that several measures be undertaken to address sea turtle concerns for non-emergency armoring and for placement of permanent rigid coastal structures subsequent to an emergency (temporary) armoring event. For example, the new regulations require that (1) special conditions be placed on permitted activities to limit the nature, timing, and sequence of construction, as well as address lighting concerns; (2) structures not be used where the construction would result in a significant adverse impact, and (3) armoring be removed if it is determined to not be effective or to be causing a significant adverse impact to the beach and dune system.

Beach nourishment is a better alternative for sea turtles than seawalls and jetties. When beach nourishment was done mostly in the summer, all nests had to be moved from the beach prior to nourishment. Now FWS and State natural resource agencies review beach nourishment projects to ensure appropriate timing of nourishment during the nesting and hatching season. In southeast Florida, the leatherback nesting and hatching season is from February 15 through November 30. Any management decisions regarding beach nourishment, beach armoring and other coastal construction, marina and dock development, and artificial lighting should consider these dates. Beaches where compaction after nourishment is a problem are plowed to a depth of 92 cm to soften the sand so that it is useable for nesting turtles (Nelson and Dickerson 1987). Progress is being made toward better timing of projects and sand quality.

Progress is being made by counties and cities to prevent disorientation and misorientation of hatchlings due to artificial lighting (Ernest *et al.* 1987, Shoup and Wolf 1987). In South Florida, lighting ordinances have been passed by Indian River, St. Lucie, Martin, Palm Beach, Broward, Monroe, Collier, Charlotte, Sarasota and Lee counties, as well as numerous municipalities. Most recently, Witherington and Martin (1996) provide a thorough discussion of the effects of light pollution on sea turtle nesting beaches and on juvenile and adult turtles, and offer a variety of effective management solutions for ameliorating this problem.

Information on the status and distribution of the leatherback sea turtle is critical to its conservation. Monitoring the various life stages of the turtles on nesting beaches is being conducted to evaluate current and past management practices. Data are collected on the number of nests laid, the number of nests that successfully hatch, and the production of hatchlings reaching the ocean. Standardized ground surveys on index beaches are underway throughout Florida by the FWS, DEP, and private groups and universities. Because of the turtles' slow growth rates and subsequent delayed sexual maturity, all monitoring will need to be conducted over a long period of time to establish population trends.

Mortality of leatherback turtles has been monitored since 1980 through the implementation of a regional data collection effort. This voluntary stranding network from Maine to Texas is coordinated by the NMFS and serves to document the geographic and seasonal distribution of sea turtle mortality (Schroeder 1987). Since 1987, four index zones have been systematically surveyed. It is clear that strandings represent an absolute minimum mortality. However, they can be used as an annual index to mortality and are an indication of the size and distribution of turtles being killed. They can also provide valuable biological information on food habits, reproductive condition, and sex ratios.

A substantial effort is being made by government and non-government agencies and private individuals to increase public awareness of sea turtle conservation issues. Federal and State agencies and private conservation organizations, such as the Center for Marine Conservation, Greenpeace, and National Audubon Society, have produced and distributed a variety of audio-visual aids and printed materials about sea turtles. These include: a booklet on the different types of light fixtures and ways of screening lights to lessen their effects on hatchlings (Raymond 1984b), the brochure “Attention Beach Users”, “Lights Out” bumper stickers and decals, a coloring book, video tapes, slide/tape programs, full color identification posters of the various species of sea turtles, and a leatherback poster. Florida Power and Light Company also has produced a booklet (Van Meter 1990) and two leaflets with information on sea turtles, as well as a coastal roadway lighting manual. Many beaches have been posted with signs informing people of the laws protecting sea turtles and providing either a local or a hotline number to report violations.

Literature Cited

Ackerman, R. A. 1980. Physiological and ecological aspects of gas exchange by sea turtle eggs. American Zoologist 20:575-583.

Adams, T. W. 1988. Manchenil Bay leatherback sea turtle research and conservation project, 1988. Final report, submitted to U.S. Virgin Islands Division Fish and Wildlife.

Allen, E. R., and W. T. Neill. 1957. Another record of the Atlantic leatherback, Dermochelys coriacea, on the Florida coast. Copeia 1957:143-144.

Bacon, P. R. 1970. Studies on the leatherback turtle, *Dermochelys coriacea* (L.), in Trinidad, West Indies. Biological Conservation 2:213-217.

Bacon, P. R., and G. K. Maliphant. 1971. Further studies on sea turtles in Trinidad and Tobago with a guide to the common species and their hatchlings. Journal Trinidad Field Naturalists' Club 1971:2-17.

Barnard, D. E., J. A. Keinath, and J. A. Musick. 1989. Distribution of ridley, green and leatherback turtles in Chesapeake Bay and adjacent waters. Pages 201-203 *in* S. A. Eckert, K.L. Eckert and T. H. Richardson, eds. Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA Technical Memorandum NMFS-SEFC 232. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Basford, S. J., R. L. Brandner, and R. H. Boulon. 1986. Tagging and nesting research on leatherback sea turtles *Dermochelys coriacea* on Sandy Point, St. Croix, U.S. Virgin Islands, 1986. Annual report. U.S. Virgin Islands Division of Fish and Wildlife. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Basford, S. J., R. L. Brandner, and R. H. Boulon. 1988. Tagging and nesting research on leatherback sea turtles *Dermochelys coriacea* on Sandy Point, St. Croix, U.S. Virgin Islands, 1988. Annual Report. U.S. Virgin Islands Division of Fish and Wildlife. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Bels, V., F. Rimblot-Baly, and J. Lescure. 1988. Croissance et maintien en captivity de la tortue luth, Dermochelys coriacea (Vandelli 1761). Revue Française d' Aquariologie 15(l988)2:59-64.

Bickham, J. W., and J. L. Carr. 1983. Taxonomy and phylogeny of the higher categories of cryptodiran turtles based on a cladistic analysis of chromosomal data. Copeia 1983:918-932.

Bleakney, J. S. 1965. Reports of marine turtles from New England and eastern Canada. Canadian Field Naturalist 79:120-128.

Boulon, R. H. 1989. Virgin Island turtle recoveries outside of the U.S. Virgin Islands. Pages 207-209 *in* S. A. Eckert, K. L. Eckert, and T. H. Richardson, compilers. Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA Technical Memorandum NMFS-SEFC-232. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Boulon, R. H., K. L. Eckert, and S. A. Eckert. 1988. *Dermochelys coriacea.* (leatherback sea turtle) migration. Herpetological Review 19(4):88.

Brahim, S., E. H. Chan, and A. K. Rahman. 1987. An update on the population status and conservation of the leatherback turtle of Terengganu. Pages 69-77 *in* A. Sasekumar, S. M. Phang, and E. L. Chong, eds. Proceedings of the tenth annual seminar towards conserving Malaysia's marine heritage, 28 March 1987; Malaysian Society of Marine Sciences, University of Malaya.

Brandner, R. L., S. J. Basford, and R. H. Boulon. 1987. Tagging and nesting research on leatherback sea turtles *Dermochelys coriacea* on Sandy Point, St. Croix, U.S. Virgin Islands, 1987. Annual report. U.S. Virgin Islands Division of Fish and Wildlife. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Brongersma, L. D. 1969. Miscellaneous notes on turtles. IIA, IIB. Proceedings of the Koninklljke Nederlandse Akademie van Wetenschappen, Amsterdam C 72(l):76-102.

Brongersma, L. D. 1970. Miscellaneous notes on turtles, III. Proceedings of the Koninklljk Nederlandse Akademie van Wetenschappen, Amsterdam C 73(4):323-335.

Broward County Erosion Prevention District Environmental Quality Control Board. 1987. Sea turtle conservation project, Broward County, Florida, 1987 report. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Caldwell, D. K. 1959. On the status of the Atlantic leatherback turtle, *Dermochelys coriacea*, as a visitant to Florida nesting beaches, with natural history notes. Quarterly Journal of the Florida Academy of Science 21(3):285-291.

Caldwell, D. K., A. Carr, and T. R. Hellier, Jr. 1956. A nest of the Atlantic leatherback turtle, *Dermochelys coriacea* (Linnaeus), on the Atlantic coast of Florida, with a summary of American nesting records. Quarterly Journal of the Florida Academy of Science 18(4):279-284.

Caldwell, D. K., and Rathjen, W. F. 1969. Unrecorded West Indian nesting sites for the leatherback and hawksbill sea turtles *Dermochelys coriacea* and *Eretmochelys imbricate*. Copeia 1969: 622-623.

Cameron, T. H. 1923. Notes on turtles. Journal Bombay Natural History Society 29:299-300.

Carr, A. 1952. Handbook of turtles. Comstock Publishing Associates, Cornell University Press; Ithaca, New York.

Carr, A. 1987. New perspectives on the pelagic stage of sea turtle development. Conservation Biology 1(2):103-121.

Carr, A., A. Meylan, J. Mortimer, K. Bjorndal and T. Carr. 1982. Surveys of sea turtle populations and habitats in the Western Atlantic. NOAA Technical Memorandum NMFS-SEFC-91.

Carr, A., and L. Ogren. 1959. The ecology and migrations of sea turtles, 3: *Dermochelys* in Costa Rica. American Museum Novitiates 1958:1-29.

Carr, A. F., Jr., and L. H. Ogren. 1960. The ecology and migrations of sea turtles, 4. The green turtle in the Caribbean Sea. Bulletin American Museum of Natural History 121:1-48.

Carr, T., and N. Carr. 1986. *Dermochelys coriacea* (leatherback sea turtle) copulation. Herpetological review 17(1):24-25.

Coastal Engineering Research Center. 1984. Shore Protection Manual, volumes I and II. U.S. Army Corps of Engineers Waterways Experiment Station; Vicksburg, Mississippi.

Daniel, R. S., and K. U. Smith. 1947. The sea-approach behavior of the neonate loggerhead turtle. Journal Comparative Physiological Psychology 40:413-420.

Davenport, J., D. L. Holland, and J. East. 1990. Thermal and biochemical characteristics of the lipids of the leatherback, *Dermochelys coriacea*: evidence of endothermy. Journal Marine Biological Association United Kingdom 70:33-41.

Davis, G.E., and M.C. Whiting. 1977. Loggerhead sea turtle nesting in Everglades National Park, Florida, USA. Herpetologica 33:18-28

Deraniyagala, P. E. P. 1936. The nesting habit of the leathery turtle, *Dermochelys coriacea*. Notes, Ceylon Journal Science B 19(3):331-336.

Dickerson, D. D., and D. A. Nelson. 1989. Recent results on hatchling orientation responses to light wavelengths and intensities. Page 41 *in* S. A. Eckert, K. L. Eckert, and T. H. Richardson, compilers. Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA Technical Memorandum NMFS-SEFC-232. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Dodd, C. K. 1978. Terrestrial critical habitat and marine turtles. Paper presented at Symposium: Recovery and Management of Marine Turtles in the Southeast Region, 26-27 June 1978; Tampa, Florida. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Duron, M. 1978. Contribution a l'etude de la biologie de *Dermochelys coriacea* (Linne) dans les Pertuis Charentais. Unpublished PhD dissertation. University of Bordeaux.

Duron-DeFrenne, M. 1987. Premier suivi par satellite en Atlantique d'une tortue luth *Dermochelys coriacea*. C. R. Academic des Sciences de Paris 304, serie III n° 15, 1987:399-402.

Eckert, K. L. 1987. Environmental unpredictability and leatherback sea turtle Dermochelys coriacea nest loss. Herpetologica 43(3):31 5-323.

Eckert, K. L. 1989. (Draft) WIDECAST sea turtle recovery action plan for the U.S. Virgin Islands. Caribbean Environment Programme, United Nations Environment Programme. Contract #CR/5102-86. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Eckert, K. L., and S. A. Eckert. 1985. Tagging and nesting research of leatherback sea turtles *Dermochelys coriacea* on Sandy Point, St. Croix, 1985. Annual report. U.S. Virgin Islands Division of Fish and Wildlife, U.S. Fish Wildlife Reference Service MIN 54-8680431. Laurel, Maryland.

Eckert, K. L., and S. A. Eckert. 1988. Pre-reproductive movements of leatherback sea turtles *Dermochelys coriacea* nesting in the Caribbean. Copeia 1988:400-406.

Eckert, K. L., S. A. Eckert, and D. W. Nellis. 1984. Tagging and nesting research of leatherback sea turtles *Dermochelys coriacea* on Sandy Point, St. Croix, 1984, with management recommendations for the population. Annual report. U.S. Virgin Islands Division of Fish and Wildlife, U.S. Fish Wildlife Reference Service. MIN 54-8580175. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Eckert, K. L., and B. B. Lettsome. 1988. (Draft) WIDECAST sea turtle recovery action plan for the British Virgin Islands. Caribbean Environment Programme, United Nations Environment Programme. Contract #CR/5102-86. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Eckert, S. A., K. L. Eckert, P. Ponganis, and G. L. Kooyman. 1989. Diving and foraging behavior of leatherback sea turtles *Dermochelys coriacea*. Canadian Journal of Zoology 67:2834-2840.

Ehrenfeld, D. W., and A. Carr. 1967. The role of vision in the sea-finding orientation of the green turtle *Chelonia mydas*. Animal Behavior 15:25-36.

Ehrhart, L. M. 1983. A survey of nesting by the green turtle, *Chelonia mydas*, and loggerhead turtle, *Caretta caretta*, in south Brevard County, Florida. Unpublished. Report to World Wildlife Fund--U.S.; Washington, D.C. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Eisenberg, J. F., and J. Frazier. 1983. A leatherback turtle *Dermochelys coriacea* feeding in the wild. Journal of Herpetology. 17:81-82.

Ernest, R.G., R. Erick, and C.J. Bove. 1987. Development of a comprehensive sea turtle protection ordinance for St. Lucie County, Florida. (Abstract). seventh annual workshop on sea turtle biology and conservation. February 1987, Wekiva Springs State Park, Florida. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Florida Department of Environmental Protection [DEP]. 1996. Unpublished data. Reported nesting activity of the leatherback, *Dermochelys coriacea*, in Florida, 1993-1995. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Frair, W. 1970. The world's largest living turtle. Salt Water Aquarium 5:235-241.

Frair, W., R. G. Ackman, and N. Mrosovsky. 1972. Body temperature of *Dermochelys coriacea*: warm turtle from cold water. Science 177:791-793.

Fretey, J., and M. Girondot. 1989. L'activite de ponte de la tortue luths, *Dermochelys coriacea* (Vandelli, 1761), pendant la saison 1988 en Guyane Française. Revue d'Ecologie (Terre Vie) 44:261-274.

Gaffney, E. S. 1975. A phylogeny and classification of the higher categories of turtles. Bulletin American Museum of Natural History 155:397-436.

Gaffney, E. S. 1984. Historical analysis of theories of Chelonian relationship. Systematic Zoology 33:283-301.

Garcia, V. F. A. 1987. National Report for Panama to the western Atlantic turtle symposium, October 1987; Mayaguez, Puerto Rico. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Glusing, G. 1967. Aufrucht-versuch junger Lederschild Kroten *Dermochelys coriacea*. Aguarien-und Terrarien Zeitschrift 20:61-63.

Goff, G. P., and J. Lien. 1988. Atlantic leatherback turtle, *Dermochelys coriacea*, in cold water off Newfoundland and Labrador. Canadian Field Naturalist 102(l):1-5.

Goff, G. P., and G. B. Stenson. 1988. Brown adipose tissue in leatherback sea turtles: a thermogenic organ in an endothermic reptile? Copeia 1988:1071-1074.

Greer, A. E., J. D. Lazell, and R. M. Wright. 1973. Anatomical evidence for counter-current heat exchanger in the leatherback turtle *Dermochelys coriacea*. Nature 244:181.

Hartog, J. C. den. 1980. Notes on the food of sea turtles: *Eretmochelys imbricata* (Linnaeus) and *Dermochelys coriacea* (Linnaeus). Netherlands Journal of Zoology 30(4):595-610.

Hartog, J. C. den., and M. M. Van Nierop. 1984. A study on the gut contents of six leathery turtles, *Dermochelys coriacea* (Linnaeus) (Reptilia: Testudines: Dermochelyidae) from British waters and from the Netherlands. Zoologische Verhandelingen 209(l984):1-36.

Hendrickson, J. R. 1958. The green sea turtle, *Chelonia mydas* (Linn.) in Malaya and Sarawak. Proceedings Zoological Society of London 130:455-535.

Hendrickson, J. R. 1980. The ecological strategies of sea turtles. American Zoologist 20:597-608.

Hildebrand, H. H. 1963. Hallazgo del area de anidacion de la tortuga marina "lora", *Lepidochelys kempi* (Garman), en la costa occidental del Golfo de Mexico. Ciencia Mexicana 26(4):105-112.

Hildebrand, H. 1987. A reconnaissance of beaches and coastal waters from the border of Belize to the Mississippi River as habitats for marine turtles. Final report, NOAA/NMFS/SEFC Panama City Lab (purchase order #NA-84-CF-A-134). On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Hirth, H. G. 1980. Some aspects of the nesting behavior and reproductive biology of sea turtles. American Zoologist 20:507-523.

Hirth, H. G., and L. H. Ogren. 1987. Some aspects of the ecology of the leatherback turtle, *Dermochelys coriacea*, at Laguna Jalova, Costa Rica. NOAA Technical Report NMFS 56. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Hopkins-Murphy, S. R. 1988. Sea turtle recovery efforts in the southeastern U.S. Pages 63-71 *in* R. R. Odum, K. A. Riddleberger, and J. C. Ozier, eds., Proceedings of the third southeastern non-game and endangered wildlife symposium, August 1987; Athens, Georgia.

Hopkins, S.R., and T.M. Murphy. 1980. Reproductive ecology of *Caretta caretta* in South Carolina. South Carolina Wildlife Marine Resources Department completion report. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Horrocks, J. A. 1987. Leatherbacks in Barbados. Marine Turtle Newsletter 41:7.

Hosier, P. E., M. Kochhar, and V. Thayer. 1981. Off-road vehicle and pedestrian track effects on the sea-approach of hatchling loggerhead turtles. Environmental Conservation 8:158-161.

Hughes, G. R. 1974. The sea turtles of South-East Africa, 11. Investigational report No. 36. Oceanographic Research Institutuion; Durban, Republic of South Africa.

Johnson, M. L. 1989. Juvenile leatherback cared for in captivity. Marine Turtle Newsletter 47:13-14.

Kar, C. S., and S. Bhaskar. 1982. Status of sea turtles in the eastern Indian Ocean. Pages 365-372 in K. A. Bjorndal, ed. Biology and conservation of sea turtles. Smithsonian Institution Press; Washington D.C.

Knowlton, A. R., and B. Weigle. 1989. A note on the distribution of leatherback turtles *Dermochelys coriacea* along the Florida coast in February 1988. Pages 83-85 *in* S. A. Eckert, K. L. Eckert, and T. H. Richardson, compilers. Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA Technical Memornadum NMFS-SEFC-232. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Labisky, R.F., M.A. Mercadante, and W.L. Finger. 1986. Factors affecting reproductive success of sea turtles on Cape Canaveral Air Force Station, Florida, 1985. Final report to the U.S. Air Force; U.S. Fish and Wildlife Service Cooperative Fish and Wildlife Research Unit, Agreement No. 14-16-0009-1544, Work Order No. 25. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Lambie, I. 1983. Two tagging records from Trinidad. Marine Turtle Newsletter 24:17.

Lazell, J. D. 1980. New England waters: critical habitat for marine turtles. Copeia 1980:290-295.

Leary, T. R. 1957. A schooling of leatherback turtles, *Dermochelys coriacea*, on the Texas coast. Copeia 1957:232.

LeBuff, C. R., Jr. 1990. The loggerhead turtle in the eastern Gulf of Mexico. Caretta Research Incorporated; Sanibel Island, Florida.

Lee, D. S., and W. M. Palmer. 1981. Records of leatherback turtles, *Dermochelys coriacea* (Linnaeus), and other marine turtles in North Carolina waters. Brimleyana 5:95-106.

Limpus, C. J. 1984. A benthic feeding record from neritic water for the leathery turtle *Dermochelys coriacea*. Copia 1984:552-553.

Lohoefener, R. R., W. Hoggard, C. L. Roden, K. Mullin, and C. M. Rogers. 1988. Distribution and relative abundance of surfaced sea turtles in the north-central Gulf of Mexico: spring and fall 1987. Pages 47-50 *in* B.A. Schroeder, compiler. Proceedings of the eighth annual workshop on sea turtle conservation and biology. NOAA Technical Memorandum NMFS-SEFC-214. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

MacPherson, S. 1997. Personal communication.

Mann, T. M. 1977. Impact of developed coastline on nesting and hatchling sea turtles in southeastern Florida. Unpublished M.S. Thesis. Florida Atlantic University, Boca Raton.

Matos, R. 1986. Sea turtle hatchery project with specific reference to the leatherback *Dermochelys coriacea*, Humacao, Puerto Rico, 1986. Annual Report, Puerto Rico Department of Natural Resources.

Matos, R. 1987. Sea turtle hatchery project with specific reference to the leatherback *Dermochelys coriacea* and hawksbill *Eretmochelys imbricata* sea turtles, Humacao, Puerto Rico, 1987. Annual report, Puerto Rico Department of Natural Resources.

McDonald, D., P. H. Dutton, and R. H. Boulon. 1991. Tagging and nesting research on leatherback sea turtles (*Dermochelys coriacea*) on Sandy Point, St. Croix, U.S. Virgin Islands. Annual report to the U.S. Fish and Wildlife Service. Contract No. PC-P&NR-287-91 to U.S. Virgin Islands Department of Planning and Natural Resources, October, 1991. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

McDonald, D., P. H. Dutton, and R. H. Boulon. 1992. Tagging and nesting research on leatherback sea turtles (*Dermochelys coriacea*) on Sandy Point, St. Croix, U.S. Virgin Islands. Annual report to the U.S. Fish and Wildlife Service. Contract No. PC-P&NR-287-92 to U.S. Virgin Islands Department of Planning and Natural Resources, November, 1991. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

McDonald, D., P. H. Dutton, and R. H. Boulon. 1993. Tagging and nesting research on leatherback sea turtles (*Dermochelys coriacea*) on Sandy Point, St. Croix, U.S. Virgin Islands, 1993. Annual report to the U.S. Fish and Wildlife Service. Contract No. PC-P&NR-287-93 to U.S. Virgin Islands Department of Planning and Natural Resources, November, 1991. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

McDonald, D., P. H. Dutton, and R. H. Boulon. 1994. Tagging and nesting research on leatherback sea turtles (*Dermochelys coriacea*) on Sandy Point, St. Croix, U.S. Virgin Islands, 1994. Annual Report to the U.S. Fish and Wildlife Service. Contract No. PC-P&NR-287-94 to U.S. Virgin Islands Department of Planning and Natural Resources, October, 1994. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

McFarlane, R. W. 1963. Disorientation of loggerhead hatchlings by artificial road lighting. Copeia 1963:153.

Medrano, L., M. Dorizzi, F. Rimblot, and C. Pieau. 1987. Karyotypes of the sea turtle *Dermochelys coriacea* (Vandelli, 1761). Amphibia-Reptilia 8(1987):171-178.

Meylan, A. 1983. Marine turtles of the Leeward Islands, Lesser Antilles. Atoll Research Bulletin 278:1-24.

Meylan, A., P. Meylan, and A. Ruiz. 1985. Nesting of *Dermochelys coriacea* in Caribbean Panama. Journal of Herpetology 19(2):293-297.

Meylan, A., B. Schroeder, and A. Mosier. 1995. Sea turtle nesting activity in the State of Florida 1979-1992. Florida Marine Research Publications Number 52; St. Petersburg, Florida.

Michel, H. B., and M. Foyo. 1976. Caribbean zooplankton, Part 1. Department of Defense, Navy Department, Office of Naval Research. Government Printing Office; Washington D.C.

Morgan, P. J. 1989. Occurrence of leatherback turtles *Dermochelys coriacea* in the British Isles in 1988 with reference to a record specimen. Pages 119-120 *in* S. A. Eckert, K. L. Eckert, and T. H. Richardson, compilers. Proceedings of the ninth annual conference on sea turtle conservation and biology. NOAA Technical Memorandum NMFS-SEFC-232. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Mortimer, J. A. 1979. Ascension Island: British jeopardize 45 years of conservation. Marine Turtle Newsletter 10:7-8.

Mortimer, J. A. 1982. Factors influencing beach selection by nesting sea turtles, Pages 45-51 *in* K. A. Bjorndal, ed., Biology and Conservation of Sea Turtles. Smithsonian Institution Press; Washington, D.C.

Mrosovsky, N. 1983. Ecology and nest-site selection of leatherback turtles, *Dermochelys coriacea*. Biological Conservation 26:47-56.

Mrosovsky, N., and P. C. H. Pritchard. 1971. Body temperatures of *Dermochelys coriacea* and other sea turtles. Copeia 1971(4):624-631.

Murphy, T. M. 1985. Telemetric monitoring of nesting loggerhead sea turtles subjected to disturbance on the beach. Paper presented at fifth annual workshop on sea turtle biology and conservation, 13-16 March 1985; Waverly, Georgia.

Musick, J. A. 1988. The sea turtles of Virginia with notes on identification and natural history. Virginia Sea Grant Program, Virginia Institute of Marine Science; Gloucester Point, Virginia.

National Marine Fisheries Service [NMFS] and U.S. Fish and Wildlife Service [FWS]. 1992. Recovery plan for leatherback turtles in the U.S. Caribbean, Atlantic, and Gulf of Mexico. National Marine Fisheries Service; Washington, D.C.

National Research Council. 1990. Managing coastal erosion. National Academy Press, Washington, D.C.

Neill, W. H., and E. D. Stevens. 1974. Thermal inertia versus thermoregulation in “warm” turtles and tunas. Science 184:1008-1010.

Nelson, D.A., and D.D. Dickerson. 1987. Correlation of loggerhead turtle nesting digging with beach sand consistency. (Abstract). Seventh annual workshop on sea turtle biology and conservation, February 1987; Wekiva Springs State Park, Florida.

Nelson, D.A., and D.D. Dickerson. 1988a. Effects of beach nourishment on sea turtles. in L.S. Tait, ed. Proceedings of the beach preservation technology conference ‘88. Florida Shore & Beach Preservation Association, Incorporated; Tallahassee, Florida.

Nelson, D.A., and D.D. Dickerson. 1988b. Hardness of nourished and natural sea turtle nesting beaches on the east coast of Florida. Unpublished report. U.S. Army Engineer Waterways Experiment Station; Vicksburg, Mississippi.

Nelson, D.A. and D.D. Dickerson. 1988c. Response of nesting sea turtles to tilling of compacted beaches, Jupiter Island, Florida. Unpublished Report. U.S. Army Corps of Engineers Waterways Experiment Station; Vicksburg, Mississippi.

Paladino, F. V., M. P. O’Connor, and J. R. Spotila. 1990. Metabolism of leatherback turtles, gigantothermy, and thermoregulation of dinosaurs. Nature 344:858-860.

Philibosian, R. 1976. Disorientation of hawksbill turtle hatchlings, *Eretmochelys imbricata*, by stadium lights. Copeia 1976:824.

Phillips, E. J. 1977. Raising hatchlings of the leatherback turtle, *Dermochelys coriacea*. Britanic Journal of Herpetology 5:677-678.

Pilkey, 0. H., Jr., D. C. Sharma, H. R. Wanless, L. J. Doyle, 0. H. Pilkey, Sr., W. J. Neal, and B. L. Gruver. 1984. Living with the east Florida shore. Duke University Press; Durham, North Carolina.

Polunin, N. V. C. 1977. Wildlife Thailand. Conservation News 1977:6-10.

Possardt, E. E. 1991. A conservation program for sea turtles in the southeastern continental U.S. Journal of Alabama Academy of Science 62:35-48.

Pritchard, P. C. H. 1971. The leatherback or leathery turtle, *Dermochelys coriacea*. International Union for Conservation of Nature Monograph 1:1-39. Morges, Switzerland.

Pritchard, P. C. H. 1973. International migrations of South American sea turtles (Cheloniidae and Dermochelyidae). Animal Behavior 21:18-27.

Pritchard, P. C. H. 1976. Post-nesting movements of marine turtles (Cheloniidae and Dermochelyidae) tagged in the Guianas. Copeia 1976:749-754.

Pritchard, P. C. H. 1977. Marine Turtles of Micronesia. Chelonia Press; San Francisco, California.

Pritchard, P. C. H. 1982. Nesting of the leatherback turtle *Dermochelys coriacea*, in Pacific Mexico, with a new estimate of the world population status. Copeia 1982: 741-747.

Pritchard, P. C. H. 1988a. (Draft) WIDECAST Recovery Action Plan for Guyana. Caribbean Environment Programme, United Nations Environment Programme. Contract #CR/5102-86. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Pritchard, P. C. H. 1988b. Sea turtles in Guyana, Pages 85-87 *in* B. A. Schroeder Comp., Proceedings of the eighth annual workshop on sea turtle conservation and biology. NOAA Technical Memorandum. NMFS-SEFC-214. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Pritchard, P. C. H. 1992. Leatherback turtle *Dermochelys coriacea*. Pages 214-218 *in* P.E. Moler, ed. rare and endangered biota of florida, volume III. University Press of Florida, Gainesville, Florida.

Pritchard, P. C. H., and P. Trebbau. 1984. The turtles of Venezuela. Society for the Study of Amphibians and Reptiles.

Pritchard, P.C.H. P.R. Bacon, F.H. Berry, J. Fletemeyer, A.F. Carr, R.M. Gallagher. R.R. Lankford, R. Marquez, L.H. Ogren, W.G. Pringle, Jr., H.M. Reichardt, and R. Witham. 1983. Sea turtle manual of research and conservation techniques. Western Atlantic Turtle Symposium.

Raymond, P. W. 1984a. The effects of beach restoration on marine turtles nesting in south Brevard County, Florida. Unpublished M.S. Thesis. University of Central Florida, Orlando.

Raymond, P. W. 1984b. Sea turtle hatchling disorientation and artificial beachfront lighting; a review of the problem and potential solutions. Center for Environmental Education; Washington, D.C.

Rhodin, A. G. J. 1985. Comparative chondro-osseous development and growth in marine turtles. Copeia 1985:752-771.

Rhodin, A. G. J., J. A. Ogden, and G. J. Conlogue. 1981. Chondro-osseous morphology of *Dermochelys coriacea*, a marine reptile with mammalian skeletal features. Nature 290:244-246.

Rhodin, A. G. J., and R. C. Schoelkopf. 1982. Reproductive data on a female leatherback turtle, *Dermochelys coriacea*, stranded in New Jersey. Copeia 1982:181-183.

Rhodin, A. G. J., and H. M. Smith. 1982. The original authorship and type specimen of *Dermochelys coriacea*. Journal of Herpetology 16(3):316-317.

Ross, J. P., and J. P. Ottenwalder. 1983. The leatherback sea turtle, *Dermochelys coriacea*, nesting in the Dominican Republic. Pages 189-209 *in* A. Rhodin and K. Miyata, eds. Advances in herpetology and evolutionary biology. Smithsonian Institution Press; Washington D.C.

Ruckdeschel, C., L. Ellis, and C.R. Shoop. 1982. *Dermochelys coriacea* (Leatherback sea turtle) nesting. Herpetological Review 13:126.

Schroeder, B.A. 1981. Predation and nest success in two species of marine turtles (*Caretta caretta* and *Chelonia mydas*) at Merritt Island, Florida. Florida Scientist 44(l):35.

Schroeder, B. A., and N. B. Thompson. 1987. Distribution of the loggerhead turtle, *Caretta caretta*, and the leatherback turtle, *Dermochelys coriacea*, in the Cape Canaveral, Florida area: results of aerial surveys. Pages 45-53 *in* W. N. Witzell, ed. Ecology of east Florida sea turtles. NOAA Technical Report NMFS 53. National Marine Fisheries Service; Miami, Florida.

Schulz, J. 1975. Sea turtles nesting in Surinam. Zoologische Verhandelingen. (Leiden) No. 143. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Shoop, C. R., T. L. Doty, and N. E. Bray. 1981. Sea turtles in the region between Cape Hatteras and Nova Scotia in 1979. Pages 68-75 *in* A characterization of marine mammals and turtles in the mid- and north-Atlantic areas of the U.S. outer continental shelf (CeTAP), executive summary. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Shoup, L.P., and R.E. Wolf. 1987. Boca Raton beach area outdoor lighting restrictions for the protection of sea turtles. (Abstract). Seventh annual workshop on sea turtle biology and conservation, February 1987; Wekiva Springs State Park, Florida.

Spoczinska, J.O.I. 1970. Rearing hatchlings of *Dermochelys coriacea* (L.) British Journal of Herpetology 4:189-192

Stancyk, S.E., O.R. Talbert, and J.M. Dean. 1980. Nesting activity of the loggerhead turtle *Caretta caretta* in South Carolina, II: protection of nests from raccoon predation by transplantation. Biological Conservation 18:289-298.

Sternberg, J. 1981. The worldwide distribution of sea turtle nesting beaches. Center for Environmental Education; Washington, D.C.

Talbert, O.R., Jr., S.E. Stancyk, J.M. Dean, and J.M. Will. 1980. Nesting activity of the loggerhead turtle *Caretta caretta* in South Carolina I: a rookery in transition. Copeia 1980:709-718.

Tallevast, T., J. Howell, C. Campbell, N. Colon, W. Colon, and V. Nichols. 1990. Leatherback turtle, *Dermochelys coriacea*, nesting study in Culebra, Puerto Rico, 1989. Annual Report to Puerto Rico Conservation Foundation and the U.S. Fish Wildlife Service.

Thompson, N. S. 1984. Progress report on estimating density and abundance of marine turtles: results of first year pelagic surveys in the Southeast U.S. National Marine Fisheries Service; Miami, Florida.

Threlfall, W. 1978. First record of the Atlantic leatherback turtle *Dermochelys coriacea* from Labrador. Canadian Field Naturalist 92(3):287.

Tucker, A. D. 1988. A summary of leatherback turtle *Dermochelys coriacea* nesting at Culebra, Puerto Rico, from 1984-1987 with management recommendations. Report submitted to U.S. Fish Wildlife Service. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Tucker, A. D. 1989. The influence of reproductive variations and spatial distribution on nesting success for leatherback sea turtles *Dermochelys coriacea*. Unpublished M.S. Thesis. University of Georgia.

Van Meter, V. B. 1990. Florida's Sea Turtles. Florida Power and Light Company; Miami, Florida.

Witham, R. 1977. *Dermochelys coriacea* in captivity. Marine Turtle Newsletter 3:6.

Witherington, B. E. 1986. Human and natural causes of marine turtle clutch and hatchling mortality and their relationship to hatchling production on an important Florida nesting beach. Unpublished M.S. Thesis. University of Central Florida, Orlando.

Witherington, B.E., K.A. Bjorndal, and C.M. McCabe. 1990. Temporal pattern of nocturnal emergence of loggerhead turtle hatchlings from natural nests. Copeia 1990:1165-1168.

Witherington, B. E., and K. A. Bjorndal. 1991. Influences of artificial lighting on the seaward orientation of hatchling loggerhead turtles *Caretta caretta*. Biological Conservation 55:139-149.

Witherington, B.E., and R.E. Martin. 1996. Understanding, assessing, and resolving light pollution problems on sea turtle nesting beaches. FMRI Technical Report TR-2. Florida Marine Research Institute, St. Petersburg, Florida.

Recovery for the Leatherback Sea Turtle

Dermochelys coriacea

Recovery Objective: Delist the species once recovery criteria are met.

South Florida Contribution: Support delisting actions..

Recovery Criteria

The South Florida recovery contribution parallels the existing recovery plans for sea turtles. South Florida's objective for the loggerhead, green, leatherback and hawksbill sea turtles will be achieved when: the level of nesting for each species is continuously monitored and increases to the species-specific recovery goal; beaches supporting greater than 50 percent of the nesting activity are in public ownership; all important nesting beaches are protected and appropriately managed to prevent further degradation; non-native nuisance species have been controlled or eliminated on public lands; at least 60 percent hatch success is documented on major nesting beaches; effective lighting ordinances or lighting plans are implemented; and beaches are restored or rehabilitated to be suitable for nesting where appropriate.

Species-level Recovery Actions

S1. **Continue standardized surveys of nesting beaches.** Nesting surveys are undertaken on the majority of nesting beaches. In the past, beach coverage varied from year to year, as did the frequency of surveys, experience and training of surveyors, and data reporting. Consequently, no determination of nesting population trends had been possible with any degree of certainty. However, in 1989, to better assess trends in nesting, DEP, in cooperation with FWS, initiated an Index Nesting Beach Survey (INBS) program to collect nesting data that could be used to statistically and scientifically analyze population trends. The INBS program should continue to gather a long-term data base on nesting activities in Florida that can be used as an index of nesting population trends.

S2. **Protect and manage populations on nesting beaches.** Predators, poaching, tidal inundation, artificial lighting, and human activities on nesting beaches diminish reproductive success. Monitoring of nesting activity is necessary to implement and evaluate appropriate nest protection measures and determine trends in the nesting population.

S2.1. **Evaluate nest success and implement appropriate nest protection measures.** Nesting and hatching success and hatchling emerging success on beaches occurring on State or Federal lands and all other important local or regional nesting beaches should be evaluated. Appropriate nest protection measures should be implemented by FWS and DEP, and appropriate local governments or organizations, to ensure greater than 60 percent hatch rate. Until recovery is ensured, however, projects on all Federal and State lands and key nesting beaches, such as those in Brevard, Indian

River, St. Lucie, Martin, and Palm Beach counties, should strive for a higher rate of hatching success. In all cases, the least manipulative method should be employed to avoid interfering with known or unknown natural biological processes. Artificial incubation should be avoided. Where beach hatcheries are necessary, they should be located and constructed to allow self release, and hatch rates approaching 90 percent should be attained. Nest protection measures should always enable hatchling release the same night of hatching.

S2.2. Determine influence of factors such as tidal inundation and foot traffic on hatching success. Tidal inundation can diminish hatching success, depending on frequency, duration, and developmental stage of embryos. Some nests are relocated due to the perceived threat from tides. The extent to which eggs can tolerate tidal inundation needs to be quantified to enable development of guidelines for nest relocation relative to tidal threats. The effect of foot traffic on hatching success is unknown, although many beaches with significant nesting also have high public use. FWS should support research and, in conjunction with DEP, develop recommendations for nest protection from tidal threat and foot traffic.

S2.3. Reduce effects of artificial lighting on hatchlings and nesting females. Studies have shown that light pollution can deter female sea turtles from coming onto the beach to nest; in fact, brightly lit beaches have been determined to be used less frequently for nesting. Also, females attempting to return to sea after nesting can be disoriented by beach lighting and have difficulties making it back to the ocean. In some cases, nesting females have ended up on coastal highways and been struck by vehicles. Artificial beach lighting is even more detrimental to hatchling sea turtles, which emerge from nests at night. Under natural conditions, hatchlings move toward the brightest, most open horizon, which is over the ocean. However, when bright light sources are present on the beach, they become the brightest spot on the horizon and attract hatchlings in the wrong direction, making them more vulnerable to predators, desiccation, exhaustion, and vehicles.

S2.3.1. Implement and enforce lighting ordinances and resolve lighting problems in areas where lighting ordinances have not been adopted. FWS and DEP should identify and resolve artificial lighting impacts to sea turtles in South Florida. Since 1987, hatchling disorientation incidents observed by DEP marine turtle permit holders and park personnel have been reported through standardized reporting forms. Report forms serve as documentation for lighting problems on nesting beaches and allow the identification of specific problem light sources. FWS and DEP should use these report forms to locate and resolve lighting problems, with the help of local governments, through public education efforts, and by directly contacting the owners of the problem lights and making recommendations for their modification. FWS and DEP should also proactively conduct pre-season lighting inspections to identify and make recommendations for correcting problem light sources before they result in disorientation events.

Where lighting ordinances have been adopted and enforced, hatchling disorientation and misorientation have been drastically reduced. All coastal counties and communities with nesting beaches should adopt ordinances (March through October on the Atlantic Coast and May through October on the Gulf Coast). Many incorporated communities within Broward and Palm Beach counties, Florida, are particularly problematic because of the high-density nesting beaches and the lack of effective lighting regulations. DEP should ensure appropriate lighting on new construction projects.

S2.3.2. **Evaluate extent of hatchling disorientation and misorientation on all important nesting beaches.** FWS, DEP, and counties should continue to evaluate hatchling disorientation and misorientation problems on all important nesting beaches. Many lighting ordinance requirements do not become effective until 11 p.m., whereas over 30 percent of hatchling emergence occurs prior to this time (Witherington *et al*. 1990). FWS, DEP, and county governments should also support research to gather additional quantitative data on hatchling emergence times and nesting times on representative beaches throughout South Florida to support the most effective time requirements for lighting ordinances.

S2.3.3. **Prosecute individuals or entities responsible for hatchling disorientation and misorientation under the Endangered Species Act or appropriate State laws.** Hatchling disorientation and misorientation from artificial lights can cause high mortality and be the major source of hatchling mortality on some nesting beaches if not controlled. Law enforcement efforts should be focused where lighting ordinances are not being implemented or enforced on major nesting beaches and where repeated violations are not corrected.

S2.4. **Ensure beach nourishment and coastal construction activities are planned to avoid disruption of nesting and hatching activities.** These activities can cause significant disruption of nesting activities during the nesting season when viewed cumulatively over the nesting range. Nest relocation can involve manipulation of large numbers of nests, which can result in lowered hatch success and altered hatchling sex ratios, and therefore is not an acceptable alternative to altering the timing of projects during the peak nesting period. COE, FWS, and DEP should ensure beach nourishment and other beach construction activities are not permitted during the nesting season on important nesting beaches.

S2.5. **Ensure law enforcement activities eliminate poaching and harassment.** Poaching, while not a significant cause of nest loss regionally, is occasionally a local problem. Poaching has been repeatedly reported around the Ten Thousand Islands NWR and adjacent islands in southwest Florida. In addition, intentional and unintentional disturbance and harassment of nesting turtles is an increasing problem on many beaches. FWS should work closely with DEP to identify problem areas and focus intensive law enforcement efforts to eliminate poaching and deter harassment of nesting turtles.

S3. **Continue to gather information on species and population biology.**

S3.1. **Determine etiology of fibropapillomatosis. Research on the leatherback sea turtle fibropapilloma disease should be continued and expanded.** Fibropapillomatosis (FP) is a disease of sea turtles characterized by the development of multiple tumors on the skin and also internal organs, most frequently the lungs and kidneys. The tumors interfere with swimming, eating, breathing, seeing, and reproduction, and turtles with heavy tumor burdens become severely debilitated and die. FP has seriously impacted green turtle populations in Florida (about 50 percent of juvenile green turtles in Indian River Lagoon and Florida Bay have fibropapillomas) and is now emerging as a significant threat to the loggerhead as well. FP is a transmissible disease caused by a virus, and, while both a unique herpesvirus and retroviruses have been identified in FP tumors, neither has yet been proven to be the cause of the disease. Researchers are concerned that there may be environmental (contaminant) cofactors for this disease in nearshore areas. Continuation and expansion of research on the disease is essential to developing an approach to remedying the problem.

S3.2. Maintain the Sea Turtle Stranding and Salvage Network. Most accessible U.S. beaches in the Atlantic and Gulf of Mexico are surveyed for stranded sea turtles by volunteer or contract personnel. Through the Sea Turtle Stranding and Salvage Network, stranding data are archived and summarized by the NMFS Miami Laboratory. These data provide an index of sea turtle mortality, and are thought to be a cost-effective means of evaluating the effectiveness of the Turtle Exclusion Device (TED) regulations. These data also provide basic biological information on sea turtles and are useful in determining other sources of mortality. The systematic stranding surveys of index areas need to be continued in South Florida. Periodic review of the efficacy of surveys should also be conducted.

S3.3. Centralize administration and coordination of tagging programs. Sea turtle researchers commonly tag turtles encountered during their research projects and usually maintain independent tagging data bases. The lack of centralization for administering these tagging data bases often results in confusion when tagged turtles are recaptured, and delays in reporting of recaptures to the person originally tagging the turtle. NMFS and FWS should investigate the possibilities of establishing a centralized tagging data base, including Passive Integrated Transponder (PIT) tags.

S3.3.1. Centralize tag series records. A centralized tag series data base is needed to ensure that recaptured tagged turtles can be promptly reported to persons who initially tagged the animal. The tag series data base would include listings of all tag series that have been placed on sea turtles in the wild, including the name and address of the researcher. This would eliminate problems in determining which researcher is using which tag series or types of tags, and would preclude unnecessary delays in reporting of tag returns. NMFS and/or FWS should establish and maintain this data base.

S3.3.2. Centralize turtle tagging records. In addition to the need for a centralization of tag series records, there are advantages in developing a centralized turtle tagging data base. Such a data base would allow all turtle researchers to trace unfamiliar tag series or types to their source, and also to have immediate access to important biological information collected at the time of original capture. The major disadvantage is that this data base would require frequent editing and updating, and would be costly and somewhat time consuming to maintain. It would also make it possible for unethical researchers to exploit the work of others, while providing no guarantees that such contributions would be acknowledged. NMFS and FWS should determine whether such a data base can be established and is feasible to maintain.

S3.4. **Develop requirements for care and maintenance of turtles in captivity, including diet, water quality, tank size, and treatment of injury and disease.** Sea turtles are maintained in captivity for rehabilitation, research, or educational display. Proper care will ensure the maximum number of rehabilitated turtles can be returned to the wild and a minimum number removed from the wild for research or education purposes. None of these requirements has been scientifically evaluated to determine the best possible captive conditions for sea turtles. FWS and NMFS should support the necessary research to develop these criteria, particularly relating to diet and the treatment of injury and disease. These criteria should be published and required for any permit to hold sea turtles in captivity. FWS, NMFS and/or DEP should inspect permitted facilities at least annually for compliance with permit requirements.

S4. **Monitor trends in nesting activity.** DEP and FWS should continue to refine standardized nest survey criteria, identify additional index survey beaches to be monitored, and continue to conduct training workshops for surveyors. Surveys in Florida do not routinely cover the first two months of the leatherback nesting season. Consequently, DEP and FWS should ensure that routine monitoring of nesting beaches is done on at least a weekly basis during the time that leatherback turtles are nesting, including any nesting that occurs outside of the regular survey period.

S5. **Continue information and education activities.** Sea turtle conservation requires long-term public support over a large geographic area. The public must be factually informed of the issues, particularly when conservation measures conflict with human activities, such as commercial fisheries, beach development, and public use of nesting beaches. Public education is the foundation upon which a long-term conservation program will succeed or fail.

S5.1. **Update existing slide programs and information leaflets on sea turtle conservation for the general public.** FWS has developed a bilingual slide tape program on sea turtle conservation and should keep the program current and available for all public institutions and conservation organizations. FWS and DEP should continually update and supply the public with informational brochures on sea turtle ecology and conservation needs.

S5.2. **Disseminate information from brochures and reports on recommended lighting modifications or measures to reduce hatchling disorientation and misorientation.** Recently published literature contains information on the types of light, screening, or shading that is best for turtles (e.g., Witherington and Martin 1996).

S5.3. **Develop public service announcements (PSA) regarding the sea turtle artificial lighting conflict and disturbance of nesting activities by public nighttime beach activities.** A professionally produced public service announcement for radio and TV would provide tremendous support and reinforcement of the many coastal lighting ordinances. It would generate greater support through understanding. FWS should develop a high-quality PSA that could be used throughout the Southeast during the nesting season.

S5.4. **Ensure that facilities permitted to hold and display captive sea turtles have appropriate informational displays.** Over 50 facilities are permitted to hold sea turtles for rehabilitation, research, and public education. Many are on public display and afford opportunities for public education. Display of accurate information on the basic biology and conservation problems should be a requirement of all permittees. All facilities should be visited by FWS, NMFS and/or DEP to ensure captive sea turtles are being displayed in a way to meet these criteria.

S5.5. Post informational signs at public access points on nesting beaches. Public access points to nesting beaches provide excellent opportunities to inform the public of necessary precautions for compatible public use on the nesting beach and to develop public support through informational and educational signs. FWS, NPS, DEP and other appropriate organizations should post such educational and informational signs on nesting beaches as appropriate.

Habitat-level Recovery Actions

H1. Protect and manage nesting habitat. Coastal development has already destroyed or degraded many miles of nesting habitat in South Florida. Although sea turtle nesting occurs on over 2,240 km of beaches within the southeast United States, development pressures are so great that cumulative impacts could result in increased degradation or destruction of nesting habitat and eventually lead to a significant population decline if not properly managed.

H1.1. Ensure beach nourishment projects are compatible with maintaining good quality nesting habitat. Beach nourishment can improve nesting habitat in areas of severe erosion and is a preferred alternative to beach armoring. However, placement of sand on an eroded section of beach or an existing beach in and of itself may not provide suitable nesting habitat for sea turtles. Although beach nourishment may increase the potential nesting area, significant negative impacts to sea turtles may result if protective measures are not incorporated during construction.

H1.1.2. Evaluate sand transfer systems as an alternative to beach nourishment. Sand transfer systems can diminish the necessity for frequent beach renourishment and thereby reduce disruption of nesting activities and eliminate sand compaction. The construction and operation of these systems must be carefully evaluated to ensure important nearshore habitats are not degraded or sea turtles injured or destroyed.

H1.1.3. Refine a sand budget formulation methodology for Sebastian Inlet. Inlets interrupt the natural flow of longshore sediment transport along the shoreline. The interrupted flow of sand is diverted either offshore in ebb tide shoals, into bays or lagoons in flood tide shoals, or in navigation channels (National Research Council 1990). As a result, erosion occurs downdrift of the interrupted shoreline. There are six man-made inlets on the Atlantic coast from Indian River County to Broward County. In Indian River County, for example, erosion has been nearly 2 m per year at Sebastian Inlet SRA (just south of Sebastian Inlet), when the average erosion rate for the county is just under 0.3 m per year (J. Tabar, Indian River County, personal communication 1996). DEP, Sebastian Inlet Tax District, and Indian River County should conduct engineering studies to refine a sand budget formulation methodology for the Sebastian Inlet. Other needs include: annually bypassing sand to downdrift beaches, conducting further studies of the long-term effects of the flood shoal on the inlet-related sediment budget, identifying the long-term impacts associated with the inlet in terms of sand impoundment and sediment volume deficit to downdrift areas, and determining the area of inlet influence.

H1.2. Prevent degradation of nesting habitat from seawalls, revetments, sand bags, sand fences or other erosion-control measures. One of the most difficult habitat protection efforts throughout South Florida is trying to minimize or eliminate the construction of seawalls, riprap, groins, sandbags, and improperly placed drift or sand fences. In 1995, the Florida Legislature passed a law giving coastal counties and municipalities the authority to approve construction of coastal armoring during certain emergency situations. (All non-emergency armoring situations must still receive an DEP permit prior to construction.) Although the new law weakened prior regulations on armoring, it does require that emergency armoring structures approved by a coastal county or municipality be temporary and that the structure be removed, or a permit application submitted to DEP for a permanent rigid coastal structure, within 60 days after the emergency installation of the structure. In addition, to implement this new law, DEP finalized a formal agency rule on coastal armoring on September 12, 1996.

H1.2.1. Ensure laws regulating coastal construction and beach armoring are enforced. The 1996 DEP rule recommends that local governments obtain an incidental take permit from FWS under section 10 of the Endangered Species Act and develop a sea turtle habitat conservation plan prior to authorizing armoring projects. The new rule also requires that several measures be undertaken to address sea turtle concerns for non-emergency armoring and for placement of permanent rigid coastal structures subsequent to an emergency (temporary) armoring event. For example, the new regulations require that (1) special conditions be placed on permitted activities to limit the nature, timing, and sequence of construction, as well as address lighting concerns; (2) structures not be used where the construction would result in a significant adverse impact; and (3) armoring be removed if it is determined to not be effective or to be causing a significant adverse impact to the beach and dune system.

H1.2.2. Ensure failed erosion control structures are removed. Failed erosion control structures such as uncovered plastic bags or tubes and fragmented concrete or wooden structures degrade nesting habitat and deter nesting activities. DEP should ensure failed structures are removed from nesting beaches.

H1.2.3. Develop standard requirements for sand fence construction. Sand fences can effectively build dune systems and improve nesting habitat; however, improperly designed sand fences can trap nesting females or hatchlings and prevent access to suitable nesting habitat. DEP and FWS should develop and evaluate sand fencing designs and establish standard requirements for sand fence construction.

H1.3. Identify important nesting beaches experiencing greater than 40 percent nest loss from erosion and implement appropriate habitat restoration measures (without relocation). Some important nesting beaches now suffer severe erosion as a result of inlet maintenance or jetty construction. In some situations, limited safe locations for relocating nests place constraints on nest relocation programs. Nest relocation programs should be considered as a short-term measure at best to protect nests in these situations with primary efforts directed toward habitat restoration.

DEP and FWS should review all important nesting beaches and identify those with 40 percent or more nest loss due to erosion or tidal inundation. Habitat restoration plans should be developed and implemented for identified nesting beaches.

H1.4. Acquire or otherwise ensure the long-term protection of important nesting beaches. Acquisition of important sea turtle nesting beaches would ensure long-term protection of U.S. nesting habitat. Acquisition and protection of undisturbed nesting habitat would enhance sea turtle nesting and hatching success.

H1.4.1. Continue to acquire in fee title all undeveloped beaches between Melbourne Beach and Wabasso Beach, Florida, for the Archie Carr National Wildlife Refuge. The Archie Carr NWR was designated by Congress in 1989 in recognition of the need for long stretches of quiet, undisturbed sandy beaches, with little or no artificial lighting, to ensure the reproductive success and survival of sea turtles. The refuge is located within a 33-km stretch of beach on the barrier islands of Brevard and Indian River Counties on the Atlantic coast of Florida. The proposed acquisition plan for the refuge set a goal for purchase of 15 km within four sections of this 33-km stretch. Three of the sections are located in Brevard County and one in Indian River County.

Partners in the land acquisition effort for the refuge and adjacent buffer areas on the barrier island include FWS, DEP, Brevard County, Indian River County, Richard King Mellon Foundation, The Conservation Fund, and The Nature Conservancy. To date, contributions from the State of Florida and local county partnerships account for over 70 percent of land acquisition expenditures, while contributions from the Richard King Mellon Foundation account for over 21 percent of acquisition costs for lands on the barrier island. Federal acquisition efforts account for about 8 percent of purchases to date.

About 61 percent of the available beachfront acquisitions for the Refuge have been completed. Of the original 15 km of beachfront identified for acquisition, approximately 8 km have been acquired and 5 km are awaiting purchase. The remaining lands have been purchased for private development and are no longer available. Escalating coastal development in Brevard and Indian River counties threatens the remaining parcels identified for acquisition. Ongoing development continues to fragment the remaining habitat and could result in increased lighting and beach armoring, which negatively impact sea turtles. A narrow window of opportunity is left to acquire the last remaining lands required for the refuge.

H1.4.2. Evaluate status of other undeveloped beaches that provide important habitat for maintaining the historic nesting distribution and develop a plan for long-term protection. DEP and FWS should evaluate other nesting beaches in the Southeast that contribute significantly to the historic nesting distribution to ensure long-term protection.

H2. Restore areas to suitable habitat.

H2.1. Reestablish dunes and native vegetation. Dune restoration and revegetation with native plants should be a required component of all renourishment projects. This will enhance beach stability and nesting habitat and may result in the need for less frequent renourishment activities.

H2.2. Remove exotic vegetation and prevent spread to nesting beaches. Australian pine trees shade nests and can alter natural hatchling sex ratios. Australian pines also aggressively replace native dune and beach vegetation through shading and chemical inhibition and consequently exacerbate erosion and loss of nesting habitat. Erosion can topple trees and leave exposed roots that can entrap nesting females. Removal of exotics, such as is ongoing at St. Lucie Inlet SP, Hobe Sound NWR, and Dry Tortugas NP, Florida, should continue. DEP, FWS, and NPS should identify other important nesting beaches where exotic vegetation is degrading nesting habitat and work with responsible parties to restore natural vegetation.

H3. Conduct research to evaluate the relationship of sand characteristics (including aragonite) and female nesting behavior, nesting success, hatching success, hatchling emerging success, hatchling fitness, and sex ratios. Beach nourishment may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content if the placed sand is dissimilar from the original beach sand. These changes could result in adverse impacts on nest site selection, digging behavior, clutch viability, and emergence by hatchlings. Gas diffusion of nests could be affected by sand grain shape, size, and compaction and variations could alter hatching success. Sand color and moisture influence nest incubation temperature and can affect hatchling sex determination. The effect of importing non-native materials, such as aragonite, to U.S. beaches for beach nourishment adds additional unknowns that could conceivably affect female nesting behavior, nesting success, hatching success, hatchling emerging success, hatchling fitness and sex ratios, and should be fully evaluated before large-scale use.

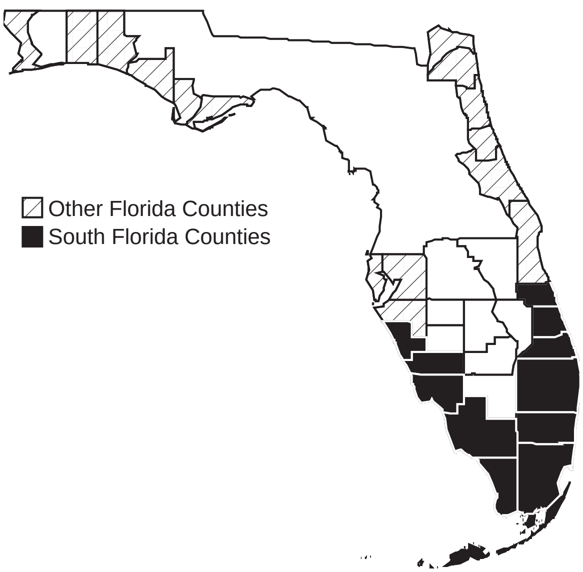
Studies of alternative sand sources for beach renourishment and their suitability for sea turtles are needed. After years of beach renourishment, Miami-Dade County is running out of suitable sand material for future renourishment projects. Broward and Palm Beach counties will also be running out of sand sources in the near future. COE is exploring the potential use of sand from upland sand sources and the importation of sand from the Bahamas and the Turks and Caicos Islands. Concerns have been raised about the long-term consequences to nesting and incubating sea turtles using these alternative beach renourishing materials. In order to adequately address these concerns in section 7 consultations, studies must be conducted on the suitability of these materials prior to receiving a proposal for large-scale nourishment of Florida beaches with these alternative sand sources.

Loggerhead Sea Turtle

Caretta caretta

Federal Status:	**Threatened (July 28, 1978)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. Florida nesting distribution of the loggerhead sea turtle.



The loggerhead sea turtle is the most common sea turtle species in South Florida. The nesting and hatching season for loggerhead sea turtles in South Florida extends from mid-March through November. The total number of loggerhead sea turtle nests surveyed in South Florida accounts for approximately 60 percent of all nests reported statewide (Meylan *et al*. 1995). Sea turtles, in general, are susceptible to human-related changes to the marine environment, and to their nesting beaches. This account provides an overview of the biology of the loggerhead turtle throughout its range. The discussion of environmental threats and management activities, however, pertains only to nesting beaches in South Florida. Serious threats to the loggerhead turtle on South Florida's nesting beaches include: destruction or modification of nesting habitat from coastal development, armoring, artificial lighting, beach nourishment, increased human presence, and exotic beach and dune vegetation.

This account is modified from the 1991 Recovery Plan for U.S. Population of Loggerhead Turtle and represents South Florida's contribution to the range-wide recovery plan for the loggerhead sea turtle (NMFS and FWS 1991).

Description

Adult and subadult loggerhead sea turtles have a reddish-brown carapace. The dorsal and lateral head scales and the dorsal scales of the extremities are also reddish-brown, but with light yellow margins that vary enough in extent to provide considerable disparity in appearance among individuals. The unscaled area of the integument (neck, shoulders, limb bases) are dull brown above and medium yellow laterally and ventrally. The plastron is also medium yellow. The thick, bony carapace is covered by non-imbricated horny scutes. There are five pairs of costals (pleurals), 11 or 12 pairs of marginals, five vertebrals and a nuchal (precentral) that is in contact with the first costal. Ventrally there are usually three pairs of poreless inframarginals, paired gulars, humerals, pectorals, abdominals, femorals and anals. An interanal is variable and inconstant. Mean straight carapace length (sCL) of adult Southeastern U.S. loggerheads is about 92 cm; corresponding mean body mass is about 113 kg. Elsewhere adult loggerheads are somewhat smaller; the most notable being those in Colombia (Kaufmann 1975), Greece (Margaritoulis 1982) and Tongaland (Hughes 1975). Loggerheads rarely exceed 122 cm sCL and 227 kg mass.

Hatchling loggerhead turtles lack the reddish tinge of adults and vary from light to dark brown dorsally. Both pairs of appendages are dark brown above and have distinct white margins. The plastron and other ventral surfaces may be described as dull yellowish tan and there is usually some brown pigmentation in the phalangeal portion of the web ventrally. At hatching mean body mass is about 20 g and mean sCL is about 45 mm. Hatchlings have three dorsal keels and two plastral ones.

The loggerhead turtle can be distinguished from other sea turtles by noting, collectively, the presence of five pairs of costal scutes and three pairs of inframarginals. Loggerheads are noted for their disproportionately large head (adults; 20 to 25 cm), and their heart-shaped carapace (DEP undated).

The crawls of nesting female sea turtles are distinctive interspecifically. Female loggerhead sea turtles leave a moderately deep cut track with alternating (asymmetrical) diagonal marks made by the front flippers (Pritchard *et al*. 1983). The nest itself is a smaller mound of sand than those formed by Atlantic green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) sea turtles. The body pit depression is also considered insignificant relative to that of Atlantic green and leatherback sea turtles (LeBuff 1990).

Taxonomy

The loggerhead sea turtle was described by Linnaeus (1758) and named *Testudo caretta.* Over the next two centuries more than 35 names were applied to the species (Dodd 1988), but there is now general agreement on *Caretta caretta* as the valid name. While Deraniyagala described an Indo-Pacific form as *C. gigas* in 1933, he revised that view in 1939 to hold that *gigas* was only a subspecies of *C. caretta* and the genus has generally been regarded as monotypic since that time. The subspecific designation of *gigas* has likewise been challenged persuasively (Brongersma 1961, Pritchard 1979). Dodd (1988) declared flatly that “the diagnostic characters used to distinguish *C. c. gigas* from *C. c. caretta* are not valid.” Thorough synonymies and taxonomic reviews of this form are given most recently by Pritchard and Trebbau (1984) and Dodd (1988).

Distribution

The geographic distribution of loggerhead sea turtles includes the temperate and tropical waters worldwide. The species inhabits the continental shelves and estuarine environments along the margins of the Atlantic, Pacific and Indian Oceans. In the Western Hemisphere it ranges as far north as Newfoundland (Squires 1954) and as far south as Argentina (Frazier 1984) and Chile (Frazier

Loggerhead sea turtle.
Original photograph courtesy of U.S. Fish and Wildlife Service.

and Salas 1982). The nesting range is confined to lower latitudes, but loggerhead nesting is clearly concentrated in the north and south temperate zones and subtropics. Pritchard (1979) used the term “antitropical” to describe the aversion exhibited by loggerheads to beaches in Central America, northern South America and throughout the Old World Tropics. Notable exceptions to this rule would include one of the largest known nesting aggregation, on Masirah and the Kuria Muria Islands of Oman in the Arabian Sea (Ross and Barwani 1982) and perhaps, the recently reported nesting assemblage on the Caribbean coast of Quintana Roo (NMFS and FWS 1991). Worldwide, about 88 percent of the loggerhead sea turtle nesting occurs in the southeastern U.S., Oman, and Australia (NMFS and FWS 1991).

Loggerhead sea turtles nest along the coast within the continental U.S. from Louisiana to Virginia. Major nesting concentrations are found on the coastal islands of North Carolina, South Carolina, and Georgia, and on the Atlantic and Gulf coasts of Florida (Hopkins and Richardson 1984). Although they nest in all coastal counties in South Florida (Figure 1), approximately 80 percent of nesting occurs along the east coast of Florida, particularly in Brevard, Indian River, St. Lucie, Martin, Palm Beach and Broward counties (NMFS and FWS 1991).

Habitat

Habitat selection for loggerhead sea turtles is not well understood, but it seems clear that adults can utilize a variety of habitats. Remote recoveries of female loggerhead sea turtles tagged in Florida indicate that many migrate to the Gulf of Mexico, often to the turbid, detritus-laden, muddy-bottom bays and bayous of the northern Gulf Coast. Still others apparently occupy the clear waters of the Bahamas and Antilles, with sandy bottoms, reefs and shoals that constitute a totally different type of habitat. Nothing is known of the relative period of time that loggerhead sea turtles may spend in these disparate habitats or of their propensity to move from one to another.

In most nearshore waters in the Southeast, adult and subadult loggerhead sea turtles appear to use the same habitats. In some of the inshore waters such as the Indian River Lagoon of east Florida the subadults are virtually isolated from the adults, whose foraging areas outside of the nesting season are apparently elsewhere.

As a generality, adult female loggerheads select high-to moderate-energy beaches on barrier strands adjacent to continental land masses for nesting. There is some evidence that loggerhead sea turtles favor steeply-sloped beaches with gradually-sloped offshore approaches (Provancha and Ehrhart 1987). After leaving the beach, hatchlings apparently swim directly offshore and eventually become associated with *Sargassum* and/or debris in pelagic drift lines that result from current convergences (Carr 1986a, 1986b, 1987). The evidence suggests that when post-hatchlings become a part of the *Sargassum* raft community they remain there as juveniles, riding circulating currents for several years and growing to about 45 cm sCL. At that point they abandon the pelagic habitat, migrate to the nearshore and estuarine waters along continental margins and utilize those areas as the developmental habitat for the subadult stage (NMFS and FWS 1991).

Behavior

The recent literature dealing with the biology of loggerhead sea turtles is extensive and only a brief treatment is warranted here. However, a number of thorough synopses of loggerhead biology are currently available. The most recent and extensive is the work of Dodd (1988) but those of Pritchard and Trebbau (1984) and Groombridge (1982) are also very comprehensive and useful.

Reproduction and Demography

It has been assumed that male loggerheads migrate with females from distant foraging areas to the waters off nesting beaches and that courtship and mating take place there. The few reports concerning the seasonality of mating clearly place it in the late-March to early-June period (Caldwell 1959, Caldwell *et al.* 1959a, Fritts *et al.* 1983). While a few adult males may remain off the Florida coast throughout the year (Henwood 1987), most of them apparently depart by about mid-June, leaving the females to ascend the nesting beaches and deposit clutches throughout the summer. Nevertheless, courtship and mating are not well studied in loggerheads and there is no doubt that this and virtually every other aspect of the biology of male loggerheads needs further research and clarification.

In the southeastern U.S., adult female loggerheads begin to nest as early as mid-March and they continue to do so until late September. Nesting activity is greatest in June and July. In Georgia, South Carolina, and North Carolina, the season generally begins in mid-May and ends by mid-August. Loggerheads are known to nest from one to seven times within a nesting season (Talbert *et al.* 1980, Richardson and Richardson 1982, Lenarz *et al.* 1981); the mean is approximately four times (Murphy and Hopkins 1984). The inter-nesting interval varies around a mean of about 14 days. There is general agreement with Caldwell *et al.* (1959b) that female loggerhead sea turtles mate prior to the nesting season (and possibly only once during the nesting season) and then lay multiple clutches of fertile eggs throughout some portion of the nesting season. Along the southeastern U.S. coast, mean clutch size varies from about 100 to 126 eggs (NMFS and FWS 1991).

Loggerheads are nocturnal nesters, but they will infrequently nest during the day (Fritts and Hoffman 1982, Witherington 1986). Although a definitive study of loggerhead nesting behavior has yet to be published, good descriptive accounts have been given by Carr (1952), Litwin (1978) and Caldwell *et al.* (1959a). Multi-annual remigration intervals of two and three years are most common in loggerheads, but the number can vary from 1 to 6 years (Richardson *et al.* 1978, Bjorndal *et al.* 1983). Natural incubation periods for U.S. loggerheads average from 53-55 days in Florida (Davis and Whiting 1977, Witherington 1986) to 63 and 68 days in Georgia (Kraemer 1979) and North Carolina (Crouse 1985), respectively. The length of the incubation period is inversely related to nest temperature (McGehee 1979). Sex determination in loggerhead hatchings is temperature dependent (Yntema 1982, Yntema and Mrosovsky 1980) and the species apparently lacks sex chromosomes (Standora and Spotila 1985). Natural hatching success rates of 73.4 percent and 55.7 percent have been reported in South Carolina (Caldwell 1959) and Florida (Witherington 1986), respectively.

While a number of workers have reported growth rates of post-hatchling and juvenile loggerheads in captivity *(e.g.*, Witham and Futch 1977), such information is totally lacking for these stages in the wild. In captivity young loggerheads can grow to about 63 cm sCL and 37 kg in mass in 4.5 years (Parker 1926). In wild subadults, Limpus (1979) has reported linear growth rates of 1.5 cm/yr in Australia and Mendonca (1981) has reported average linear growth rates of 5.9 cm/yr in Florida. It seems clear now that growth rates of subadults decrease with increasing carapace length (i.e., growth is not linear). Although they lacked data for loggerheads smaller than 53 cm sCL, Frazer and Ehrhart (1985) fitted growth data for Florida subadults to both logistic and van Bertalanffy curves and estimated age at maturity as 12 to 30 years.

Migration

Adults loggerheads become migratory for the purpose of breeding. Recoveries of females tagged while nesting on the Florida east coast suggest widely dispersed foraging in the Gulf of Mexico, Cuba and elsewhere in the Greater Antilles, and the Bahamas (Meylan *et al.* 1983). While conclusive evidence is lacking as yet, it is assumed that these females remigrate hundreds or thousands of km at multi-annual intervals to nest on the good, high energy nesting beaches of east Florida. Bell and Richardson (1978) reported tag recoveries suggesting a migratory path from Georgia to Cape Hatteras, North Carolina and a single recovery of a Georgia tagged female on the Florida Gulf Coast (Tampa Bay). Little else is known of the travels of loggerhead sea turtles that nest in Georgia, South Carolina, and North Carolina outside of the nesting season.

Loggerhead hatchlings engage in a swimming frenzy for about 20 hours after they enter the sea and that frenzy takes them about 22 to 28 km offshore

(Salmon and Wyneken 1987). Upon reaching about 45 cm sCL, they abandon the pelagic existence and migrate to nearshore and estuarine waters, including the eastern U.S., the Gulf of Mexico and the Bahamas, and begin the subadult stage (NMFS and FWS 1991). Little is known of their seasonal movements there, but Henwood (1987) has reported a tendency for subadults of the Port Canaveral (Florida) aggregation to disperse more widely in the spring and early summer. Also, Chesapeake Bay subadults are known to exhibit a variety of movements between waters of differing temperatures and salinities (Killingly and Lutcavage 1983).

Foraging

While the list of food items eaten by loggerheads is lengthy and includes invertebrates from eight phyla (Dodd 1988), it is clear that subadult and adult loggerheads are, first and foremost, predators of benthic invertebrates such as gastropod and pelecypod molluscs and decapod crustaceans. Coelenterates and cephalopod molluscs are also taken by larger turtles but these invertebrates are especially favored by loggerheads in the pelagic stage. Most of the evidence for the latter statement comes from the island groups of the eastern Atlantic (van Nierop and den Hartog 1984). Post-hatchling loggerheads evidently ingest macroplankton associated with weed lines. In one of the few studies of post-hatchling food habits in the southeastern U.S., Carr and Meylan (1980) found two species of small gastropods characteristic of the *Sargassum* raft community as well as fragments of crustaceans and the *Sargassum* plant itself. Although Brongersma (1972) listed Syngnathid fishes among the items found in the stomach contents of loggerhead sea turtles, this species is not a significant fish eater. Loggerheads may scavenge fish or fish parts or ingest fish incidentally in some circumstances.

Relationship to Other Species

In South Florida, loggerhead sea turtles share nesting beaches with the endangered Atlantic green sea turtle, in every county where it nests, and with the endangered leatherback sea turtle, which most commonly nests in Martin and Palm Beach counties. Other federally listed species that occur in coastal dune and coastal strand habitat, and that need to be considered when managing nesting beaches, are the southeastern beach mouse (*Peromyscus polionotus niveiventris*) and the beach jacquemontia (*Jacquemontia reclinata*). Beach nourishment projects, in particular, could affect these species as well as the turtles. The range of the beach mouse in South Florida is estimated to include Indian River County south to Broward County. The beach jacquemontia is found in Palm Beach County south to Miami, Miami-Dade County.

A variety of natural and introduced predators such as raccoons (*Procyon lotor*), feral hogs, opossums (*Didelphis virginiana*), foxes, ghost crabs and ants prey on incubating eggs and hatchling sea turtles. The principal predator of loggerhead sea turtle eggs is the raccoon, which is particularly destructive and may take up to 96 percent of all eggs laid in nests deposited on a beach (Davis and Whiting 1977, Hopkins and Murphy 1980, Stancyk *et al.* 1980, Talbert *et al.* 1980, Schroeder 1981, Labisky *et al.* 1986). In 1996, Hobe Sound NWR experienced depredation in 23 percent of the nests enumerated (FWS 1996). In addition to the destruction of eggs, some of these predators may take considerable numbers of hatchlings just prior to or upon emergence from the sand.

Predation of hatchlings and very young turtles is assumed to be significant and predation of subadult through adult stage turtles is assumed less common, but valid estimates of mortality due to predation at various life history stages are extremely difficult, if not impossible, to obtain, and have not been determined. Hatchlings entering the surf zone and pelagic stage hatchlings may be preyed upon by a wide variety of fish species and to a lesser extent, marine birds. Stancyk (1982), in an extensive literature review, reported predators of juvenile and adult turtles to include at least six species of sharks, *orca* whales, bass and grouper. Tiger sharks appear to be the principal marine predator of subadult and adult turtles.

Status and Trends

The loggerhead was listed on July 28, 1978 as a threatened species under the Endangered Species Act of 1973 (43 FR 32800). Internationally, it is considered endangered by the International Union for Conservation of Nature and Natural Resources (IUCN) and is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

It is not possible, at present, to estimate the size of the loggerhead sea turtle population in U.S. territorial waters if one includes subadults. There is, however, general agreement with Meylan (1982) that enumeration of nesting females provides a useful index to population size and stability. The estimate of 14,150 females nesting per year in the southeastern U.S. given by Murphy and Hopkins (1984) and based on aerial survey data from 1983, was accepted by Mager (1985) and more recently by Ehrhart (1989) as the current best approximation. Given Murphy and Hopkins' (1984) stochastically derived mean number of nests per female (4.1), this figure provides an estimate of approximately 58,000 nests deposited per year in the Southeast. Based on more extensive ground and aerial surveys since 1990, an estimated 60,000 nests are deposited annually in the Southeast (Meylan *et al*. 1995). However, according to Dodd (1995), the numbers of turtles nesting fluctuates substantially from one year to the next, making interpretation of beach counts difficult. These numbers are believed to constitute about 35 to 40 percent of the loggerhead nesting known worldwide (NMFS and FWS 1991).

From a global perspective, the southeastern U.S. nesting aggregation is of paramount importance to the survival of the species and may be second in size only to the nesting aggregation of the islands in the Arabian Sea off of Oman (Ross 1982, Ehrhart 1989, NMFS and FWS 1991). The status of the Oman nesting aggregation has not been evaluated recently, but its location in a part of the world that is vulnerable to disruptive events (e.g., political upheavals, wars, catastrophic oil spills) is cause for considerable concern (Meylan *et al*. 1995). The loggerhead nesting aggregations in Oman, the southeastern U.S., and Australia account for about 88 percent of nesting worldwide (NMFS and FWS 1991). About 80 percent of loggerhead nesting in the southeastern U.S. occurs in six Florida counties: Brevard, Indian River, St. Lucie, Martin, Palm Beach, and Broward (NMFS and FWS 1991).

Table 1. Average annual number of loggerhead nests by county from 1985 to 1995.

County	Average
Indian River	2242.5
St. Lucie	4258.2
Martin	8405.4
Palm Beach	9159.6
Broward	1912.2
Dade	347.45
Monroe	115.73
Collier	480.55
Lee	384.27
Charlotte	420
Sarasota	1643.09

Recent genetic analyses using restriction fragment analysis and direct sequencing of mitochondrial DNA have been employed to resolve management units among loggerhead nesting cohorts of the southeastern U.S. (Bowen *et al.* 1993, B.W. Bowen, University of Florida, personal communication 1994, 1995). Assays of nest samples from North Carolina to the Florida Panhandle have identified three genetically distinct nesting subpopulations: (1) northern nesting subpopulation--Hatteras, North Carolina, to Cape Canaveral, Florida; (2) South Florida nesting subpopulation -Cape Canaveral to Naples, Florida; and (3) Florida Panhandle nesting subpopulation -Eglin Air Force Base and the beaches around Panama City, Florida. These data indicate that gene flow between the three regions is very low. If nesting females are extirpated from one of these regions, regional dispersal will not be sufficient to replenish the depleted nesting subpopulation (Bowen *et al.* 1993, B. Bowen, University of Florida, personal communication 1995).

Throughout Florida, loggerhead sea turtle nests account for the vast majority of reported nesting; they comprised 97.9 percent of the total nesting activity during 1979 to 1992 (Meylan *et al.* 1995). From 1988 to 1992, while survey efforts remained relatively constant, the total number of reported loggerhead nests statewide fluctuated between 37,242 and 68,614. However, to better assess trends in nesting, the State of Florida, in cooperation with the FWS, initiated an Index Nesting Beach Survey (INBS) program in 1989 to collect nesting data that can be used to statistically and scientifically analyze population trends. Between 1989 and 1995, INBS nesting numbers have fluctuated between 39,172 and 59,379. While the results of the INBS program in Florida have shown small fluctuations in the numbers of nests laid annually, it is too soon to decipher with any confidence the trend in nesting population size.

Although the majority of loggerhead nesting during 1988 to 1992 occurred in Brevard County (39.4 percent), just outside of the South Florida Ecosystem, Palm Beach County supported the second highest percentage of nests during that time period with 17.8 percent of loggerhead nests. The average number of nests annually within the South Florida Ecosystem are shown in Table 1. These data show that Palm Beach County is clearly the most important nesting location within South Florida for the threatened loggerhead sea turtle. We chose to only represent the past 10 years of survey data in Table 1, because there was less beach surveyed and the data were not as complete prior to 1985.

Environmental Threats

A number of threats exist to sea turtles in the marine environment, including: oil and gas exploration, development, and transportation; pollution; trawl, purse seine, hook and line, gill net, pound net, longline, and trap fisheries; underwater explosions; dredging; offshore artificial lighting; power plant entrapment; entanglement in debris; ingestion of marine debris; marina and dock development; boat collisions; and poaching. These threats and protective measures are discussed in detail in the Recovery Plan for U.S. Population of Loggerhead Turtle (NMFS and FWS 1991). In South Florida, and for this Recovery Plan, the focus is on the threats to nesting beaches, including: beach erosion, armoring and nourishment; artificial lighting; beach cleaning;

increased human presence; recreational beach equipment; exotic dune and beach vegetation; nest loss to abiotic factors; and poaching.

Beach Erosion: Erosion of nesting beaches can result in partial or total loss of suitable nesting habitat. Erosion rates are influenced by dynamic coastal processes, including sea level rise. Man's interference with these natural processes through coastal development and associated activities has resulted in accelerated erosion rates and interruption of natural shoreline migration (National Research Council 1990).

Beach Armoring: Where beachfront development occurs, the site is often fortified to protect the property from erosion. Virtually all shoreline engineering is carried out to save structures, not dry sandy beaches, and ultimately results in environmental damage. One type of shoreline engineering, collectively referred to as beach armoring, includes sea walls, rock revetments, riprap, sandbag installations, groins and jetties. Beach armoring can result in permanent loss of a dry nesting beach through accelerated erosion and prevention of natural beach/dune accretion and can prevent or hamper nesting females from accessing suitable nesting sites. Clutches deposited seaward of these structures may be inundated at high tide or washed out entirely by increased wave action near the base of these structures.

As these structures fail and break apart they spread debris on the beach, which may further impede access to suitable nesting sites (resulting in higher incidences of false crawls) and trap hatchlings and nesting turtles. Sandbags are particularly susceptible to rapid failure and result in extensive debris on nesting beaches. Rock revetments, riprap, and sandbags can cause nesting turtles to abandon nesting attempts or to construct improperly sized and shaped egg cavities when inadequate amounts of sand cover these structures. Information obtained during preparation of the sea turtle recovery plans indicated that approximately 21 percent (234 km) of Florida's beaches were armored at that time (NMFS and FWS 1991).

Groins and jetties are designed to trap sand during transport in longshore currents or to keep sand from flowing into channels in the case of the latter. These structures prevent normal sand transport and accrete beaches on one side of the structure while starving neighboring beaches on the other side thereby resulting in severe beach erosion (Pilkey *et al.* 1984) and corresponding degradation of suitable nesting habitat.

Drift fences, also commonly called sand fences, are erected to build and stabilize dunes by trapping sand moving along the beach and preventing excessive sand loss. Additionally, these fences can serve to protect dune systems by deterring public access. Constructed of narrowly spaced wooden or plastic slats or plastic fabric, drift fences when improperly placed can impede nesting attempts and/or trap emergent hatchlings and nesting females.

Beach Nourishment: Beach nourishment consists of pumping, trucking, or scraping sand onto the beach to rebuild what has been lost to erosion. Although beach nourishment may increase the potential nesting area, significant adverse effects to sea turtles may result if protective measures are not taken. Placement of sand on an eroded section of beach or an existing beach in and of itself may not provide suitable nesting habitat for sea turtles. Beach nourishment can harm turtles through direct burial of nests and by disturbance to nesting turtles if conducted during the nesting season. Beach nourishment may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope and profile, sand color, sand grain size, sand grain shape, and sand grain mineral content, if the placed sand is dissimilar from the original beach sand (Nelson and Dickerson 1988a). These changes can affect nest site selection, digging behavior, incubation temperature (and hence sex ratios), gas exchange parameters within incubating nests, hydric environment of the nest, hatching success and hatchling emerging success (Mann 1977, Ackerman 1980, Mortimer 1982, Raymond 1984a).

Beach compaction and unnatural beach profiles that may result from beach nourishment activities could adversely affect sea turtles regardless of the timing of the projects. Very fine sand and/or the use of heavy machinery can cause sand compaction on nourished beaches (Nelson *et al*. 1987, Nelson and Dickerson 1988a). Significant reductions in nesting success have been documented on severely compacted nourished beaches (Raymond 1984a). Increased false crawls result in increased physiological stress to nesting females. Sand compaction may increase the length of time required for female sea turtles to excavate nests, also causing increased physiological stress to the animals (Nelson and Dickerson 1988c).

Nelson and Dickerson (1988b) evaluated compaction levels at 10 renourished east coast Florida beaches and concluded that 50 percent were hard enough to inhibit nest digging, 30 percent were questionable as to whether their hardness affected nest digging, and 20 percent were probably not hard enough to affect nest digging. They further concluded that, in general, beaches nourished from offshore borrow sites are harder than natural beaches, and, while some may soften over time through erosion and accretion of sand, others may remain hard for 10 years or more.

On nourished beaches, steep escarpments may develop along their water line interface as they adjust from an unnatural construction profile to a more natural beach profile (Coastal Engineering Research Center 1984, Nelson *et al*. 1987). These escarpments can hamper or prevent access to nesting sites. Female turtles coming ashore to nest can be discouraged by the formation of an escarpment, leading to situations where they choose marginal or unsuitable nesting areas to deposit eggs (*e.g*., in front of the escarpments, which often results in failure of nests due to repeated tidal inundation). This effect can be minimized by leveling the beach prior to the nesting season.

Beach nourishment may cause changes to the beach profile (wider and higher) which may cause additional light to be visible from the beach and lower the apparent elevation of the landward horizon making sea finding by the hatchlings more difficult (DERM, personal communication 1998).

A change in sediment color due to beach nourishment could change the natural incubation temperatures of nests. This, in turn, could alter natural sex ratios. To provide the most suitable sediment for nesting sea turtles, the color of the nourished sediments must resemble the natural beach sand in the area. Natural reworking of sediments and bleaching from exposure to the sun would help to lighten dark nourishment sediments; however, the time frame for sediment mixing and bleaching to occur could be critical to a successful sea turtle nesting season.

Nourishment projects result in heavy machinery, pipelines, increased human activity and artificial lighting on the project beach. These activities are normally conducted on a 24-hour basis and can adversely affect nesting and hatching activities if conducted during the nesting and hatching season. Pipelines and heavy machinery can create barriers to nesting females emerging from the surf and crawling up the beach, causing a higher incidence of false crawls (non-nesting emergences) and an unnecessary energy expenditure. Heavy equipment on the beach during nesting season and hatching season can also create ruts which can trap hatchlings (DERM, personal communication 1998). Increased human activity on the project beach at night may cause further disturbance to nesting females. Artificial lights along the project beach and in the nearshore area of the borrow site may deter nesting females and disorient or misorient emergent hatchlings from adjacent non-project beaches.

Beach nourishment projects require continual maintenance (subsequent nourishment) as beaches erode; therefore their negative impacts to turtles are repeated on a regular basis. Nourishment of highly eroded beaches (especially those with a complete absence of dry beach) can be beneficial to nesting turtles if conducted properly. Careful consideration and advance planning and coordination must be carried out to ensure timing, methodology and sand sources are compatible with nesting and hatching requirements.

Artificial Lighting: Extensive research has demonstrated that the principal component of the sea finding behavior of emergent hatchlings is a visual response to light (Daniel and Smith 1947, Hendrickson 1958, Carr and Ogren 1960, Ehrenfeld and Carr 1967, Dickerson and Nelson 1989, Witherington and Bjorndal 1991). Artificial beachfront lighting from buildings, streetlights, dune crossovers, vehicles and other types of beachfront lights have been documented in the disorientation (loss of bearings) and misorientation (incorrect orientation) of hatchling turtles (McFarlane 1963, Philibosian 1976, Mann 1977, Ehrhart 1983).

The results of disorientation or misorientation are often fatal. Many lighting ordinance requirements do not become effective until 11 p.m., whereas over 30 percent of hatchling emergence occurs prior to this time (Witherington *et al.* 1990). As hatchlings head toward lights or meander along the beach, their exposure to predators and likelihood of desiccation is greatly increased. Misoriented hatchlings can become entrapped in vegetation or debris, and many hatchlings are found dead on nearby roadways and in parking lots after being struck by vehicles. Hatchlings that successfully find the water may be misoriented after entering the surf zone or while in nearshore waters. Intense artificial lighting can even draw hatchlings back out of the surf (Daniel and Smith 1947, Carr and Ogren 1960). During the period 1989 to 1990, a total of 37,159 misoriented hatchlings were reported to the Florida Department of Natural Resources (now DEP). Undoubtedly a large but unquantifiable number of additional misorientation events occurred but were not documented due to obliteration of observable sign, depredation, entrapment in thick vegetation, loss in storm drains, or obliteration of carcasses by vehicle tires.

The problem of artificial beachfront lighting is not restricted to hatchlings. In June 1992, a nesting loggerhead was killed by an automobile as it wandered onto Highway AlA at Patrick Air Force Base in Cocoa Beach, Florida, misoriented by lights from the west side of the highway. Raymond (1984a) indicated that adult loggerhead emergence patterns were correlated with variations in beachfront lighting in south Brevard County, Florida, and that nesting females avoided areas where beachfront lights were the most intense. Witherington (1986) noted that loggerheads aborted nesting attempts at a greater frequency in lighted areas. Problem lights may not be restricted to those placed directly on or in close proximity to nesting beaches. The background glow associated with intensive inland lighting, such as that emanating from nearby large metropolitan areas, may deter nesting females and disorient or misorient hatchlings crawling on nearby beaches. Cumulatively, along the heavily developed beaches of the southeastern U.S., the negative effects of artificial lights are profound. Another significant effect of heavy coastal development is the increased cutting of coastal vegetation, which blocks beachfront lighting and lowers the darker, landward horizon, thus discouraging adults from nesting and reducing hatchlings ability to find the ocean (DERM, personal communication 1998).

Beach Cleaning: Beach cleaning refers to the redistribution and periodic removal of both abiotic and biotic debris from developed beaches. There are several methods employed, including mechanical raking, hand raking, and picking up debris by hand. Mechanical raking can result in heavy machinery repeatedly traversing nests and potentially compacting sand above nests and also results in tire ruts along the beach, which may hinder or trap emergent hatchlings. Mann (1977) suggested that nest mortality may increase when beach cleaning machinery is used on soft, large-grained sand beaches. Mechanically pulled rakes and hand rakes can penetrate the surface and disturb the sealed nest or may actually uncover pre-emergent hatchlings near the surface of the nest. In some areas, collected debris is buried directly on the beach, and this can lead to excavation and destruction of incubating egg clutches. Disposal of debris near the dune line or on the high beach can cover incubating egg clutches and subsequently hinder and entrap emergent hatchlings and may alter natural nest temperatures.

Increased Human Presence: Residential and tourist use of developed (and developing) nesting beaches can result in negative impacts to nesting turtles, incubating egg clutches, and hatchlings. The most serious threat caused by increased human presence on the beach is the disturbance to nesting females. Nighttime human activity can cause nesting females to abort nesting attempts at all stages of the behavioral process. Murphy (1985) reported that disturbance can cause turtles to shift their nesting beaches, delay egg laying, and select poor nesting sites. Heavy utilization of nesting beaches by humans (pedestrian traffic) may result in lowered hatchling emerging success rates due to compaction of sand above nests (Mann 1977), and pedestrian tracks can interfere with the ability of hatchlings to reach the ocean (Hosier *et al.* 1981). Campfires and the use of flashlights on nesting beaches misorient hatchlings and can deter nesting females (Mortimer 1979).

Recreational Beach Equipment: The placement of physical obstacles (e.g., lounge chairs, cabanas, umbrellas, Hobie cats, canoes, small boats and beach cycles) on nesting beaches can hamper or deter nesting attempts and interfere with incubating egg clutches and the sea approach of hatchlings. The documentation of false crawls at these obstacles is becoming increasingly common as more recreational beach equipment is left in place nightly on nesting beaches. Additionally, there are documented reports of nesting females becoming entrapped under heavy wooden lounge chairs and cabanas on South Florida nesting beaches (NMFS and FWS 1991). The placement of recreational beach equipment directly above incubating egg clutches may hamper hatchlings during emergence and can destroy eggs through direct invasion of the nest (NMFS and FWS 1991).

Exotic Dune and Beach Vegetation: Non-native vegetation has invaded many coastal areas and often outcompetes native species such as sea oats, railroad vine, sea grape, dune panic grass and pennywort. The invasion of less stabilizing vegetation can lead to increased erosion and degradation of suitable nesting habitat. Exotic vegetation may also form impenetrable root mats which can prevent proper nest cavity excavation, invade and desiccate eggs, or trap hatchlings. The Australian pine *(Casuarina equisetifolia)* is particularly detrimental. Dense stands of this species have taken over many coastal strand areas throughout central and South Florida. Australian pines cause excessive shading of the beach that would not otherwise occur. Studies in Florida suggest that nests laid in shaded areas are subjected to lower incubation temperatures, which may alter the natural hatchling sex ratio (Marcus and Maley 1987, Schmelz and Mezich 1988). Fallen Australian pines limit access to suitable nest sites and can entrap nesting females. Davis and Whiting (1977) reported that nesting activity declined in Everglades NP where dense stands of Australian pine took over native beach berm vegetation on a remote nesting beach. Conversely, along highly developed beaches, nesting may be concentrated in areas where dense stands of Australian pines create a barrier to intense beachfront and beach vicinity lighting (NMFS and FWS 1991).

Nest Loss to Abiotic Factors: Erosion or inundation and accretion of sand above incubating nests appear to be the principal abiotic factors that may negatively affect incubating egg clutches. While these factors are often widely perceived as contributing significantly to nest mortality or lowered hatching success, few quantitative studies have been conducted (Mortimer 1989). Studies on a relatively undisturbed nesting beach by Witherington (1986) indicated that, with the exception of a late season severe storm event, erosion and inundation played a relatively minor role in destruction of incubating nests. Inundation of nests and accretion of sand above incubating nests as a result of the late season storm played a major role in destroying nests from which hatchlings had not yet emerged. Severe storm events (e.g., tropical storms and hurricanes) may result in significant nest loss, but these events are typically aperiodic rather than annual occurrences. In the southeastern U.S., severe storm events are generally experienced after the peak of the hatching season and hence would not be expected to affect the majority of incubating nests. Erosion and inundation of nests are exacerbated through coastal development and shoreline engineering. These threats are discussed above under beach armoring.

Predation: Predators, particularly exotics such as fire ants (*Solenopsis invicta*) and human-associated ones including raccoons and opossums are becoming increasingly detrimental to nesting beaches.

Poaching: In the U.S., killing of female loggerheads is infrequent. However, in a number of areas, egg poaching and clandestine markets for eggs

Table 2. Major loggerhead nest survey/protection projects in the South Florida Ecosystem, 1985 to 1990. Includes consistently monitored survey areas reporting greater than 100 nests annually. Not all beaches were surveyed during the entire 6-year period.

Project	Beach length (km)	Number of nests	Conservation measure(s)*
Sebastian Inlet SRA, FL	4.8	513-921	S/PR
Wabasso Beach, FL	8.0	1155-1256	S/PR
Vero Beach, FL	7.0	199-349	S/NR
Hutchinson Island, FL	36.5	4637-6711	S
St. Lucie Inlet SP, FL	4.3	289-432	S/PR
Hobe Sound NWR, FL	5.3	1202-1732	S/PR
Town of Jupiter Island, FL	12.1	2640-6431	S
Juno Beach, FL	8.1	2790-4664**	S
J.D. MacArthur SP, FL	2.9	496-1062	S/PR
Delray Beach, FL	3.5	138-288	S/NR
City of Boca Raton, FL	8.0	874-1100	S/NR/NS
Broward County Beaches, FL	38.6	1244-2283	S/NR/NS
Miami Area Beaches, FL	16.9	64-182	S/NR
Manasota Key, FL	18.9	312-884	S/NR
Casey Key, FL	8.2	107-459	S/NR
Sanibel Island, FL	18.5	110-137	S
Wiggins Pass Area Beaches, FL	6.4	106-215	S/NS
Keewaydin Island, FL	7.2	96-137	S/NR/NS

*S=Survey NR=Nest Relocation
**1989-1990 data only NS=Nest Screening PR=Predator Removal

are not uncommon. From 1983 to 1989, the Florida Marine Patrol, DEP, made 29 arrests for illegal possession of turtle eggs.

Disease

There is little information available to assess the comprehensive effects of disease and/or parasites on wild populations of marine turtles. The vast majority of diseases and conditions which have been identified or diagnosed in sea turtles are described from captive stock, either turtles in experimental headstart programs or mariculture facilities (Wolke 1989). One notable exception is the identification of the disease spirorchidiasis, resulting from infection with intravascular trematodes (Wolke *et al.* 1982). The observable external characteristics of this disease, however, are not exhibited in the majority of loggerhead carcasses that strand along the Atlantic and Gulf of Mexico coasts. In addition, fibropapilloma disease most comonly seen in green turtles is now emerging as a significant threat to the loggerhead.

Management

There are a number of management activities ongoing in South Florida to benefit the loggerhead sea turtle. Table 2 lists some of the major Federal, State and private nest survey and protection projects in the South Florida Ecosystem. In addition to management of coastal habitats, NMFS and FWS (1991) discuss additional conservation measures for the loggerhead turtle in the marine environment. Additional reviews of sea turtle conservation efforts in the southeastern U.S. appear in Possardt (1991).

Conservation of sea turtle nesting habitat is continuing on several NWRs in South Florida, including Archie Carr, Hobe Sound, Ten Thousand Islands, and the complex of satellite refuges in the Florida Keys. Acquisition of high-density nesting beaches between Melbourne Beach and Wabasso Beach, Florida, is continuing to complete the Archie Carr NWR. Approximately 25 percent of the loggerhead nesting in the U.S. occurs along this 33 km stretch of beach. The State of Florida purchased the first parcel specifically for the refuge in July 1990. Federal acquisition began in 1991. When completed, the refuge will protect up to 16 km of nesting beach. Since the initial acquisition, Brevard County and the Richard King Mellon Foundation have joined in as acquisition partners. Hobe

Sound NWR, located north of West Palm Beach in Martin County, contains 5.25 km of Atlantic coast shoreline for nesting habitat. In addition to providing some of the most productive sea turtle nesting habitat in the U.S., the refuge is also home to Florida scrub-jays (*Aphelocoma coerulescens*) and gopher tortoises *(Gopherus polyphemus*). The most longstanding beach management program has been to reduce destruction of nests by natural predators, such as raccoons. Control of numerous exotic plants such as Australian pine and Brazilian pepper (*Schinus terebinthifolius*) are also major issues in managing the refuge.

One of the most difficult habitat protection efforts throughout South Florida is trying to minimize or eliminate the construction of seawalls, riprap, groins, sandbags, and improperly placed drift or sand fences. State and Federal laws designed to protect the beach and dune habitat in South Florida include the Coastal Barrier Resources Act of 1982 and the Coastal Zone Protection Act of 1985. These have had varying degrees of success at maintaining suitable nesting sites for loggerheads. Prior to 1995, DEP permits were required for all coastal armoring projects prior to construction. When issuing these permits, DEP incorporated sea turtle protection measures, and sea turtle concerns were generally well addressed.

However, in 1995, the Florida Legislature passed a law giving coastal counties and municipalities the authority to approve construction of coastal armoring during certain emergency situations. (All non-emergency armoring situations must still receive a DEP permit prior to construction.). Although the new law weakened prior regulations on armoring, it does require that emergency armoring structures approved by a coastal county or municipality be temporary and that the structure be removed or a permit application submitted to DEP for a permanent rigid coastal structure within 60 days after the emergency installation of the structure.

In addition, to implement this new law, DEP finalized a formal agency rule on coastal armoring on September 12, 1996. The new rule recommends that local governments obtain the necessary approval from the FWS prior to authorizing armoring projects. The new rule also requires that several measures be undertaken to address sea turtle concerns for non-emergency armoring and for placement of permanent rigid coastal structures subsequent to an emergency (temporary) armoring event. For example, the new regulations require that (1) special conditions be placed on permitted activities to limit the nature, timing, and sequence of construction, as well as address lighting concerns; (2) structures not be used where the construction would result in a significant adverse impact, and (3) armoring be removed if it is determined to not be effective or to be causing a significant adverse impact to the beach and dune system.

Beach nourishment is a better alternative for sea turtles than seawalls and jetties. When beach nourishment was done mostly in the summer, all nests had to be moved from the beach prior to nourishment. Now FWS and State natural resource agencies review beach nourishment projects with timing in mind, such as abstaining from construction activities on the beach during the nesting and hatching season. In southeast Florida, (Indian River County through Miami-Dade County), the loggerhead nesting and hatching season is from March 15 through November 30. In southwest Florida, Gulf of Mexico (Sarasota County through Monroe County), the nesting and hatching season is from April 1 through November 30. Any management decisions regarding beach nourishment, waterway dredging involving beach disposal, beach armoring and other coastal construction, marina and dock development, and artificial lighting should consider these dates. Beaches where compaction after nourishment is a problem are plowed to a depth of 92 cm to soften the sand so that it is useable for nesting turtles (Nelson and Dickerson 1987). Progress is being made toward better timing of projects and sand quality.

Progress is being made by counties and cities to prevent disorientation and misorientation of hatchlings due to artificial lighting (Ernest *et al.* 1987, Shoup and Wolf 1987). In South Florida, lighting ordinances have been passed by Indian River, St. Lucie, Martin, Palm Beach, Broward, Monroe, Collier, Charlotte, Sarasota and Lee counties, as well as numerous municipalities. Most recently, Witherington and Martin (1996) provide a thorough discussion of the effects of light pollution on sea turtle nesting beaches and on juvenile and adult turtles. They also offer a variety of effective management solutions for ameliorating this problem.

Information on the status and distribution of the loggerhead turtle is critical to its conservation. Monitoring the various life stages of the turtles on nesting beaches is being conducted to evaluate current and past management practices. Data are collected on the number of nests laid, the number of nests that successfully hatch, and the production of hatchlings reaching the ocean. In addition, long-term tagging studies have determined many population attributes for nesting loggerheads (Richardson 1982). Research on hatchling orientation and nesting behavior and how various wavelengths of light affect them is providing needed information to managers (Witherington and Bjorndal 1991, Witherington 1992).

The number of nesting females is determined by knowing the rangewide nesting effort and dividing by the average number of nests a female lays each season (Hopkins and Richardson 1984). Nests can be counted by both aerial and ground surveys. Estimates of nesting females were made from rangewide aerial surveys made in 1980 (Powers 1981), 1982 (Thompson 1983) and 1983 (Murphy and Hopkins 1984). Standardized ground surveys on index beaches are underway throughout the Southeast by the FWS, DEP, county and local agencies, and by private groups and universities. Index beaches include 80 percent of the nesting activity in Florida. Because of turtles' slow growth rates and subsequent delayed sexual maturity, all monitoring will need to be conducted over a long period of time to establish population trends for loggerheads.

Mortality of loggerhead turtles has been monitored since 1980 through the implementation of a regional data collection effort. This voluntary stranding network from Maine to Texas is coordinated by the NMFS and serves to document the geographic and seasonal distribution of sea turtle mortality (Schroeder 1987). DEP is primarily responsible for coordination of the stranding and salvage network in South Florida. Since 1987, four index zones have been systematically surveyed. It is clear that strandings represent an absolute minimum mortality. However, they can be used as an annual index to mortality and are an indication of the size and distribution of turtles being killed. They can also provide valuable biological information on food habits, reproductive condition, and sex ratios.

Public support for sea turtle conservation efforts is essential for the long-term success of conservation programs. This is particularly true when conservation measures are controversial or expensive. To heighten public awareness and understanding of sea turtle conservation issues, a number of educational activities and efforts are underway. For example, personnel conducting turtle projects often advise tourists on what they can do to minimize disturbance to nesting turtles, protect nests and prevent hatchlings from being disoriented. Likewise, State and Federal parks which conduct public awareness sea turtle interpretive walks provide information to visitors. The DEP has developed guidelines for organized sea turtle interpretive walks in order to minimize any disturbance to nesting turtles while still allowing them to be viewed by the public. Many beaches have been posted with signs informing people of the laws protecting sea turtles and providing either a local or a hotline number to report violations.

Private conservation organizations, such as the Center for Marine Conservation, Greenpeace, National Audubon Society, and Federal and State agencies have produced and distributed a variety of audio-visual aids and printed materials about sea turtles. These include: the brochure “Attention Beach Users,” a booklet (Raymond 1984b) on the various types of light fixtures and ways of screening lights to lessen their effects on hatchings, “Lights Out” bumper stickers and decals, a coloring book, video tapes, slide/tape programs, full color identification posters of the different species of sea turtles, and a hawksbill poster. Florida Power and Light Company also has produced a booklet (Van Meter 1990) and two leaflets with information on sea turtles, as well as a coastal roadway lighting manual.

Literature Cited

Ackerman, R.A. 1980. Physiological and ecological aspects of gas exchange by sea turtle eggs. American Zoologist 20:575-583.

Bell, R., and J. I. Richardson. 1978. An analysis of tag recoveries from loggerhead sea turtles *(Caretta caretta)* nesting on Little Cumberland Island, Georgia. Florida Marine Research Publication 33:20-24.

Bjorndal, K.A., A.B. Meylan, and B.J. Turner. 1983. Sea turtles nesting at Melbourne Beach, Florida, I. Size, growth and reproductive biology. Biological Conservation 26:65-77.

Bowen, B., J.C. Avise, J.I. Richardson, A.B. Meylan, D. Margaritoulis, and S.R. Hopkins-Murphy. 1993. Population structure of loggerhead turtles (*Caretta caretta*) in the northwestern Atlantic Ocean and Mediterranean Sea. Conservation Biology 7(4):834-844.

Bowen, B. 1994. Letter. 17 November, 1994. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Bowen, B. 1995. Letter. 26 October, 1995. On file at U. S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Brongersma, L.D. 1961. Notes upon some sea turtles. Zoologische Verhandelingen Rijksmuseum van Natuurlijke Historie te Leiden No. 52:1-45.

Brongersma, L.D. 1972. European Atlantic turtles. Zoologische Verhandelingen Rijksmuseum van Natuurlijke Historie te Leiden No. 121.

Caldwell, D.K. 1959. The loggerhead turtles of Cape Romain, South Carolina. (abridged and annotated manuscript of W.P. Baldwin, Jr. and J.P. Loftin, Jr.). Bulletin of the Florida State Museum. Biological Science 4:319-348.

Caldwell, D.K., F.H. Berry, A. Carr, and R.A. Ragotzkie. 1959a. Multiple and group nesting by the Atlantic loggerhead turtle. Bulletin of the Florida State Museum. Biological Science 4:309-318.

Caldwell, D.K., A. Carr, and L.H. Ogren. 1959b. Nesting and migration of the Atlantic loggerhead turtle. Bulletin of the Florida State Museum. Biological Science 4:295-308.

Carr, A.F., Jr. 1952. Handbook of turtles. The turtles of the U.S., Canada and Baja California. Cornell University Press; Ithaca, New York.

Carr, A.F., Jr. 1986a. Rips, FADS and little loggerheads. Bioscience 36:92-100.

Carr, A.F., Jr. 1986b. New perspectives on the pelagic stage of sea turtle development. NOAA Technical Memorandum NMFS-SEFC-190.

Carr. A.F., Jr. 1987. Impact of nondegradable marine debris on the ecology and survival outlook of sea turtles. Marine Pollution Bulletin 18(6B):352-356.

Carr, A.F., Jr., and L.H. Ogren. 1960. The ecology and migrations of sea turtles, 4. The green turtle in the Caribbean Sea. Bulletin of the American Museum of Natural History 121:1-48.

Carr, A.F., Jr., and A.B. Meylan. 1980. Evidence of passive migration of green turtle hatchlings in sargassum. Copeia 1980:366-368.

Coastal Engineering Research Center. 1984. Shore protection manual, volumes I and II. U.S. Army Corps of Engineers Waterways Experiment Station; Vicksburg, Mississippi.

Crouse, D.T. 1985. Biology and conservation of sea turtles in North Carolina. Unpublished Ph.D. Dissertation; University of Wisconsin, Madison.

Daniel, R.S., and K.U. Smith. 1947. The sea-approach behavior of the neonate loggerhead turtle. Journal of Comparative Physiological Psychology 40:413-420.

Davis, G.E., and M.C. Whiting. 1977. Loggerhead sea turtle nesting in Everglades National Park, Florida, USA. Herpetologica 33:18-28.

Department of Environmental Resources Management, Palm Beach. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30, 1998.

Deraniyagala, P.E.P. 1933. The loggerhead turtles (Carettidae) of Ceylon. Ceylon Journal of Science (B) 18:61-72.

Deraniyagala, P.E.P. 1939. The Tetrapod reptiles of Ceylon. vol. 1. Testudinates and Crocodilians. Colombo Museum of National History Service, Colombo, Ceylon.

Dickerson, D.D., and D.A. Nelson. 1989. Recent results on hatchling orientation responses to light wavelengths and intensities. Page 41 *in* S.A. Eckert, K.L. Eckert, and T.H. Richardson, compilers. Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA Technical Memorandum NMFS-SEFC-232. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Dodd, C.K., Jr. 1988. Synopsis of the biological data on the loggerhead sea turtle *Caretta* (Linnaeus 1758). U.S. Fish and Wildlife Service Biological Report 88(14). Government Printing Office; Washington, D.C.

Dodd, C.K., Jr. 1995. Marine turtles in the southeast. Pages 121-123 *in* E.T. LaRoe, G.S. Farris. C.E. Puckett, P.D. Doran, and M.J. Mac, eds. Our living resources: a report to the nation on the distribution, abundance and health of U.S. plants, animals and ecosystems. U.S. Department of the Interior, National Biological Service; Washington, D.C.

Ehrenfeld, D.W., and A. Carr. 1967. The role of vision in the sea-finding orientation of the green turtle *Chelonia mydas.* Animal Behavior 15:25-36.

Ehrhart, L.M. 1983. A survey of nesting by the green turtle, *Chelonia mydas,* and loggerhead turtle, *Caretta caretta,* in south Brevard County, Florida. Unpublished Report to World Wildlife Fund--U.S.; Washington, D.C.

Ehrhart, L.M. 1989. Status report of the loggerhead turtle. Pages 122-139 *in* L. Ogren, F. Berry, K. Bjorndal, H. Kumpf, R. Mast, G. Medina, H. Reichart, and R. Witham, eds. Proceedings of the second western Atlantic turtle symposium. NOAA Technical Memorandum NMFS-SEFC-226.

Ernest, R.G., R. Erick, and C.J. Bove. 1987. Development of a comprehensive sea turtle protection ordinance for St. Lucie County, Florida. (Abstract). Seventh annual workshop on sea turtle biology and conservation. February 1987; Wekiva Springs State Park, Florida.

Florida Department of Environmental Protection. Undated. Marine turtle identification. On file at South Florida Ecosystem Office, U. S. Fish and Wildlife Service; Vero Beach, Florida.

Frazer, N.B., and L.M. Ehrhart. 1985. Preliminary growth models for green, *Chelonia mydas,* and loggerhead, *Caretta caretta,* turtles in the wild. Copeia 1985:73-79.

Frazier, J. 1984. Las tortugas marinas en el Oceano Atlantico Sur Occidental. Asociación Herpetológica Argentina 2:2-21.

Frazier, J., and S. Salas. 1982. Tortugas marinas en Chile. Boletin Museo Nacional Historia Natural. Chile 39:63-73.

Fritts, T.H., and W. Hoffman. 1982. Diurnal nesting of marine turtles in southern Brevard County, Florida. Journal of Herpetology 16:84-86.

Fritts, T.H., A.B. Irvine, R.D. Jennings, L.A. Collum, W. Hoffman, and M.A. McGehee. 1983. Turtles, birds and mammals in the northern Gulf of Mexico and nearby waters. U.S. Fish and Wildlife Service; FWS/OBS 82/65.

Groombridge, B. 1982. The IUCN Amphibia-Reptilia red data book. Part 1. Testudines, Crocodylia, Rhynchocephalia. International Union for the Conservation of Nature; Gland, Switzerland.

Hendrickson, J.R. 1958. The green sea turtle, *Chelonia mydas* (Linn.) in Malaya and Sarawak. Proceedings Zoological Society, London 130:455-535.

Henwood, T.A. 1987. Movements and seasonal changes in loggerhead turtle *Caretta caretta* aggregations in the vicinity of Cape Canaveral, Florida (1978-1984). Biological Conservation 40:191-202.

Hopkins, S.R., and T.M. Murphy. 1980. Reproductive ecology of *Caretta caretta* in South Carolina. South Carolina Wildlife Marine Resources Department completion report.

Hopkins, S.R., and J.I. Richardson, eds. 1984. Recovery plan for marine turtles. National Marine Fisheries Service; Washington, D.C.

Hosier, P.E., M. Kochhar, and V. Thayer. 1981. Off-road vehicle and pedestrian track effects on the sea-approach of hatchling loggerhead turtles. Environmental Conservation 8:158-161.

Hughes, G.R. 1975. The marine turtles of Tongaland, VIE. Lammergeyer 22:9-18.

Kaufmann, R. 1975. Studies on the loggerhead sea turtle, *Caretta caretta caretta* (Linne) in Colombia, South America. Herpetologica 31:323-326.

Killingly, J.S., and M. Lutcavage. 1983. Loggerhead turtle movements reconstructed from 18O and 13C profiles from commensal barnacle shells. Estuarine Coastal Shelf Science 16:345-349.

Kraemer, J.E. 1979. Variation in incubation length of loggerhead sea turtle, *Caretta caretta,* clutches on the Georgia coast. Unpublished M.S. Thesis; University of Georgia, Athens.

Labisky, R.F., M.A. Mercadante, and W.L. Finger. 1986. Factors affecting reproductive success of sea turtles on Cape Canaveral Air Force Station, Florida, 1985. Final report to the U.S. Air Force; U.S. Fish and Wildlife Service Cooperative Fish and Wildlife Research Unit, Agreement No. 14-16-0009-1544, Work Order No. 25.

LeBuff, C. R. Jr. 1990. The loggerhead turtle in the eastern Gulf of Mexico. Caretta Research, Incorporated; Sanibel, Florida.

Lenarz, M.S., N.B. Frazer, M.S. Ralston, and R.B. Mast. 1981. Seven nests recorded for loggerhead turtle *Caretta caretta* in one season. Herpetological Review 12:9.

Limpus, C.J. 1979. Notes on growth rates of wild turtles. Marine Turtle Newsletter 10:3-5.

Linnaeus, C. 1758. Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Ed. 10, Tomus 1. L. Salvii; Stockholm, Sweden.

Litwin, S.C. 1978. Loggerhead sea turtles of Jekyll Island, Georgia; a report on conservation. Herpetology Bulletin New York Herpetological Society 14:18-21.

Mager, A., Jr. 1985. Five-year status reviews of sea turtles listed under the Endangered Species Act of 1973. National Marine Fisheries Service; Washington, D.C.

Mann, T.M. 1977. Impact of developed coastline on nesting and hatchling sea turtles in southeastern Florida. Unpublished M.S. Thesis; Florida Atlantic University, Boca Raton.

Marcus, S.J., and C.G. Maley. 1987. Comparison of sand temperatures between a shaded and unshaded turtle nesting beach in south Florida. (Abstract) Seventh annual workshop on sea turtle biology and conservation, February 1987; Wekiva Springs State Park, Florida.

Margaritoulis, D. 1982. Observations on loggerhead sea turtle *Caretta caretta* activity during three nesting seasons (1977-1979) in Zakynthos, Greece. Biological Conservation 24:193-204.

McFarlane, R.W. 1963. Disorientation of loggerhead hatchlings by artificial road lighting. Copeia 1963:153.

McGehee, M.A. 1979. Factors affecting the hatching success of loggerhead sea turtle eggs *Caretta caretta caretta.* Unpublished M.S. Thesis; University of Central Florida, Orlando.

Mendonca, M.T. 1981. Comparative growth rates of wild immature *Chelonia mydas* and *Caretta caretta* in Florida. Journal of Herpetology 15:447-451.

Meylan, A.B. 1982. Sea turtle migration—evidence from tag returns. Pages 91-100 *in* K. Bjornal, ed. Biology and conservation of sea turtles. Smithsonian Institution Press; Washington, D.C.

Meylan, A.B., K.A. Bjorndal, and B.J. Turner. 1983. Sea turtles nesting at Melbourne Beach, Florida, II. Post-nesting movements of *Caretta caretta.* Biological Conservation 26:79-90.

Meylan, A., B. Schroeder, and A. Mosier. 1995. Sea turtle nesting activity in the State of Florida 1979-1992. Florida Marine Reseach Publications Number 52; St. Petersburg, Florida.

Mortimer, J.A. 1979. Ascension Island: British jeopardize 45 years of conservation. Marine Turtle Newsletter 10:7-8.

Mortimer, J.A. 1982. Factors influencing beach selection by nesting sea turtles. Pages 45-51 *in* K.A. Bjorndal, ed. Biology and conservation of sea turtles. Smithsonian Institution Press; Washington, D.C.

Mortimer, J.A. 1989. Research needed for management of the beach habitat. Pages 236-246 *in* L. Ogren, F. Berry, K. Bjorndal, H. Kumpf, R. Mast, G. Medina, H. Reichart, and R. Witham, eds. Proceedings of the second western Atlantic turtle symposium. NOAA Technical Memorandum NMFS-SEFC-226. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Murphy, T.M. 1985. Telemetric monitoring of nesting loggerhead sea turtles subjected to disturbance on the beach. Paper presented at fifth annual workshop on sea turtle biology and conservation, 13-16 March 1985; Waverly, Georgia.

Murphy, T.M., and S.R. Hopkins. 1984. Aerial and ground surveys of marine turtle nesting beaches in the southeast region, U.S. Final report to NMFS-SEFC.

National Marine Fisheries Service [NMFS] and U.S. Fish and Wildlife Service [FWS]. 1991. Recovery plan for U.S. population of loggerhead turtle. National Marine Fisheries Service; Washington, D.C.

National Research Council. 1990. Managing coastal erosion. National Academy Press; Washington, D.C.

Nelson, D.A., and D.D. Dickerson. 1987. Correlation of loggerhead turtle nesting digging with beach sand consistency. (Abstract). Seventh annual workshop on sea turtle biology and conservation, February 1987; Wekiva Springs State Park, Florida. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Nelson, D.A., and D.D. Dickerson. 1988a. Effects of beach nourishment on sea turtles *in* L.S. Tait, ed. Proceedings of the beach preservation technology conference '88. Florida Shore & Beach Preservation Association, Incorporated; Tallahassee, Florida.

Nelson, D.A., and D.D. Dickerson. 1988b. Hardness of nourished and natural sea turtle nesting beaches on the east coast of Florida. Unpublished report. U.S. Army Corps of Engineers Waterways Experiment Station; Vicksburg, Mississippi.

Nelson, D.A., and D.D. Dickerson. 1988c. Response of nesting sea turtles to tilling of compacted beaches, Jupiter Island, Florida. Unpublished report. U.S. Army Corps of Engineers Waterways Experiment Station; Vicksburg, Mississippi.

Nelson, D.A., K. Mauck, and J. Fletemeyer. 1987. Physical effects of beach nourishment on sea turtle nesting, Delray Beach, Florida. Technical Report EL-87-15. U.S. Army Corps of Engineers Waterways Experiment Station; Vicksburg, Mississippi.

Parker, G.H. 1926. The growth of turtles. Proceedings of the National Academy of Sciences 12:422- 424.

Philibosian, R. 1976. Disorientation of hawksbill turtle hatchlings, *Eretmochelys imbricata,* by stadium lights. Copeia 1976:824.

Pilkey, O.H., Jr., D.C. Sharma, H.R. Wanless, L.J. Doyle, O.H. Pilkey, Sr., W.J. Neal, and B.L. Gruver. 1984. Living with the east Florida shore. Duke University Press; Durham, North Carolina.

Possardt, E.E. 1991. A conservation program for sea turtles in the southeastern continental U.S.. Journal of Alabama Academy of Science 62: 35-48.

Powers, J.E. 1981. An estimate of nesting female loggerhead turtles on the south Atlantic coast of the U.S. in 1980. NMFS; Miami, Florida.

Pritchard, P.C.H. 1979. Encyclopedia of turtles. Tropical Fish Hobbyist Publications; Neptune, New Jersey.

Pritchard, P.C., P.R. Bacon, F.H. Berry, J. Fletemeyer, A.F. Carr, R.M. Gallagher, R.R. Lankford, R. Marquez, L.H. Ogren, W.G. Pringle, Jr., H.M. Reichardt, and R. Witham. 1983. Sea turtle manual of research and conservation techniques. Western Atlantic turtle symposium. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Pritchard, P.C.H., and P. Trebbau. 1984. The turtles of Venezuela. Society for the Study of Amphibians and Reptiles, Contributions to Herpetology, No. 2.

Provancha, J.A., and L.M. Ehrhart. 1987. Sea turtle nesting trends at John F. Kennedy Space Center and Cape Canaveral Air Force Station, Florida, and relationships with factors influencing nest site selection, Pages 33-44 *in* W.N. Witzell, ed. NOAA Technical Report NWS No. 53. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Raymond, P.W. 1984a. The effects of beach restoration on marine turtles nesting in south Brevard County, Florida. Unpublished M.S. Thesis; University of Central Florida, Orlando.

Raymond, P.W. 1984b. Sea turtle hatching disorientation and artificial beachfront lighting. Center for Environmental Education; Washington, D.C.

Richardson, J.I. 1982. A population model for adult female loggerhead sea turtles *Caretta caretta* nesting in Georgia. Unpublished Ph.D. Dissertation; University of Georgia, Athens.

Richardson, J.I., and T.H. Richardson. 1982. An experimental population model for the loggerhead sea turtle *Caretta caretta.* Pages 165-176 *in* K. Bjorndal, ed. Biology and conservation of sea turtles. Smithsonian Institution Press; Washington, D.C.

Richardson, T.H., J.I. Richardson, C. Ruckdeschel, and M.W. Dix. 1978. Remigration patterns of loggerhead sea turtles *Caretta caretta* nesting on Little Cumberland and Cumberland Islands, Georgia. Marine Research Publications 33:39-44.

Ross, J.P. 1982. Historical decline of loggerhead, ridley, and leatherback sea turtles. Pages 189-195 *in* K. Bjorndal, ed. Biology and conservation of sea turtles. Smithsonian Institution Press; Washington, D.C.

Ross, J.P., and M.A. Barwani. 1982. Review of sea turtles in the Arabian area. Pages 373-383 *in* K. Bjorndal, ed. Biology and conservation of sea turtles. Smithsonian Institution Press; Washington, D.C.

Salmon, M., and J. Wyneken. 1987. Orientation and swimming behavior of hatchling loggerhead sea turtles *Caretta caretta* during their off-shore migration. Journal of Experimental Marine Biology and Ecology 109:137-153.

Schmelz, G.W., and R.R. Mezich. 1988. A preliminary investigation of the potential impact of Australian pines on the nesting activities of the loggerhead turtle. Pages 63-66 *in* B.A. Schroeder, compiler. Proceedings of the eighth annual conference on sea turtle conservation and biology. NOAA Technical Memorandum NMFS-SEFC-214. On file at U.S. Fish and Wildlife Service, South Forida Ecosystem Office; Vero Beach, Florida.

Schroeder, B.A. 1981. Predation and nest success in two species of marine turtles *(Caretta caretta and Chelonia mydas)* at Merritt Island, Florida. Florida Scientist 44(l):35.

Schroeder, B.A. 1987. Strandings of marine turtles along the U.S. Atlantic and Gulf of Mexico coasts (1986). (Abstract). Seventh annual workshop on sea turtle biology and conservation, February 1987; Wekiva Springs State Park, Florida.

Shoup, L.P., and R.E. Wolf. 1987. Boca Raton beach area outdoor lighting restrictions for the protection of sea turtles. (Abstract). Seventh annual workshop on sea turtle biology and conservation. February 1987; Wekiva Springs State Park, Florida. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Squires, H.J. 1954. Records of marine turtles in the Newfoundland area. Copeia 1954:68.

Stancyk, S.E. 1982. Non-human predators of sea turtles and their control. Pages 139-152 *in* K.A. Bjorndal, ed. Biology and conservation of sea turtles. Smithsonian Institution Press; Washington, D.C.

Stancyk, S.E., O.R. Talbert, and J.M. Dean. 1980. Nesting activity of the loggerhead turtle *Caretta caretta* in South Carolina, II: protection of nests from raccoon predation by transplantation. Biological Conservation 18:289-298.

Standora, E.A., and J.R. Spotila. 1985. Temperature dependent sex determination in sea turtles. Copeia 1985:711-722.

Talbert, O.R., Jr., S.E. Stancyk, J.M. Dean, and J.M. Will. 1980. Nesting activity of the loggerhead turtle *Caretta caretta* in South Carolina I: a rookery in transition. Copeia 1980:709-718.

Thompson, N.B. 1983. Abundance of female *Caretta caretta* (loggerhead turtles) nesting along the southeast U.S. coast 1982 nesting season. National Marine Fisheries Service; Miami, Florida.

U.S. Fish and Wildlife Service [FWS]. 1996. Hobe Sound National Wildlife Refuge, 1996 Sea Turtle Nesting Report. On file at South Florida Ecosystem Office, U.S. Fish and Wildlife Service; Vero Beach, Florida.

Van Meter, V.B. 1990. Florida's sea turtles. Florida Power and Light Company; Miami, Florida.

van Nierop, M.M., and J.C. den Hartog. 1984. A study of the gut contents of five juvenile loggerhead turtles, *Caretta caretta* (Linnaeus) (Reptilia, Cheloniidae), from the southeastern part of the north Atlantic Ocean, with emphasis on coelenterate identification. Zoologische Mededelingen. (Leiden) 59(4):35-54.

Witham, R., and C.R. Futch. 1977. Early growth and oceanic survival of pen-reared sea turtles. Herpetologica 33:404-409.

Witherington, B.E. 1986. Human and natural causes of marine turtle clutch and hatchling mortality and their relationship to hatchling production on an important Florida nesting beach. Unpublished M.S. Thesis; University of Central Florida, Orlando.

Witherington, B.E. 1992. Behavioral responses of nesting sea turtles to artificial lighting. Herpetologica 48:31-39.

Witherinton, B.E., and K.A. Bjorndal, and C.M. McCabe. 1990. Temporal pattern of nocturnal emergence of loggerhead turtle hatchlings from natural nests. Copeia 1990:1168.

Witherington, B.E., and K.A. Bjorndal. 1991. Influences of artificial lighting on the seaward orientation of hatchling loggerhead turtles *Caretta caretta.* Biological Conservation 55: 139-149.

Witherington, B.E., and R.E. Martin. 1996. Understanding, assessing, and resolving light pollution problems on sea turtle nesting beaches. FMRI Technical Report TR-2. Florida Marine Research Institute, St. Petersburg, Florida.

Wolke, R.E. 1989. Pathology and sea turtle conservation. Unpublished report. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Wolke, R.E., D.R. Brooks, and A. George. 1982. Spirorchidiasis in loggerhead sea turtles *Caretta caretta:* pathology. Journal of Wildlife Diseases 18:175-185.

Yntema, C.I. 1982. Critical periods and pivotal temperatures for sexual differentiation in loggerhead sea turtles. Canadian Journal of Zoology 60:1012-1016.

Yntema, C.I., and N. Mrosovsky. 1980. Sexual differentiation in hatchling loggerheads *Caretta caretta* incubated at different controlled temperatures. Herpetologica 36:33-36.

Recovery for the Loggerhead Sea Turtle

Caretta caretta

Recovery Objective: DELIST the species once recovery criteria have been met.

South Florida Contribution: SUPPORT delisting actions.

Recovery Criteria

The South Florida recovery contribution parallels the existing recovery plans for sea turtles. South Florida's objective for the loggerhead, green, leatherback and hawksbill sea turtles will be achieved when: the level of nesting for each species is continuously monitored and increases to the species-specific recovery goal; beaches supporting greater than 50 percent of the nesting activity are in public ownership; all important nesting beaches are protected and appropriately managed to prevent further degradation; non-native nuisance species have been controlled or eliminated on public lands; at least 60 percent hatch success is documented on major nesting beaches; effective lighting ordinances or lighting plans are implemented; and beaches are restored or rehabilitated to be suitable for nesting where appropriate.

Species-level Recovery Actions

S1. **Continue standardized surveys of nesting beaches.** Nesting surveys are undertaken on the majority of nesting beaches. In the past, beach coverage varied from year to year, as did the frequency of surveys, experience and training of surveyors, and data reporting. Consequently, no determination of nesting population trends had been possible with any degree of certainty. However, in 1989, to better assess trends in nesting, DEP, in cooperation with FWS, initiated an Index Nesting Beach Survey (INBS) program to collect nesting data that could be used to statistically and scientifically analyze population trends. The INBS program should continue to gather a long-term data base on nesting activities in Florida that can be used as an index of nesting population trends.

S2. **Protect and manage populations on nesting beaches.** Predators, poaching, tidal inundation, artificial lighting, and human activities on nesting beaches diminish reproductive success. Monitoring of nesting activity is necessary to implement and evaluate appropriate nest protection measures and determine trends in the nesting population.

S2.1. **Evaluate nest success and implement appropriate nest protection measures.** Nesting and hatching success and hatchling emerging success on beaches occurring on State or Federal lands and all other important local or regional nesting beaches should be evaluated. Appropriate nest protection measures should be implemented by FWS and DEP, and appropriate local governments or organizations, to ensure greater than 60 percent hatch rate. Until recovery is ensured, however, projects on all Federal and State lands and key nesting beaches, such as those in Brevard, Indian River, St. Lucie, Martin, and Palm Beach Counties, should strive for a higher rate of hatching success. In all cases, the least manipulative method should be employed to avoid interfering with known or unknown natural biological processes. Artificial incubation should be avoided. Where beach hatcheries are necessary, they should be located and constructed to allow self release, and hatch rates approaching 90 percent should be attained. Nest protection measures should always enable hatchling release the same night of hatching.

S2.2. **Determine influence of factors such as tidal inundation and foot traffic on hatching success.** Tidal inundation can diminish hatching success, depending on frequency, duration and developmental stage of embryos. Some nests are relocated due to the perceived threat from tides. The extent to which eggs can tolerate tidal inundation needs to be quantified to enable development of guidelines for nest relocation relative to tidal threats. The effect of foot traffic on hatching success is unknown, although many beaches with significant nesting also have high public use. FWS should support research and, in conjunction with DEP, develop recommendations for nest protection from tidal threat and foot traffic.

S2.3. **Reduce effects of artificial lighting on hatchlings and nesting females.** Studies have shown that light pollution can deter female sea turtles from coming onto the beach to nest; in fact, brightly lit beaches have been determined to be used less frequently for nesting. Also, females attempting to return to sea after nesting can be disoriented by beach lighting and have difficulties making it back to the ocean. In some cases, nesting females have ended up on coastal highways and been struck by vehicles. Artificial beach lighting is even more detrimental to hatchling sea turtles, which emerge from nests at night. Under natural conditions, hatchlings move toward the brightest, most open horizon, which is over the ocean. However, when bright light sources are present on the beach, they become the brightest spot on the horizon and attract hatchlings in the wrong direction, making them more vulnerable to predators, desiccation, exhaustion, and vehicles.

S2.3.1. **Implement and enforce lighting ordinances and resolve lighting problems in areas where lighting ordinances have not been adopted.** FWS and DEP should identify and resolve artificial lighting impacts to sea turtles in South Florida. Since 1987, hatchling disorientation incidents observed by DEP marine turtle permit holders and park personnel have been reported through standardized reporting forms. Report forms serve as documentation for lighting problems on nesting beaches and allow the identification of specific problem light sources. FWS and DEP should use these report forms to locate and resolve lighting problems, with the help of local governments, through public education efforts, and by directly contacting the owners of the problem lights and making recommendations for their modification. FWS and DEP should also proactively conduct pre-season lighting inspections to identify and make recommendations for correcting problem light sources before they result in disorientation events.

Where lighting ordinances have been adopted and enforced, hatchling disorientation and misorientation have been drastically reduced. All coastal counties and communities with nesting beaches should adopt ordinances (March through October on the Atlantic Coast and May through October on the Gulf Coast). Many incorporated communities within Broward and Palm Beach counties, Florida, are particularly problematic because of the high-density nesting beaches and the lack of effective lighting regulations. DEP should ensure appropriate lighting on new construction projects.

S2.3.2. **Evaluate extent of hatchling disorientation and misorientation on all important nesting beaches.** FWS, DEP, and counties should continue to evaluate hatchling disorientation and misorientation problems on all important nesting beaches. Many lighting ordinance requirements do not become effective until 11 p.m., whereas over 30 percent of hatchling emergence occurs prior to this time (Witherington *et al*. 1990). FWS, DEP, and county governments should also support research to gather additional quantitative data on hatchling emergence times and nesting times on representative beaches throughout South Florida to support the most effective time requirements for lighting ordinances.

S2.3.3. **Prosecute individuals or entities responsible for hatchling disorientation and misorientation under the Endangered Species Act or appropriate State laws.** Hatchling disorientation and misorientation from artificial lights can cause high mortality and be the major source of hatchling mortality on some nesting beaches if not controlled. Law enforcement efforts should be focused where lighting ordinances are not being implemented or enforced on major nesting beaches and where repeated violations are not corrected.

S2.4. **Ensure beach nourishment and coastal construction activities are planned to avoid disruption of nesting and hatching activities.** These activities can cause significant disruption of nesting activities during the nesting season when viewed cumulatively over the nesting range. Nest relocation can involve manipulation of large numbers of nests, which can result in lowered hatch success and altered hatchling sex ratios, and therefore is not an acceptable alternative to altering the timing of projects during the peak nesting period. COE, FWS, and DEP should ensure beach nourishment and other beach construction activities are not permitted during the nesting season on important nesting beaches.

S2.5. **Ensure law enforcement activities eliminate poaching and harassment.** Poaching, while not a significant cause of nest loss regionally, is occasionally a local problem. Poaching has been repeatedly reported around the Ten Thousand Islands NWR and adjacent islands in southwest Florida. In addition, intentional and unintentional disturbance and harassment of nesting turtles is an increasing problem on many beaches. FWS should work closely with DEP to identify problem areas and focus intensive law enforcement efforts to eliminate poaching and deter harassment of nesting turtles.

S3. **Continue to gather information on species and population biology.**

S3.1. **Determine etiology of fibropapillomatosis. Research on the sea turtle fibropapilloma disease should be continued and expanded.** Fibropapillomatosis (FP) is a disease of sea turtles characterized by the development of multiple tumors on the skin and also internal organs, most frequently the lungs and kidneys. The tumors interfere with swimming, eating, breathing, seeing, and reproduction, and turtles with heavy tumor burdens become severely debilitated and die. FP has seriously impacted green turtle populations in Florida (about 50 percent of juvenile green turtles in Indian River Lagoon and Florida Bay have fibropapillomas) and is now emerging as a significant threat to the loggerhead as well. FP is a transmissible disease caused by a virus, and, while both a unique herpesvirus and retroviruses have been identified in FP tumors, neither has yet been proven to be the cause of the disease. Researchers are concerned that there may be environmental (contaminant) cofactors for this disease in nearshore areas. Continuation and expansion of research on the disease is essential to developing an approach to remedying the problem.

S3.2. Maintain the Sea Turtle Stranding and Salvage Network. Most accessible U.S. beaches in the Atlantic and Gulf of Mexico are surveyed for stranded sea turtles by volunteer or contract personnel. Through the Sea Turtle Stranding and Salvage Network, stranding data are archived and summarized by the NMFS Miami Laboratory. These data provide an index of sea turtle mortality and are thought to be a cost-effective means of evaluating the effectiveness of the Turtle Exclusion Device (TED) regulations. These data also provide basic biological information on sea turtles and are useful in determining other sources of mortality. The systematic stranding surveys of index areas need to be continued in South Florida. Periodic review of the efficacy of surveys should also be conducted.

S3.3. Centralize administration and coordination of tagging programs. Sea turtle researchers commonly tag turtles encountered during their research projects, and usually maintain independent tagging data bases. The lack of centralization for administering these tagging data bases often results in confusion when tagged turtles are recaptured, and delays in reporting of recaptures to the person originally tagging the turtle. NMFS and FWS should investigate the possibilities of establishing a centralized tagging data base, including Passive Integrated Transponder (PIT) tags.

S3.3.1. Centralize tag series records. A centralized tag series data base is needed to ensure that recaptured tagged turtles can be promptly reported to persons who initially tagged the animal. The tag series data base would include listings of all tag series that have been placed on sea turtles in the wild, including the name and address of the researcher. This would eliminate problems in determining which researcher is using which tag series or types of tags, and would preclude unnecessary delays in reporting of tag returns. NMFS and/or FWS should establish and maintain this data base.

S3.3.2. Centralize turtle tagging records. In addition to the need for a centralization of tag series records, there are advantages in developing a centralized turtle tagging data base. Such a data base would allow all turtle researchers to trace unfamiliar tag series or types to their source, and also to have immediate access to important biological information collected at the time of original capture. The major disadvantage is that this data base would require frequent editing and updating, and would be costly and somewhat time consuming to maintain. It would also make it possible for unethical researchers to exploit the work of others, while providing no guarantees that such contributions would be acknowledged. NMFS and FWS should determine whether such a data base can be established and is feasible to maintain.

S3.4. **Develop requirements for care and maintenance of turtles in captivity, including diet, water quality, tank size, and treatment of injury and disease.** Sea turtles are maintained in captivity for rehabilitation, research, or educational display. Proper care will ensure the maximum number of rehabilitated turtles can be returned to the wild and a minimum number removed from the wild for research or education purposes. None of these requirements has been scientifically evaluated to determine the best possible captive conditions for sea turtles. FWS and NMFS should support the necessary research to develop these criteria, particularly relating to diet and the treatment of injury and disease. These criteria should be published and required for any permit to hold sea turtles in captivity. FWS, NMFS and/or DEP should inspect permitted facilities at least annually for compliance with permit requirements.

S4. **Monitor trends in nesting activity.** DEP and FWS should continue to refine standardized nest survey criteria, identify additional index survey beaches to be monitored, and continue to conduct training workshops for surveyors. Consequently, DEP and FWS should ensure that routine monitoring of nesting beaches is done on at least a weekly basis during the nesting period of the loggerhead turtle, and any nesting period outside of their regular survey period.

S5. **Continue information and education activities.** Sea turtle conservation requires long-term public support over a large geographic area. The public must be factually informed of the issues, particularly when conservation measures conflict with human activities, such as commercial fisheries, beach development, and public use of nesting beaches. Public education is the foundation upon which a long-term conservation program will succeed or fail.

S5.1. **Update existing slide programs and information leaflets on sea turtle conservation for the general public.** FWS has developed a bilingual slide tape program on sea turtle conservation and should keep the program current and available for all public institutions and conservation organizations. FWS and DEP should continually update and supply the public with informational brochures on sea turtle ecology and conservation needs.

S5.2. **Disseminate information from brochures and reports on recommended lighting modifications or measures to reduce hatchling disorientation and misorientation.** Recently published literature contains information on the types of light, screening or shading that is best for turtles (*e.g.*, Witherington and Martin 1996).

S5.3. **Develop public service announcements (PSA) regarding the sea turtle artificial lighting conflict and disturbance of nesting activities by public nighttime beach activities.** A professionally produced public service announcement for radio and TV would provide tremendous support and reinforcement of the many coastal lighting ordinances. It would generate greater support through understanding. FWS should develop a high-quality PSA that could be used throughout the Southeast during the nesting season.

S5.4. **Ensure facilities permitted to hold and display captive sea turtles have appropriate informational displays.** Over 50 facilities are permitted to hold sea turtles for rehabilitation, research, and public education. Many are on public display and afford opportunities for public education. Display of accurate information on the basic biology and conservation problems should be a requirement of all permittees. All facilities should be visited by FWS, NMFS and/or DEP to ensure captive sea turtles are being displayed in a way to meet these criteria.

S5.5. Ensure standard criteria and recommendations for loggerhead sea turtle nesting interpretive walks are being implemented. Sea turtle walks are popular with the public and afford tremendous opportunities for public education or, if poorly conducted, misinformation. DEP has developed standard criteria for permittees conducting walks. These objective criteria should continue to be used, and DEP should continue to evaluate sea turtle walks to ensure they are professional, provide accurate biological information, convey an accurate conservation message, and are a positive experience. Just as importantly they should not cause unnecessary or significant disturbance to nesting turtles.

S5.6. Post informational signs at public access points on nesting beaches. Public access points to nesting beaches provide excellent opportunities to inform the public of necessary precautions for compatible public use on the nesting beach and to develop public support through informational and educational signs. FWS, NPS, DEP and other appropriate organizations should post such educational and informational signs on nesting beaches as appropriate.

Habitat-level Recovery Actions

H1. Protect and manage nesting habitat. Coastal development has already destroyed or degraded many miles of nesting habitat in South Florida. Although sea turtle nesting occurs on over 2,240 km of beaches within the southeast United States, development pressures are so great that cumulative impacts could result in increased degradation or destruction of nesting habitat and eventually lead to a significant population decline if not properly managed.

H1.1. Ensure beach nourishment projects are compatible with maintaining good quality nesting habitat. Beach nourishment can improve nesting habitat in areas of severe erosion and is a preferred alternative to beach armoring. However, placement of sand on an eroded section of beach or an existing beach in and of itself may not provide suitable nesting habitat for sea turtles. Although beach nourishment may increase the potential nesting area, significant negative impacts to sea turtles may result if protective measures are not incorporated during construction.

H1.1.1. Evaluate sand transfer systems as an alternative to beach nourishment. Sand transfer systems can diminish the necessity for frequent beach renourishment, thereby reducing disruption of nesting activities. This system also minimizes sand compaction while adding sand to downdrift beachs. The construction and operation of these systems must be carefully evaluated to ensure important nearshore habitats are not degraded or sea turtles injured or destroyed.

H1.1.2. Refine a sand budget formulation methodology for Sebastian Inlet. Inlets interrupt the natural flow of longshore sediment transport along the shoreline. The interrupted flow of sand is diverted either offshore in ebb tide shoals, into bays or lagoons in flood tide shoals, or in navigation channels (National Research Council 1990). As a result, erosion occurs downdrift of the interrupted shoreline. There are six man-made inlets on the Atlantic coast from Indian River County to Broward County. In Indian River County, for example, erosion has been nearly 2 m per year at Sebastian Inlet SRA (just south of Sebastian Inlet), when the average erosion rate for the county is just under .3 m per year. DEP, Sebastian

Inlet Tax District, and Indian River County should conduct engineering studies to refine a sand budget formulation methodology for the Sebastian Inlet. Other needs include: annually bypassing sand to downdrift beaches, conducting further studies of the long-term effects of the flood shoal on the inlet-related sediment budget, identifying the long-term impacts of sand impoundment and sediment volume deficit to downdrift areas, and determining the area of inlet influence.

H1.2. **Prevent degradation of nesting habitat from seawalls, revetments, sand bags, sand fences or other erosion-control measures.** One of the most difficult habitat protection efforts throughout South Florida is trying to minimize or eliminate the construction of seawalls, riprap, groins, sandbags, and improperly placed drift or sand fences. In 1995, the Florida Legislature passed a law giving coastal counties and municipalities the authority to approve construction of coastal armoring during certain emergency situations. (All non-emergency armoring situations must still receive an DEP permit prior to construction.) Although the new law weakened prior regulations on armoring, it does require that emergency armoring structures approved by a coastal county or municipality be temporary and that the structure be removed, or a permit application submitted to DEP for a permanent rigid coastal structure, within 60 days after the emergency installation of the structure. In addition, to implement this new law, DEP finalized a formal agency rule on coastal armoring on September 12, 1996.

H1.2.1. **Ensure laws regulating coastal construction and beach armoring are enforced.** The 1996 DEP rule recommends that local governments obtain an incidental take permit from FWS under section 10 of the Endangered Species Act and develop a sea turtle habitat conservation plan prior to authorizing armoring projects. The new rule also requires that several measures be undertaken to address sea turtle concerns for non-emergency armoring and for placement of permanent rigid coastal structures subsequent to an emergency (temporary) armoring event. For example, the new regulations require that (1) special conditions be placed on permitted activities to limit the nature, timing, and sequence of construction, as well as address lighting concerns; (2) structures not be used where the construction would result in a significant adverse impact; and (3) armoring be removed if it is determined to not be effective or to be causing a significant adverse impact to the beach and dune system.

H1.2.2. **Ensure failed erosion control structures are removed.** Failed erosion control structures such as uncovered plastic bags or tubes and fragmented concrete or wooden structures degrade nesting habitat and deter nesting activities. DEP should ensure failed structures are removed from nesting beaches.

H1.2.3. **Develop standard requirements for sand fence construction.** Sand fences can effectively build dune systems and improve nesting habitat; however, improperly designed sand fences can trap nesting females or hatchlings and prevent access to suitable nesting habitat. DEP and FWS should develop and evaluate sand fencing designs and establish standard requirements for sand fence construction.

H1.3. Identify important nesting beaches experiencing greater than 40 percent nest loss from erosion and implement appropriate habitat restoration measures. Some important nesting beaches now suffer severe erosion as a result of inlet maintenance or jetty construction. In some situations, limited safe locations for relocating nests place constraints on nest relocation programs. Nest relocation programs should be considered as a short-term measure at best to protect nests in these situations, with primary efforts directed toward habitat restoration. DEP and FWS should review all important nesting beaches and identify those with 40 percent or more nest loss due to erosion or tidal inundation. Habitat restoration plans should be developed and implemented for identified nesting beaches.

H1.4. Acquire or otherwise ensure the long-term protection of important nesting beaches. Acquisition of important sea turtle nesting beaches would ensure long-term protection of U.S. nesting habitat. Acquisition and protection of undisturbed nesting habitat would enhance sea turtle nesting and hatching success.

H1.4.1. Continue to acquire in fee title all undeveloped beaches between Melbourne Beach and Wabasso Beach, Florida, for the Archie Carr National Wildlife Refuge. The Archie Carr NWR was designated by Congress in 1989 in recognition of the need for long stretches of quiet, undisturbed sandy beaches, with little or no artificial lighting, to ensure the reproductive success and survival of sea turtles. The refuge is located within a 33-km stretch of beach on the barrier islands of Brevard and Indian River Counties on the Atlantic coast of Florida. Approximately 25 percent of all loggerhead nesting in the U.S. occurs along this stretch of beach. The proposed acquisition plan for the refuge set a goal for purchase of 15 km within four sections of this 33-km stretch. Three of the sections are located in Brevard County and one in Indian River County.

Partners in the land acquisition effort for the refuge and adjacent buffer areas on the barrier island include FWS, DEP, Brevard County, Indian River County, Richard King Mellon Foundation, The Conservation Fund, and The Nature Conservancy. To date, contributions from the State of Florida and local county partnerships account for over 70 percent of land acquisition expenditures, while contributions from the Richard King Mellon Foundation account for over 21 percent of acquisition costs for lands on the barrier island. Federal acquisition efforts account for about 8 percent of purchases to date.

About 61 percent of the available beachfront acquisitions for the refuge have been completed. Of the original 15 km of beachfront identified for acquisition, approximately 8 km have been acquired and 5 km are awaiting purchase. The remaining lands have been purchased for private development and are no longer available. Escalating coastal development in Brevard and Indian River counties threatens the remaining parcels identified for acquisition. Ongoing development continues to fragment the remaining habitat and could result in increased lighting and beach armoring, which negatively impact sea turtles. A narrow window of opportunity is left to acquire the last remaining lands required for the refuge.

H1.4.2. Evaluate the status of the high density nesting beaches on Hutchinson Island, Florida, and develop a plan to ensure its long-term protection. Approximately 10 percent of loggerhead turtle nesting in the United States occurs along this 32-km beach. Development is degrading nesting habitat, and public use is causing significant disturbance to nesting activities. DEP and FWS should evaluate the threats and take appropriate measures, including acquisition, to ensure long-term protection.

H1.4.3. Evaluate status of other undeveloped beaches that provide important habitat for maintaining the historic nesting distribution and develop a plan for long-term protection. DEP and FWS should evaluate other nesting beaches in the Southeast that contribute significantly to the historic nesting distribution to ensure long-term protection.

H2. Restore areas to suitable habitat.

H2.1. Reestablish dunes and native vegetation. Dune restoration and revegetation with native plants should be a required component of all renourishment projects. This will enhance beach stability and nesting habitat and may result in the need for less frequent renourishment activities.

H2.2. Remove exotic vegetation and prevent spread to nesting beaches. Australian pine trees shade nests and can alter natural hatchling sex ratios. Australian pines also aggressively replace native dune and beach vegetation through shading and chemical inhibition and consequently exacerbate erosion and loss of nesting habitat. Erosion can topple trees and leave exposed roots that can entrap nesting females. Removal of exotics, such as is ongoing at St. Lucie Inlet SP, Hobe Sound NWR, and Dry Tortugas NP, Florida, should continue. DEP, FWS, and NPS should identify other important nesting beaches where exotic vegetation is degrading nesting habitat and work with responsible parties to restore natural vegetation.

H3. Conduct research to evaluate the relationship of sand characteristics (including aragonite) and female nesting behavior, nesting success, hatching success, hatchling emerging success, hatchling fitness, and sex ratios. Beach nourishment may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content if the placed sand is dissimilar from the original beach sand. These changes could result in adverse impacts on nest site selection, digging behavior, clutch viability, and emergence by hatchlings. Gas diffusion of nests could be affected by sand grain shape, size, and compaction and variations could alter hatching success. Sand color and moisture influence nest incubation temperature and can affect hatchling sex determination. The effect of importing non-native materials, such as aragonite, to U.S. beaches for beach nourishment adds additional unknowns that could conceivably affect female nesting behavior, nesting success, hatching success, hatchling emerging success, hatchling fitness and sex ratios, and should be fully evaluated before large-scale use.

Studies of alternative sand sources for beach renourishment and their suitability for sea turtles are needed. After years of beach renourishment, Miami-Dade County is running out of suitable sand material for future renourishment projects. Broward and Palm Beach counties will also be running out of sand sources in the near future. COE is exploring the potential use of sand from upland sand sources and the importation of sand from the Bahamas and the Turks and Caicos Islands. Concerns have been raised about the long-term consequences to nesting and incubating sea turtles using these alternative beach renourishing materials. In order to adequately address these concerns in section 7 consultations, studies must be conducted on the suitability of these materials prior to receiving a proposal for large-scale nourishment of Florida beaches with these alternative sand sources.

The Invertebrates

Only two federally-threatened or endangered invertebrate species are listed from South Florida, and both are endemic to South Florida. The Schaus swallowtail butterfly occurs in tropical hardwood hammocks from south Miami to Lower Matecumbe Key, and the Stock Island tree snail also occurs in tropical hardwood hammocks of the Keys.

This section of the Multi-Species Recovery Plan contains accounts of these threatened and endangered invertebrate species of South Florida. The accounts detail the biology, ecology, status and trends, and management for both of these species. Each account is followed by the recovery needs of the species which outline the recovery objective, criteria that will be used to determine when the objective has been achieved (called recovery criteria), and the tasks that will be necessary to achieve the objective (called recovery actions). The recovery tasks are divided into species-level recovery actions that address species-specific conservation and biology, and habitat-level recovery actions that address habitat management, conservation, and restoration needs for the species. The habitat-level recovery actions form the basis for the multi-species/community-level restoration actions that are provided in the community accounts. For species that have distributions outside of South Florida, there are two sections to the recovery objective; the first is the recovery objective for the species throughout its range; the second section identifies how South Florida will contribute to the species' recovery throughout its range.

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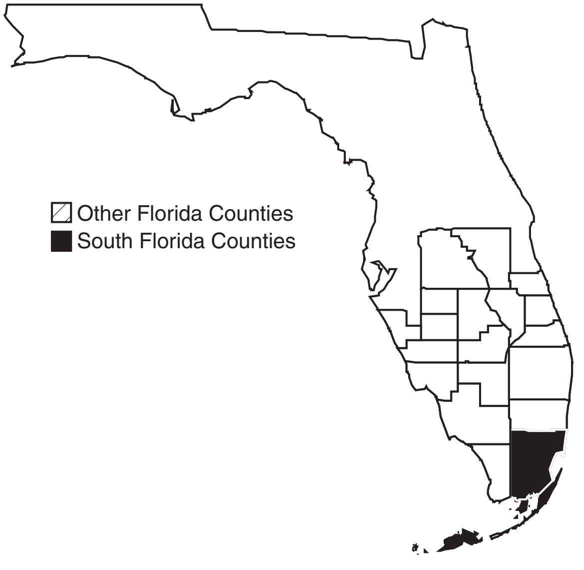
Schaus Swallowtail Butterfly

Heraclides aristodemus ponceanus

Federal Status:	**Endangered (August 31, 1984)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of Schaus swallowtail butterfly, including the Florida Keys portion of Monroe County.



The Schaus swallowtail butterfly (*Heraclides (= Papilio) aristodemus ponceanus)* is a large dark brown and yellow butterfly which historically occurred in hardwood hammocks from South Miami to Lower Matecumbe Key, Florida. The Schaus swallowtail butterfly was originally listed as a threatened species because of population declines caused by the destruction of its tropical hardwood hammock habitat, mosquito control practices, and over-harvesting by collectors. It was reclassified to an endangered species because its numbers and range had declined dramatically since the original listing.

This account represents a revision of the existing recovery plan for the Schaus swallowtail butterfly (FWS 1982).

Description

The Schaus swallowtail butterfly is a large blackish-brown swallowtail butterfly with contrasting markings that are mostly dull yellow (Klots 1951, Pyle 1981, Opler and Krizek 1984). The male's antennae are black with a yellow knob, while the female's antennae are all black. Their forewings have a dull yellow median band from the apex to about midpoint of the inner margin, with a short side branch to costa about one-third the distance from the apex. Their subterminal and terminal lines consist of lunular yellow spots from apex to anal angle. Their hindwings have a yellow median band continuing that of the forewing, and a submarginal row of large yellow lunular spots; the concavities of a deeply scalloped outermargin have yellow edging. Their blackish "tail" is straight-edged (not teardrop-shaped), and is bordered with yellow. The tails have a hollow red spot along the anal margin just above the anal angle, with bluish scaling. A small, inconspicuous red dash is sometimes present toward the base of the second yellow lunule from the anal angle (between vein M2 and Cu1).

The underside of a Schaus swallowtail's wings is yellow with black shading mostly in the median and submarginal areas of the forewing and in the terminal area and tails of the hindwing. A dull brownish-red median band extends from costa to inner margin of the hindwing, narrowing before touching these margins. When perched and fluttering its wings, the Schaus is distinctive in its extensive russet-brown to magenta scaling bordered by iridescent blue scales, on the ventral hind wing surface (T. Emmel, University of Florida, personal communication 1998). The wingspan is 8.6 to 9.5 cm (Klots 1951, Pyle 1981).

Schaus swallowtail butterfly is most easily confused with the giant swallowtail [*Papilio cresphontes* (Cramer)], which is widespread in eastern North America and also occurs in habitat occupied by the Schaus swallowtail butterfly. The two butterflies are separated by size and color. The giant swallowtail is larger than the Schaus swallowtail and is more nearly coal-black with brighter yellow lines, although this butterfly species, color may fade to brown after several days of flight (T. Emmel, University of Florida, personal communication 1998). The giant swallowtail butterfly has a broader median forewing band that is more broken into spots, and is less separated from the submarginal band toward the apex; the antennae are solid black; and its tail is teardrop-shaped, yellow inside bordered with black edging. The reddish markings on the underside of its wings are less brownish and much less extensive than on the Schaus swallowtail butterfly (Opler and Krizek 1984). The surest differentiation between the two species in the field is the tail coloration and flight behavior. The giant swallowtail flies with a more rapid fluttering flight and in a straight line, compared to the Schaus swallowtail's slower, more hesitant flight. Additionally, the giant swallowtail has more protruding forewings in flight, whereas the Schaus swallowtail has a more boxlike shape in flight (T. Emmel, University of Florida, personal communication 1998).

Taxonomy

The Schaus swallowtail butterfly is a member of the Lepidoptera, family Papilionidae. In its original description (Schaus 1911) the Schaus swallowtail was considered to be a full species, *Papilio ponceana*, with the type locality Miami, Florida. Schaus noted that it was "allied to *P. aristodemus* from Haiti, and *P. temenes* Godt. from Cuba." It was first placed as a subspecies of *aristodemus* Esper in 1917 (Barnes and McDunnough 1917), and has been cited as such since that time except for Holland's (1931) revised version of *The Butterfly Book.* Now considered an Antillean species with high propensity to vary geographically, *P. aristodemus* consists of five subspecies (Clench 1978): Nominate *P. aristodemus* (Hispaniola), *P. aristodemus temenes* Godart (Cuba), *P. a. ponceanus* Schaus (Florida), *P. a. driophilus* Clench (Bahamas), and *P. a. bjorndalae* Clench (Bahamas). The validity of some of these subspecies has been questioned (FWS 1982); however, it is believed that the Schaus swallowtail may

Schaus swallowtail butterfly. *Original photographs by Thomas Emmel.*

represent a distinct species (Emmel 1986a). Molecular studies are needed to determine the relationships between these five subspecies and whether each represents a truly separate genetic entity.

Orthography of the specific name was "*ponceana*" in the original description (Schaus 1911) and in some earlier references (Barnes and McDunnough 1917, Bates 1934, McDunnough 1938). Widespread use of the "*ponceanus*" spelling resulted from its first major appearance in *The Butterfly Book* (Holland 1931). Both subspecies status and the "*ponceanus*" orthography have been stable since 1951 (Klots 1951).

Generic usage has fluctuated recently, with North American species traditionally placed in *Papilio* Linnaeus grouped into three genera, one of which is *Heraclides* Hubner (Miller and Brown 1981). This usage has been followed by some recent workers (Pyle 1981, Loftus and Kushlan 1984), but not by others (Opler and Krizek 1984, Hower 1975, Emmel 1985, FWS 1982). These conservative workers retain *Papilio*, considering *Heraclides* to be at most a subgenus. *Heraclides* (*Papilio*) *aristodemus ponceanus* has been used incorrectly since *Papilio* is not a subgenus. *Heraclides* (=*Papilio*) *aristodemus ponceanus* is the correct representation.

Distribution

The present distribution of the Schaus swallowtail extends from southern Miami-Dade County through the Keys in Biscayne Bay and north to southern Key Largo in the Upper Keys, to Lower Matecumbe Key in the Middle Keys. Schaus swallowtail butterfly distribution is limited to tropical hardwood hammocks and is concentrated in the insular portions of Miami-Dade and Monroe counties, from Elliott Key in Biscayne National Park (NP) and associated smaller Keys to central Key Largo (Figure 1). The species is currently known from 13 areas on the mainland and the Upper and Middle Keys, following reintroduction efforts undertaken between 1995 and 1997 (T. Emmel, University of Florida, personal communication 1998).

There have been two possible, but unverified, sightings of Schaus swallowtail butterflies in the Lower Keys. One Schaus swallowtail butterfly was seen on Big Pine Key in 1966 (FWS 1982). Another Schaus swallowtail butterfly was sighted on Lignumvitae Key in 1973 (Covell 1976). The sighting on the latter Key seems possible because the butterfly's foodplant torchwood (*Amyris elemifera*), is present on Lignumvitae Key (Covell 1976, 1977). A 1984 survey from Elliott Key to Key West found no Schaus swallowtail butterflies south of north Key Largo (Emmel 1985); although a verified sighting occurred on Upper Matecumbe Key in 1986 (Emmel 1986a). In 1985, over 400 Schaus swallowtail butterflies were seen in Biscayne NP, and a few were spotted at four sites in northern Key Largo. In 1986, the population of adult Schaus swallowtail butterflies on Elliott Key was estimated at 750 to 1,000 individuals; in the same year, there were an estimated 50 to 80 individuals (adults and immatures) on each of Old Rhodes, Totten, and Adams Keys (Emmel 1986a).

The Schaus swallowtail butterfly was described by Schaus in 1911 from specimens collected in May 1898, in the south Miami area. The last known mainland specimen was collected at Coconut Grove, Miami-Dade County, in May 1924 (FWS 1982). One older specimen was reportedly collected at Key West (FWS 1982). A colony on Lower Matecumbe Key flourished from 1935 to 1946 (FWS 1982, Grimshawe 1940), with a single capture recorded there in 1964 (FWS 1982). The Schaus swallowtail butterfly has been known to occur on northern Key Largo from 1940 to present, although rare since the mid-1970s (FWS 1982). The Schaus swallowtail butterfly has been known to exist on the larger islands of Biscayne NP from a survey conducted in 1972 (Brown 1973, Covell and Rawson 1973).

Habitat

The Schaus swallowtail butterfly occurs exclusively in subtropical dry forests (hardwood hammocks) including areas that were formerly cleared and farmed, but have since regrown. Hardwood hammocks are now extensive only in the Upper Keys in Miami-Dade and Monroe counties (FWS 1982). Adults of this species may fly in clearings and along roads or even out over the ocean for short distances (Rutkowski 1971, Brown 1973). The males prefer trails and hammock edges while the females more often fly within the hammock, occasionally venturing out to feed on flowers but typically staying within the hammocks proper (Rutkowski 1971). Nectaring activity usually occurs on blossoms of cheese shrub (*Morinda royoc*), blue porterweed (*Stachytarpheta jamaicensis*), sea grape (*Coccoloba uvifera*), wild sage (*Lantana involucrata*), wild coffee (*Psychotria nervosa*), or guava (*Psidium guajava*) along the margins of these hammocks. However, up to 30 different wild plant species may be exploited (Emmel 1988, 1995a). This species rarely feeds in areas open to direct sunlight (FWS 1982, Rutkowski 1971).

Other characteristics of Schaus swallowtail butterfly habitats are that they are relatively high elevation (3.0 to 4.6 m above sea level), away from tidal waters, and have a mature overstory of trees such as gumbo-limbo (*Bursera simaruba*), pigeon plum (*Coccoloba diversifolia*), black ironwood (*Krugiodendron ferreum*), West Indian mahogany (*Swietenia mahagoni*), and wild tamarind (*Lysiloma latisiliquum*) (Covell 1976). These plants grow on a substrate of Key Largo limestone, which characterizes the Upper Keys.

Dense, mature, subtropical hardwood hammock habitat on well-drained substrate with dappled sunlight penetration is essential for the continued survival of both the Schaus swallowtail butterfly and its primary food plant, torchwood (Emmel 1985, FWS 1982, Covell 1976, Rutkowski 1971, Brown 1973, Loftus and Kushlan 1984). The minimum area of tropical hardwood hammock required for a successful butterfly population is not known, though viable wild populations have been noted over a 14-year period in areas as small as 4 ha (T. Emmel, University of Florida, personal communication 1998). Similarly, the optimum density of primary and secondary food plants is not known.

Behavior

The Schaus swallowtail butterfly is territorial only to the extent that males patrol constantly for females and may investigate other butterflies entering their territories within hardwood hammocks (Emmel 1985). The flight pattern is usually rapid and erratic at about 1 to 2 m off the ground. Male butterflies have also been reported as they “patrolled the tree tops at a height of 10 feet or more” during the “hot afternoon” on “bright days,” sometimes “descending into open spaces to investigate any other *Ponceanus*” (Rutkowski 1971). Emmel (1985) also notes that male Schaus swallowtail butterflies are remarkably adapted to flight within hardwood hammocks and are able to pick their way among branches and around spider webs.

The Schaus swallowtail butterflies spend much of their time within hammocks, particularly where sunlight penetrates to give a dappling effect (Emmel 1985). Courtship has been observed along narrow trails cut through the hammock (Rutkowski 1971). Open areas such as trails or clearings within or near the dense hammock are requisite for courtship activity and nectaring. These open areas may be natural or man-made.

The Schaus swallowtail butterfly appears to be strictly diurnal but may fly from as early as 7 am. to as late as 7 pm Rutkowski (1971) observed two female Schaus swallowtail butterflies on different days visiting cheese shrub blossoms as early as 9 am. Another female hovering over cheese shrub at 5 pm comprised his last observation (Rutkowski 1971). He found both sexes “within the hammocks, fluttering in diffused light about a foot above the ground at blossoms of Guava...” during the hottest part of the day (from 1 to 2 pm).

While no mass migration of the Schaus swallowtail butterfly has ever been reported, movement is common on individual islands and some movement between islands which are closely situated has been noted. The butterflies are capable of flying as far as 5.8 km miles in a day and marked specimens have traveled between Keys, including Elliott and Adams Keys in Biscayne NP and from Elliott or Adams Keys south to Upper Key Largo (T. Emmel, University of Florida, personal communication 1998). One Schaus was followed as it crossed a 0.8 km expanse of Biscayne Bay between two islands (Brown 1973). In 1986, a Schaus swallowtail butterfly was seen crossing about 360 m from Old Rhodes Key to Swan Key (Emmel 1986a). These observations indicate that these butterflies can travel across open water for a considerable distance among the Upper Keys and may be able to travel to and from the mainland.

Schaus swallowtail butterflies have a single annual flight season, primarily in May and June, where adults are active; most sightings have been recorded between mid-April and mid-July (FWS 1982). Post flight season emergences in August or September are extremely rare, but do occur in both the wild and captively propagated populations (T. Emmel, University of Florida, personal communication 1998).

There is only one generation of Schaus swallowtail butterfly per year and adults are short-lived (Emmel 1985). There is some evidence from rearing that diapause may extend for at least 2 years (Grimshawe 1940). If this occurs in natural populations, the Schaus swallowtail butterfly could survive extreme droughts in the season following its larval development by delaying emergence, perhaps until July-September or later (Rutkowski 1971). Some adults are active during July-September as well as during the normal flight period of late April through early July (Brown 1976).

Reproduction

The courtship of Schaus swallowtail butterflies has been partially described in the following observation: "At 10:15 am in a dimly-lit trail through brushy hammock I saw a female and two male *ponceanus* visiting flowers at opposite ends of a guava tangle. The fresher of the two males eventually approached this slightly worn female while she was still feeding. He hovered over her. She then settled on the ground with wings flattened and vibrating, raising her abdomen. The male fluttered on the ground behind and then rose over her before flying away" (Rutkowski 1971).

Three courting pairs of Schaus swallowtail butterflies were observed in 1982 on Elliott Key by Covell and photographed; details were not recorded. During part of the flight, the males were flying behind the females very low to the ground (1 to 3 m). In the pair photographed, the male was worn and heavily damaged, but the female seemed fresh and whole.

Mating has been observed in the wild and in captivity by research groups. The swallowtail rests with its wings spread open; after coupling, the pair rests facing away from each other with wings open. If disturbed, the female flies while the male holds on with his claspers and presses the wings together ventrally (M. Minno, personal communication, 1998). The Schaus swallowtail butterfly uses torchwood and wild lime (*Zanthoxylum fagara*) to deposit its eggs (Grimshawe

1940, Rutkowski 1971, Brown 1973, Loftus and Kushlan 1984). These food plants are either at the edge of hammocks along trails sheltered by the canopy or they are in the hammocks proper, at the edge of a clearing or where a fairly large opening in the canopy exists. Females deposit single eggs on the upper surface of the tips of the leaves; however, there is one record of two eggs on a leaf (FWS 1982). Eggs and larvae are not found on plants in open sunlight; however, in contrast, the giant swallowtail, *Heraclides cresphontes,* has been observed ovipositing on wild lime growing in the open (FWS 1982).

Survival rate of adults in the wild averages 3.3 days for males and 3.6 days for females (Emmel, 1988,1995b). The Schaus swallowtail butterfly may suffer damage more quickly than similar species that live in more open areas because of hazards of life in the dense brush of the hammock (Emmel 1985b). Ideal conditions in the laboratory can enhance survival and extend this time period to as long as 34 days (T. Emmel, University of Florida, personal communication 1998).

No studies on sex ratio have been published, but generally males are seen in more abundance than females. Of 245 adult *ponceanus* in collections, 136 were males, 41 females, and 68 had no sex indicated. If these figures were indicative of natural sex ratios, males would outnumber females by more than 4:1. Female butterflies are typically more secretive than males, and in the case of Schaus swallowtail butterflies, a skewed distribution might be explained by the patrolling of males in more visible areas of the hammock edges where they are more easily captured by prey or collectors. Lab-reared offspring typically have 50 50 sex ratios (M. Minno, personal communication, 1998).

While the reproductive potential for females is high, able to lay several hundred eggs, egg survival in the field is low. A survival rate of 29.7 percent (11 of 37) was cited in one case for a group of eggs collected in the wild. Further mortality of hatching larvae resulted in a survival rate of only 5 percent in the group studied (Emmel 1995).

Development from egg to adult was described by Grimshawe (1940) and Rutkowski (1971). Eggs take 3 to 5 days to hatch. Grimshawe also describes pupation:

"When ready to transform, the larva seeks a place of seclusion, each for itself, and fastens its anal extremity with a button of silk, and throws a heavy girdle around the thorax, supporting the body in an upright, or vertical, position for the long sleep. The encased segments of the body of some of the chrysalides are rusty-brown color; others are gray, etched with moss-green and conforming generally with that of their supporting object. They take on a rigid cast and show no signs of life throughout the entire period of their sleep. Unlike the double and triple-brooded related species of neotropical Florida, our butterflies remained in the chrysalis stage either 1 or 2 years. As an example, half the caterpillars transforming into the chrysalis stage July 7, 1935, emerged May 8, 1936; the other half remained, hatching May 13, 1937."

Rutkowski (1971) also noted the white osmeteria on the larvae, and drinking of water droplets by fifth-instar caterpillars.

Foraging

Torchwood is the primary source of food for the Schaus butterfly. Young caterpillars use tender, young leaves of the wild lime and will avoid older leaves, although fifth (final) instar larvae have been observed eating tougher older leaves of torchwood (FWS 1982) and, in a laboratory, prickly-ash (Rutkowski 1971). Adults have been observed taking nectar from blossoms of guava, cheese shrub, and wild coffee (FWS 1982, Rutkowski 1971). Guava, although an exotic, seemed to be the nectar source preferred by individuals observed by Rutkowski (1971) and he suggested that Schaus swallowtail butterflies will fly some distance from their hammock haunts to find blooming guava flowers. Emmel (1986a) observed frequent nectaring at seven plant species on Elliott Key: cheese shrub; blue porterweed (*Stachytarpheta jamaicensis*); sea grape (*Coccoloba uvifera*); dog's tail (*Heliotropium angiospermum*); lantana (*Lantana involucrata*); salt-and-pepper *(Melanthera nivea*); and wild coffee.

Relationship to Other Species

The survival of the Schaus swallowtail butterfly depends on survival of sufficient stands of its primary food plants, torchwood and wild lime, in appropriate tropical hardwood hammocks in the upper Florida Keys. These two rutaceous species are the only known foods for this species in nature (Emmel 1985, FWS 1982). The butterfly occasionally oviposits on individuals of Key lime (*Citrus aurantifolia*), a non-native, but it is not a normal food plant for this species in the wild (T. Emmel, University of Florida, personal communication 1998). The butterfly uses wild lime at least as frequently as torchwood, and wild lime is generally a more common food plant in its present population areas as noted by Emmel 1986, 1988, 1995a. No direct competition with other butterfly or moth species for food plant utilization has been observed. The giant swallowtail does use wild lime, but oviposits on plants in open sunlight and not on shaded plants as in the case of the Schaus swallowtail (FWS 1982, Rutkowski 1971). The relationship between birds and butterflies is important since predation by birds appears to be the most reasonable explanation for high pupal mortality rates (Emmel 1995b).

Status and Trends

Although population numbers of the Schaus swallowtail butterfly fluctuate year to year, between 1924-1981 there had been a general decline in range and numbers. The Schaus swallowtail butterfly has been considered as rare on north Key Largo since the mid-1970s. This species was listed as threatened on April 28, 1976, because of population declines caused by the destruction of its tropical hardwood hammock habitat, mosquito control practices, and over-harvesting by collectors (41 FR 17740). The Schaus swallowtail butterfly was reclassified to an endangered species on August 31, 1984, because its numbers and range had declined dramatically since its first listing (49 FR 34504).

Suitable habitat remaining for this species is estimated as 43 percent in Biscayne NP and 17 percent for north Key Largo. The decline has been attributed primarily to habitat destruction. North Key Largo contains one of the last remaining protected areas of tropical hardwood hammock habitat. The majority of the Schaus swallowtail butterfly population is found on Adams, Elliott, Old Rhodes, Swan, and Totten Keys within Biscayne NP. Between 1985 and 1990, the Elliott Key population fluctuated between 600 to 1,000 adults annually, with smaller populations of at least 50 to 100 individuals on each of the other Keys. Hurricane Andrew temporarily reduced the Biscayne NP's population in 1992 to 58 identified individuals; however, in 1994 the population rebounded to over 600 and is presumed stable (Emmel 1995a).

Within the major keys of Biscayne NP (Elliott, Old Rhodes, Totten, and Adams Keys) and on northern Key Largo, the two food plants of the Schaus swallowtail butterfly seem adequate to support a healthy population. High numbers of individuals sighted in 1985 indicate that the Schaus swallowtail butterfly's population is still capable of periodic peaks. Following 3 years of reintroductions, results of a 1997 flight season census indicate that the total annual population in the wild has increased to at least 1200 butterflies (J. Daniels, University of Florida, personal communication 1999).

Prior to human influences, populations of this butterfly were probably subject to naturally occurring population depressions caused by hurricane damage, drought, and rare freezes (Covell 1976). The influence of the Labor Day Hurricane of 1935 on the Lower Matecumbe Key population was documented by Grimshawe (1940), though the claim that the species became extinct was incorrect (it was found there and on Key Largo in succeeding years) (Henderson 1945). The results of Grimshawe's careful searching were negative; however the before and after surveys demonstrated that the hurricane had a detrimental effect on the biota of the keys southwest of Key Largo.

Threats

The principal future threats to Schaus swallowtail butterfly survival and recovery are, in descending order: loss of habitat for residential and commercial construction; introduction of pesticides and other hazardous chemicals; road kills; extreme climatic conditions, such as hurricanes, freezes, and droughts; and death by predators, parasites, and collectors.

Clearing of habitat for urban and agricultural purposes in and around Miami and Lower Matecumbe Key certainly were instrumental in eliminating the Schaus swallowtail butterfly at the extremes of its historic range. Food plants were probably either eliminated or reduced to small stands incapable of sustaining Schaus swallowtail butterfly populations (FWS 1982). Similar clearing has occurred within its known north Key Largo habitat, but litigation has slowed development of the area (Covell 1976) and many areas have been acquired by DEP. Slight alteration of habitat, such as dirt roads and trails through the hammocks, seem to be harmful only in that they permit easy access to collectors, who can catch butterflies when they fly low along these trails. However, small clearings and trail edges seem to promote proliferation of torchwood plants. Natural succession in such places, particularly following hurricanes and fires, could account for population increases in the species and its food plants. But large fires and extensive forest clearing are detrimental to the species. Paved roads through Schaus swallowtail butterfly habitat, particularly C.R. 905 on northern Key Largo, permit road kill of adults, one case of which is documented (Covell 1976).

The use of commercial pesticides has also contributed to the decline of the Schaus swallowtail butterfly. Monroe County currently operates an active mosquito control program. Although agreements with the county to avoid sensitive habitat areas in north Key Largo have been discussed, spraying in these areas still occurs. The pesticides Dibrom, Baytex, and Teknar, used in the keys for mosquito control, are toxic to the related giant swallowtail (*Heraclides cresphontes*) in the laboratory (Emmel 1986b). Mortality of Schaus swallowtail butterfly occurs from the use of these chemicals directly, and indirectly, by application to food sources and other components of the habitat. Pesticides can also cause behavioral modification and impaired reproduction and it is very likely that the extensive use of mosquito control pesticides has greatly reduced butterfly populations.

Collecting of immature stages as well as adults may have reduced numbers on Key Largo in the period from 1969-1974 and earlier; but again the lasting effects cannot be gauged (Covell 1976). Collection of specimens has been illegal since the early 1970s and today, there is no known poaching activity.

Little is known about predation by spiders, lizards, birds, or other predators. Damage to wings occurs soon after adult emergence, and beak marks on some individuals indicate frequent bird attacks (Emmel 1985). Flight behavior among the many obstacles in hammock habitat seems unusually deliberate, in that the butterflies can fly slowly and painstakingly to avoid the many large orb spider webs and branches to a remarkable degree (Emmel 1985). Emmel also observed that butterflies seem able to follow the same flight paths through hammocks repeatedly. Ants and lizards are the most likely predators of the immatures (M. Minno, personal communication 1998). Larval predation is probably minimized by oviposition behavior (one egg per leaf and few per food plant), lizard-dropping appearance of the larvae (as in other *Papilio* larvae), secretive behavior of larvae, and bad-smelling scents from the osmeteria when larvae are disturbed (Grimshawe 1940, Rutkowski 1971). Crypsis in the pupa (Grimshawe 1940) as in other swallowtails is also a factor in avoiding predation. Nothing is known about parasites of this species. No information is available regarding diseases of the Schaus swallowtail butterfly; however, high egg mortality has been observed at times (FWS 1982, Rutkowski 1971).

Management

According to the FWS's Recovery Team (FWS 1996), recovery actions for the Schaus swallowtail butterfly should focus on acquiring additional hardwood hammock habitat and protecting those areas and existing hammock from development. As part of the recovery tasks identified for the Schaus swallowtail butterfly, 760 pupae were released in 1995 on seven protected sites. Depredation by birds accounted for an estimated 85 to 90 percent mortality rate. In 1996, this effort involved the release of 248 female and 155 male adult Schaus swallowtail butterflies on those same seven sites (Figure 2). All females were mated prior to release. An additional release of adults to those same areas was undertaken in 1997. Results of these reintroductions appear to have been very successful, however, monitoring will continue through at least 1999.

In addition, habitat improvement, through the planting of hundreds of wild lime trees, is being conducted within selected colonies on Key Largo. This effort should serve to increase the breeding habitat for Schaus swallowtail buttterflies, and hopefully result in a natural population increase (J. Daniels, University of Florida, personal communication 1999).

Biscayne NP is also being managed to provide adequate cover for both Schaus swallowtail butterfly adults and food plants (Emmel 1985, FWS 1982). This cover includes mature and well-drained tropical hardwood hammock with some natural and man-made openings such as narrow trails and clearings where nectaring and courting behavior can take place close to the more

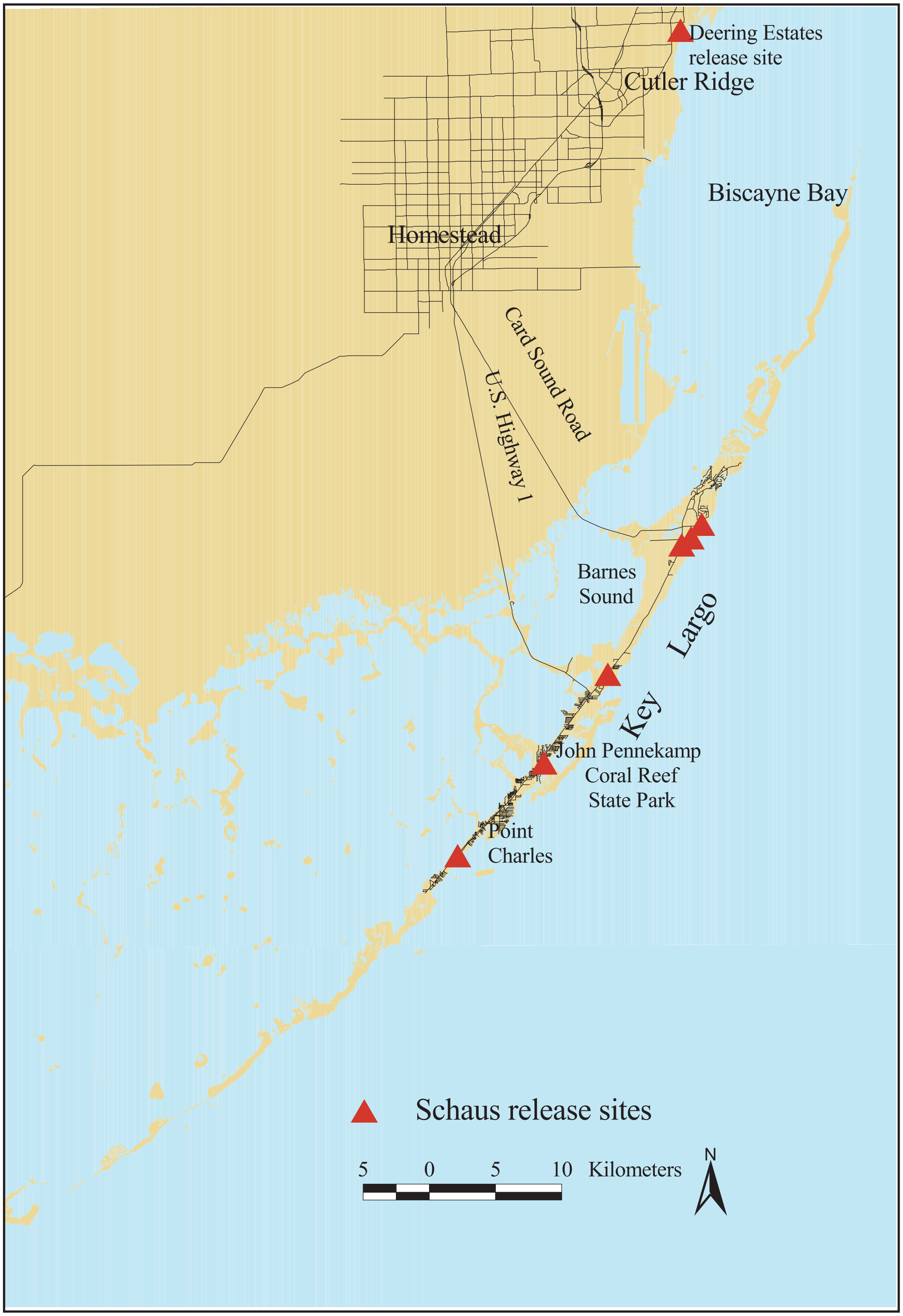


Figure 2. Release sites for Schaus swallowtail butterfly in Miami-Dade and Monroe counties.

Literature Cited

enclosed jungle-like forest where adults spend much of their time (FWS 1982).

Barnes, W., and J.H. McDunnough. 1917. Check list of the Lepidoptera of boreal America. Herald Press; Decatur, Illinois.

Bates, M. 1934. Notes on some tropical Florida butterflies (Lepidoptera*: Rhopalocera*). Entomological News 45:166-169.

Brown, C.H. 1976. A colony of *Papilio aristodemus ponceanus* (Lepidoptera: Papilionidae) in the upper Florida Keys. Journal of Georgia Entomological Society 11(2):117-118.

Brown, L.N. 1973. Populations of *Papilio andraemon bonhotei* Sharpe and *Papilio aristodemus ponceanus* Schaus in Biscayne National Monument, Florida. Journal of Lepidopterists' Society 27(2):136-140.

Clench, H. K. 1978. *Papilio aristodemus* (Papilionidae) in the Bahamas. Journal of Lepidopterists' Society 32(4):273-276.

Covell, C.V., Jr. 1976. The Schaus swallowtail: a threatened subspecies? Insect World Digest 3(59):21-26.

Covell, C.V., Jr. 1977. Project *ponceanus* and the status of the Schaus swallowtail (*Papilio aristodemus ponceanus*) in the Florida Keys. Atala 5(1):4-6.

Covell, C.V., Jr., and G.W. Rawson 1973. Project *ponceanus*: a report of first efforts to survey and preserve the Schaus swallowtail (Papilionidae) in southern Florida. Journal of Lepidopterists' Society 27(3):206-210.

Daniels, J.C., M.C. Minno, T.C. Emmel, P.J. Eliazar, and L.L. Groce. 1993. Egg color dimorphism in the endangered Schaus' swallowtail butterfly, *Papilio aristodemus ponceanus*, of South Florida (Lepidoptera:Papilionidae). Tropical Lepidoptera 4(1):65-66.

Daniels, J. 1999. Written communication to FWS South Florida Field Office. June, 1999.

Emmel, T.C. 1985. Status survey of the Schaus swallowtail in Florida in 1984. Technical report No. 145, Florida Cooperative Fish and Wildlife Research Unit, University of Florida; Gainesville, Florida.

Emmel, T.C. 1986a. Status survey and habitat requirements of Florida's endemic Schaus swallowtail butterfly. Florida Game and Fresh Water Fish Commission, Final Report GFC-84-028; Tallahassee, Florida.

Emmel, T.C. 1986b. Pesticide effects on the survival of the Schaus swallowtail butterfly. Final report to Elizabeth Ordway Dunn Foundation, Inc. University of Florida, Gainesville, Florida.

Emmel, T.C. 1988. Habitat requirements and status of the endemic Schaus swallowtail in the Florida Keys. Florida Game and Fresh Water Fish Commission, nongame Wildlife Section; Tallahassee, Florida.

Emmel, T. C. 1995a. Designated species management plan for the reintroduction of the Schaus swallowtail butterfly in the Florida Keys. University of Florida, Gainesville, Florida.

Emmel, T.C. 1995b. Captive propagation and experimental reintroduction of the Schaus swallowtail in the Florida Keys. Interim status report submitted to the U.S. Fish and

Wildlife Service, research work order no. 153; Vero Beach and Jacksonville, Florida.

Emmel, T.C. 1998. Comments on draft species account. January 29, 1998.

Grimshawe, F.M. 1940. Place of sorrow: The world's rarest butterfly and Matecumbe Key. Nature Magazine 33:565-567, 611.

Henderson, W.F. 1945. *Papilio aristodemus ponceana* Schaus (Lepidoptera: Papilionidae). Entomological News 56(2):126-136.

Holland, W.J. 1931. The butterfly book. Doubleday Publishers; New York, New York.

Hower W.H. 1975. The butterflies of North America. Doubleday Publishers; New York, New York.

Klots, A.B. 1951. A field guide to the butterflies of North America east of the Great Plains. Houghton Mifflin; Boston, Massachusettes.

Loftus, W.F., and J.A. Kushlan. 1984. Population fluctuations of the Schaus swallowtail (Lepidoptera: Papilionidae) on the islands of Biscayne Bay, Florida, with comments on the Bahamian swallowtail. Florida Entomologist 67(2):977-287.

McDunnough, J.H., 1938. Check list of the Lepidoptera of Canada and the United States of America. Part 1, Macrolepidoptera. Memoir of Southern California Academy of Science No. 1.

Miller L.D. 1975. Threatened status for two butterflies. Field Museum of Natural History Bulletin 1975:15-18,22.

Miller, L.D., and F.M. Brown 1981. A catalogue/checklist of the butterflies of America north of Mexico. Memoir of the Lepidopterists' Society No. 2.

Minno, M.C. 1998. Comments on draft species account. September 25.

Opler, P.A., and G.N. Krizek. 1984. Butterflies east of the Great Plains. Johns Hopkins University Press; Baltimore, Maryland.

Pyle, R.M. 1981. The Audubon Society field guide to North American butterflies. Alfred A. Knopf, Chanticleer, New York.

Rutkowski, F. 1971. Observations on *Papilio aristodemus ponceanus* (Papilionidae). Journal of Lepidopterists' Society 25(2):126-136.

Schaus, W. 1911. A new *Papilio* from Florida, and one from Mexico (Lepid.). Entomological News 22:438-439.

U.S. Fish and Wildlife Service [FWS]. 1996. Multi-species Recovery Team Meeting, April 1996.

U.S. Fish and Wildlife Service [FWS]. 1982. Schaus swallowtail butterfly recovery plan. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Recovery for the Schaus Swallowtail Butterfly

Heraclides aristodemus ponceanus

Recovery Objective: RECLASSIFY TO THREATENED, then delist.

Recovery Criteria

The Schaus swallowtail butterfly has always been a rare species in its historic range of Miami-Dade and Monroe counties. The destruction and degradation of Schaus swallowtail habitat and other human activities, such as collecting and mosquito spraying, increased the vulnerability of this rare species to extinction. Management actions such as acquiring and restoring habitat, enforcing prohibitions against take, reducing the effects of mosquito spraying, and increasing our biological understanding of the butterfly's biology and ecology have helped stabilize this species. Due to the effectiveness of management actions to help its recovery, the objective of this recovery plan is to delist the Schaus swallowtail butterfly. This objective will be achieved when: further loss, fragmentation, or degradation of suitable, occupied habitat within the butterfly's historic range in the Upper Florida Keys and Miami-Dade County has been prevented; when breeding sites of the Schaus swallowtail butterfly have been protected from mosquito spraying; when mosquito spraying in other areas used by the Schaus swallowtail butterfly has been reduced by 90 percent; when all suitable, occupied habitat on priority acquisition lists for the Schaus swallowtail butterfly is protected either through land acquisition or cooperative agreements; when the hardwood hammocks that form the habitat for the Schaus swallowtail butterfly are managed, restored, or rehabilitated on protected lands; and when stable populations of the Schaus swallowtail butterfly are distributed throughout its historic range. These populations will be considered demographically stable when they exhibit a rate of increase (r) equal to or greater than

Species-level Recovery Actions

S1. Determine the distribution and status of wild Schaus swallowtail butterfly populations. Schaus swallowtail butterflies are known to occur in hardwood hammock forests in Miami-Dade and Monroe counties. Their exact distribution in these counties is known, but is not being publicized due to the possible adverse effects of collectors visiting the sites while populations are still small. From 1995-1997, captively bred butterflies were released in new areas to re-establish populations. Annual monitoring of the status, location, and distribution of pre-existing wild population sites has been carried out in Biscayne NP and on Key Largo since 1984. Additional surveys to determine the distribution and status of the wild Schaus swallowtail butterfly populations are necessary in subsequent years to follow the fate of both the wild populations and the reintroduced populations.

S1.1. Determine the status of wild butterflies within current range. Survey hardwood hammocks in Deering Estate (and other suitable areas in Miami), Biscayne NP, and north Key Largo to determine the status of wild butterfly populations. Quantitatively determine the number and distribution of larvae, juveniles, and adult butterflies. The Crocodile Lake NWR is planning on conducting annual wild butterfly surveys during peak adult emergence from April through June.

S1.2. Determine the status of captively reared Schaus swallowtail butterflies. Compile all information on the locations in which captive-reared Schaus swallowtail butterflies were released and determine the reproductive success of these populations. Surveys to determine interactions between captively reared and wild populations of the Schaus swallowtail butterflies may be critical to determining possible genetic effects of captively reared individuals on wild populations. Investigate how butterflies are spatially distributed within habitat patches and their relation to other occupied habitat patches.

S1.3. Survey natural butterfly habitat and determine habitat characterization and use by both wild and captive-bred butterflies. Identify occupied and unoccupied habitat patches. Quantify habitat structure including canopy structure, species composition and diversity, and distribution, and assess the condition. Determine why butterflies are absent in areas with suitable habitat.

S1.3.1. Survey butterflies along ecotonal regions. Survey populations along edges of roads, housing developments, and other habitat types (mangroves). Evaluate status of butterflies in remote contiguous habitat as compared to fragmented habitat or areas near human habitation.

S1.3.2. Survey the amount of light or closed canopy and its effects on species numbers, *etc.*

S1.3.3. Determine species composition and abundance between different stands of forest.

S1.3.4. Survey hammock microclimate during breeding and flight time. Previous surveys extrapolated physical environmental conditions from historic records. Survey microclimate (rainfall, temperatures, photoperiod, humidity, *etc.*) of occupied habitat during breeding and flight times.

S1.3.5. Survey the distribution of adult butterflies and the distribution of host plants.

S1.4. Determine the status of habitat at release sites. Captively bred butterflies have been released at seven different sites in Monroe and Miami-Dade counties. For each site, survey spatial coordinates, spatial relation to other patches, abundance of host plants, canopy structure, open and semi-open habitat, amount of habitat degradation (*e.g.*, exotics, trash), and susceptibility to human impacts.

S1.5. Survey other butterfly populations in occupied Schaus swallowtail butterfly habitat. Identify additional butterfly species that occur in occupied Schaus swallowtail butterfly habitat. Select a species that is relatively common, yet is habitat-specific. Survey the presence/absence of these species to determine population dynamics and habitat interaction. Surveying other selected species will provide information to help assess habitat quality.

S1.6. **Maintain and improve the GIS database for butterflies information**. Compile additional survey information into existing FWS GIS database. Use GIS to identify spatial relationships between occupied and unoccupied habitat patches.

S1.7. **Conduct presence/absence surveys for Schaus swallowtail butterfly in suitable habitat throughout the Florida Keys**. Historic reports suggest butterflies may have occurred in such areas as southern of Key Largo, Key West, Lower and Upper Matecumbe, Big Pine Key, and Lignumvitae Key. Because many of these reports are old or unconfirmed, these surveys are of lower priority. Conduct butterfly surveys in these other areas in conjunction with other listed species recovery work.

S2. **Protect and enhance existing, wild populations of the Schaus swallowtail butterfly**.

S2.1. **Assign a biologist responsibility for implementing recovery actions for the threatened or endangered species of the Upper Florida Keys and Miami-Dade County (Deering Estate and Biscayne NP).** Recovery actions that benefit one of the threatened or endangered species in the Florida Keys (such as actions to recover the Schaus swallowtail butterfly) will benefit other threatened or endangered species in the same area. At the same time, the number of actions that will be necessary to recover threatened or endangered species in the Florida Keys and Miami-Dade County will require the attention of a biologist or similarly trained professional who is dedicated to addressing these recovery needs.

S2.2. **Utilize Federal regulatory mechanisms for protection**. Conduct section 7 consultations on Federal activities that may affect the Schaus swallowtail butterfly and determine a jeopardy threshold. Coordinate with law enforcement to prevent take under section 9. Identify what activities could result in take of butterflies, such as habitat loss and collecting.

S2.3. **Provide Schaus swallowtail butterfly information to Federal, State, county, and city agencies.** Provide information including GIS information regarding the presence of butterflies, their protection under the ESA, and ways to minimize impacts. Non-Federal agencies that may influence the Schaus swallowtail butterfly include DEP, DCA, GFC, DACS, Florida Keys Aqueduct Authority, and Monroe County government.

S2.4. **Reduce human-related mortalities of Schaus swallowtail butterflies**. Levels of Schaus swallowtail butterfly mortality have not been quantified, although sources of mortality are documented. Implement management actions that reduce causes of mortality. Mortality is primarily a result of habitat modification such as clearing for residential and commercial construction, fires, introduction of pesticides and other hazardous chemicals, and deaths from vehicular collisions, predators, parasites, and collectors.

S2.4.1. **Eliminate the negative effects of pesticides and other biocides**. One of the greatest current threats to butterflies is the negative effect from mosquito spraying and other biocides. Develop a Memorandum of Agreement with Miami-Dade and Monroe county mosquito control groups to eliminate mosquito spraying effects on the Schaus swallowtail butterfly. Enforce regulations that prohibit spraying over Federal and State lands. Eliminate any adverse affects on the Schaus swallowtail butterfly.

S2.4.2. **Reduce the effects of habitat loss, destruction, and modification on Schaus swallowtail butterflies in the Florida Keys**. Several areas in north Key Largo are in private ownership and subject to habitat modification. Acquire suitable habitat to prevent mortality of butterflies. Coordinate with landowners to reduce habitat modification effects on the Schaus swallowtail butterfly.

S2.4.3. **Eliminate illegal collecting of the Schaus swallowtail butterfly**. Enforce regulations that prohibit the collection of adults, larvae, or eggs of the Schaus swallowtail butterfly.

S2.4.4. **Minimize the effects of contaminants on the Schaus swallowtail butterfly**. Investigate the effects of contaminants around the old missile site on the refuge, the firing range at Harbor Course, and illegal dumpsites. Remove contaminants that pose a threat to the Schaus swallowtail butterfly.

S2.5. **Develop a captive propagation protocol for the Schaus swallowtail butterfly and implement as warranted.** Methods to breed and raise Schaus swallowtail butterflies in captivity have been established. Although several releases of captively bred butterflies have been conducted, the effects of these animals on wild Schaus swallowtail butterfly populations are still being examined. Develop captive propagation and release guidelines.

S2.6.1. **Develop criteria for captive propagation protocol.** Use the IUCN/SSC Guidelines for Reintroductions, if appropriate, as a basis for developing criteria that determine the type of release to be conducted, the selection of a release site, the source and health of release stock, short and long-term success indicators, and monitoring protocol.

S2.6.2. **Develop threshold criteria to act as a trigger for future captive propagations.** These criteria, based on a variety of biological factors (*e.g.*, population number, distribution, habitat), would be used to ensure that the Schaus swallowtail butterfly range and population status was sufficient to ensure that a catastrophic event, such as a hurricane, would not lead to the extinction of the species in the wild.

S2.6.3. **All future efforts to captively breed Schaus swallowtail butterflies should be conducted *in situ* in as natural conditions as possible**. Preferably, butterflies should be raised in enclosures in suitable habitat within the historic range. Captive propagation efforts closer to release sites are preferable for many species. This would limit transport time and possible difficulties in achieving a successful release.

S2.6.4. **Conduct appropriate health screenings of all release stock prior to reintroduction**. IUCN guidelines recommend individuals should not be removed from a wild population until the effects of translocation on the donor population have been assessed and after it is guaranteed that these effects are not negative. Ensure all captive stock are free of possible health problems.

S2.5..5. **Monitor introduced populations to determine survival, growth, and reproductive success.** Conduct additional demographic, ecological, and behavioral monitoring of wild and released butterflies. Investigate extent and causes of mortality of released and wild butterflies.

S3. **Conduct research on the biology and life history of the Schaus swallowtail butterfly**. Conduct additional studies on the reproductive success, productivity, longevity, population size, movements, and dispersal of wild populations of Schaus swallowtail butterfly, if needed.

S3.1. **Determine if the total population size is large enough to prevent functional extinction and genetic extinction**. Determine what is the effective population size necessary for survival. Conduct population modeling, (*e.g*., spatially explicit models, PVA risk assessment) to predict the persistence of this species.

S3.2. **Determine the number of subpopulations necessary to maintain a stable or increasing population.**

S3.3.1. **Determine subpopulations vulnerable to extinction**. Determine which populations are the most critical for survival. Determine if populations on ecotonal areas or near human habitation are more vulnerable to extinction.

S3.3.2. **Determine the necessary number of subpopulations and level of exchange that will enable the Schaus swallowtail butterfly to persist for 100 years.**

S3.3. **Examine factors that affect the abundance and distribution of the Schaus swallowtail butterfly**. Although extensive studies have been undertaken on factors affecting this species' distribution and abundance, the results should be assessed to determine what additional aspects of this species' ecology affects abundance and density and makes it most vulnerable to extinction (*e.g.*, predation, lack of food, inability to find a mate). If this assessment identifies aspects of the Schaus life history and ecology in need of additional investigation, then those investigations should be initiated.

S3.4. **Evaluate the effect of releasing captive-bred butterflies into the wild the persistence of the Schaus swallowtail butterfly.** Determine if augmentation is effective in establishing stable populations throughout the Schaus swallowtail butterfly's range. Investigate if released butterflies are enhancing existing wild populations and the overall stability of the Schaus swallowtail butterfly in the long term. Continuation of existing monitoring programs is essential to assess the effectiveness of this recovery tool.

S3.5. **Investigate the effects of insecticides used for mosquito control on surrogate species closely related to the Schaus swallowtail.** This research is needed to evaluate the exact effects of these chemicals on butterflies in the Keys, and determine toxicity levels.

S4. **Monitor the status of the Schaus swallowtail butterfly and its habitat**. Monitor demographic, ecological, and behavioral studies of wild and released butterflies.

S4.1. **Monitor demographic parameters.** Monitor sex ratios, age class structure, survivorship, home range size, and dispersal distance of the Schaus swallowtail butterfly. Continue development of an adaptable model for biologists and mangers to use to survey and monitor the Schaus swallowtail butterfly to help guide management efforts.

S4.2. **Continue long-term monitoring of the Schaus swallowtail butterfly**. Monitor presence/absence and degree of abundance every year until the Schaus swallowtail butterfly is recovered. Investigate extent and causes of mortality in released and wild populations.

S5. Increase public awareness and stewardship. Inform public, especially butterfly collectors about the butterfly, its protections under Federal law, and its importance as an integral part of the ecosystem. Have an incentive or reward system to encourage homeowners to plant native host plants and protect butterflies. Inform butterfly collectors on the importance of reducing the amount of illegal butterfly collecting or manipulation. Develop educational materials and host public workshops to increase awareness about butterflies and instill a sense of stewardship for the protection of this endangered species.

S6. Establish reclassification criteria. Develop measurable reclassification criteria based on factors that result in a stable or increasing population including total population size, number of subpopulations, sex ratio, age structure, habitat condition and availability, and level of threats. Evaluate and monitor the Schaus swallowtail butterfly's status in relation to reclassification criteria.

Habitat-level Recovery Actions

H1. Prevent further loss or degradation of existing Schaus swallowtail butterfly habitat. The primary threat to the Schaus swallowtail butterfly is habitat loss and fragmentation caused by increasing urbanization. Suitable habitat remaining for this species is estimated as 43 percent Biscayne NP and 17 percent for north Key Largo.

H1.1. Acquire unprotected Schaus swallowtail butterfly habitat. Identify priority areas for acquisition. The first priority is acquiring unprotected, suitable, occupied habitat, the second priority is suitable, or potentially restorable unoccupied habitat. Unoccupied, but suitable habitat is important for future reintroduction activities. Inholding areas are also high priority.

H1.1.1. Continue Federal acquisition efforts. Continue acquisition efforts within the Crocodile Lake NWR. The Crocodile Lake NWR is developing a priority acquisition and restoration list. Priority areas include land-fill, trailer park, cock-fighting ring, and military land.

H1.1.2. Support State, local, and non-government organizations acquisition efforts. Support entities to protect Schaus swallowtail butterfly habitat through the use of conservation easements, Florida Conservation's CARL and Recreational Land acquisition program, Monroe County Land Authority, Florida Community Trust, Florida Keys Land Trust, and The Nature Conservancy. Support the acquisition of lands to be incorporated into the Key Largo State Botanical Site.

H1.2. Protect and manage Schaus swallowtail butterfly habitat.

H1.2.1. Protect butterflies on private lands. Protect Schaus swallowtail butterfly populations on private land through acquisition, conservation easements or agreements, and education of landowners. Develop agreements (*e.g.*, Memorandum of Agreement) between the FWS and private landowners to minimize impacts of exotics, plant or animal species.

H1.2.2. **Protect butterflies on public lands**. Develop a habitat management plan that outlines priority habitat for acquisition and methods to protect, restore, and minimize impacts on butterflies and their habitat.

H1.2.3. **Utilize Federal mechanisms to protect and prevent degradation of Schaus swallowtail butterfly habitat**. Coordinate with all Federal agencies to ensure Federal actions do not impact Schaus swallowtail butterfly habitat.

H1.2.4. **Coordinate with State and Monroe County agencies and private entities to develop management actions to protect Schaus swallowtail butterfly habitat**. Coordinate with these entities to ensure proposed construction activities that result in land clearing or alteration do not impact the Schaus swallowtail butterfly and its habitat. Coordinate with the Audubon Society to develop a management plan for Parcel 22. Coordinate with the Trailer Park to protect and manage habitat and minimize impacts to the Schaus swallowtail butterfly.

H1.2.5. **Avoid clearing or disturbing hammocks**. Prevent direct clearing of hardwood hammock. Direct new construction activities to areas already cleared or previously disturbed.

H1.2.6. **Restrict access to Schaus swallowtail butterfly habitat.** Restrict access to remote habitat areas to prevent damage caused by campers, homesteaders, trash dumpers, and vehicular traffic.

H1.2.7. **Establish and protect 500 m buffers around priority habitat.** The necessity for 500 m protection buffer zones is based on the likelihood that human influences encroach and impact the Schaus swallowtail butterfly.

H1.2.8. **Prevent fires.** Wildfires can quickly destroy large areas of hardwood hammocks. Develop effective fire management plans. Prohibit fires and smoking in or near hardwood hammocks.

H1.2.9. **Eliminate exotic vegetation**. Remove exotic vegetation in Schaus swallowtail butterfly habitat and in adjacent upland buffers. Use deed restrictions, covenants, or other means to minimize the likelihood that exotic plants will invade hardwood hammocks. Special consideration may be necessary for guava (*Psidium guajava*) which is listed by the State as one of Florida's most invasive exotic species, but has also been shown in recent studies to be a preferred nectar source for Schaus butterflies (R. Hammer, personal communication 1998). Eradication of this pest species by resource managers in Schaus habitat may adversely affect recovery of the butterfly.

H2. **Restore both suitable occupied and unoccupied Schaus swallowtail butterfly habitat.** Several areas are suitable for restoration. Restoration efforts will benefit the hammock habitat, existing butterfly populations, and future released populations. Conduct and support restoration activities in Schaus swallowtail butterfly habitat.

H2.1. **Restore Schaus swallowtail butterfly habitat**. Restore Crocodile Lake NWR habitat near the missile site, borrow pit, gun range, cock fighting ring, and radio tower. Support the restoration of habitat on State and county lands.

H2.2. Improve habitat by planting or encouraging native plant species. Plant native vegetation in areas that have been scarified or degraded. Restore habitat along ecotones by planting early successional vegetation along ecotonal areas to encourage use by the Schaus swallowtail butterfly.

H2.3. Improve habitat by conducting selective trimming. Manage habitat to provide open spaces to encourage courtship, mating, and foraging behaviors.

H2.4. Remove exotic vegetation. Remove exotic vegetation in refuge boundaries. Support the removal of exotics in other Schaus swallowtail butterfly habitat including Port Bougainvillea and Ocean Forest Tract (Ocean side of Harrison Tract).

H2.5. Remove trash debris. Several old roads into the Crocodile Lake NWR are littered with trash and debris. Remove trash and debris from these and other areas in Schaus swallowtail butterfly habitat.

H3. Conduct research to determine habitat needs for the Schaus swallowtail butterfly. Develop a spatially explicit or incidence function model (Hanski *et al*. 1996) to predict metapopulation dynamics and evaluate habitat patches important for the survival of the Schaus swallowtail butterfly.

H3.1. Investigate how butterflies use different habitat components for survival. (*e.g.*,food, shelter, nesting, traveling).Investigate habitat preferences and adaptations to local ecological conditions.

H3.1.1. Determine minimum area requirements. Determine optimum and suboptimal hammock size, character, and configuration for colony viability.

H3.1.2. Identify host plants, their status and role in the hammock community, effects from natural factors, and how the Schaus swallowtail butterfly is dependent on them. Previous work provides data on relative abundance of host plants and not quantitative data of density and distribution. Investigate the distribution, extent and status of host plants of Schaus swallowtail butterfly. Determine if Schaus swallowtail butterflies are facultative or obligatory users of host plants.

H3.1.3. Determine the effects of forest canopy structure and light conditions on the Schaus swallowtail butterfly. Investigate optimal amounts of diffuse and direct light. Determine if management regimes (*e.g.*, thinning, opening canopy layer) can benefit Schaus swallowtail butterfly populations.

H3.1.4. Investigate the effect of habitat change. Determine how the Schaus swallowtail butterfly's distribution and abundance is affected by habitat or microclimate modification and forest maturation.

H3.2. Determine an index of habitat fragmentation. Determine optimum landscape design for long-term survival of the Schaus swallowtail butterfly.

H3.2.1. Investigate flight patterns and the spatial utilization of habitat to identify important core areas and corridors.

H3.2.2. Determine if the amount and configuration of habitat is sufficient to support a stable or increasing population of Schaus swallowtail butterflies.. Investigate the number and size of habitat patches, both occupied and unoccupied as well as any barriers, and determine if habitat patches are interconnected or isolated. Investigate the capacity of habitat patch networks to support populations of Schaus swallowtail butterflies and determine if some fragmented habitats may be too isolated or small to allow for adequate recolonization. Determine rates of recolonization in different habitat patches. Determine the minimum number of habitat patches necessary for long-term survival of the Schaus swallowtail butterfly.

H4. Monitor the status of Schaus swallowtail butterfly habitat and examine ecological processes. Conduct yearly monitoring evaluations of the status of the Schaus swallowtail butterfly's habitat. Overlay habitat quality with GIS mapping of habitat locations, including habitat alteration and loss each year. Monitor the availability of Schaus swallowtail butterfly habitat through GIS by updating the loss or change of habitat due to residential or commercial construction.

H4.1. Conduct long-term monitoring of habitat patches. Determine the rate and sequence of vegetative composition in maturing or regenerating forests.

H4.2. Monitor primary and edge forest habitat. Determine how different habitat compositions affect the distribution and abundance of the Schaus swallowtail butterfly within primary forest and along edged habitat.

H4.3. Monitor ongoing and proposed habitat restoration efforts. Restoration efforts in north Key Largo include efforts to remove and eradicate exotic species, remove trash debris, recreate habitat in scarified or degraded areas, and open canopy layer. Monitor habitat response from restoration efforts and determine the response of Schaus swallowtail butterfly.

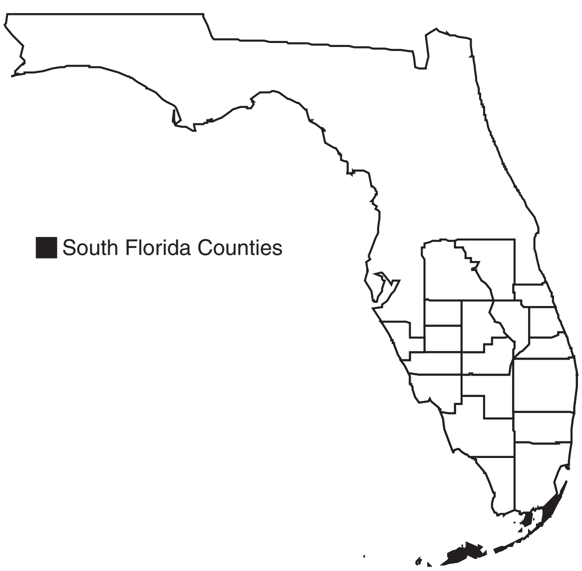
H5. Increase public awareness of Schaus swallowtail butterfly habitat and instill stewardship. Conduct workshops with the public to inform private landowners on appropriate management practices to preserve Schaus swallowtail butterfly habitat. Encourage private landowners to remove exotics, plant native vegetation, refrain from destroying butterfly habitat, and restore disturbed areas. Prepare literature to provide information regarding the Schaus swallowtail butterfly's habitat and ways to protect and conserve it.

Stock Island Tree Snail

Orthalicus reses

Federal Status:	**Threatened (July 3, 1978)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. Distribution of the Stock Island tree snail; this species is endemic to only the Florida Keys portion of Monroe County.



The Stock Island tree snail *(Orthalicus reses,* not including *nesodryas)* is an arboreal snail inhabiting the hardwood hammocks of the Florida Keys. It was listed as threatened because of population declines, habitat destruction and modification, pesticide use, and over-collecting. Snail collecting in South Florida has been popular for many years, and although the Stock Island tree snail lacks the vibrance and radiance of some of the other intricately colored snails, it has not escaped intense collecting pressures. In addition, it has not escaped the pressures of destruction of its habitat due to residential and commercial construction activities. The Stock Island tree snail historically occurred on the islands of Stock Island and Key West, both from which it has been largely extirpated from its historic range. In response to the loss of habitat and decline in the number of snails on Stock Island, collectors have moved snails and introduced them to areas outside of their historic range. The few remaining populations have continued to decline as a result of further habitat loss and other threats.

This account represents a revision of the existing recovery plan for the Stock Island tree snail (FWS 1982).

Description

The Stock Island tree snail is a large, conical snail attaining approximately 45 to 55 mm in length. The external ground color is white to buff, with three poorly developed spiral bands and several flame-like purple-brown axial stripes that stop at the lower of the spiral bands (Deisler 1982). The thickness of the shell varies, but is usually more lightweight and translucent than other species of *Orthalicus* (Pilsbry 1946). The axial stripes are typically narrower than their whitish interspaces and do not fork near the upper suture. There are two to three white apical whorls. The last whorl contains two to four darker brown growth-rest varices. The columella and parietal callus are white or faint chestnut brown. This species is distinguished from *O. r. nesodryas* by its lighter color pattern of the apical whorl, columella, and parietal callus. These characteristics are chestnut-brown or darker in *O. r. nesodryas*.

Taxonomy

The Stock Island tree snail is a subspecies of the genus *Orthalicus*, a group of large, arboreal pulmonate snails in the family Bulimulidae. *Orthalicus* occurs primarily in Central and South America. Two species occur in North America, *O. reses* and *O. floridensis* Pilsbry, both of which are restricted to South Florida. *Orthalicus reses* has two subspecies, *O. r. reses* and *O. r. nesodryas.* The Stock Island tree snail (*O. reses*) was first described by Say in 1830 based on a snail that was probably collected from Key West. That specimen was lost and the species was later described by Pilsbry (1946) using a snail collected from Stock Island.

Distribution

Pilsbry (1946) suggested the Stock Island tree snail arrived in Florida from Central America and the Caribbean shortly after the emergence of the Florida peninsula in the late Pleistocene. Snails that were sealed to floating tropical trees may have been cast ashore on the Florida peninsula by high winds and hurricanes. This form of dispersal has been suggested for both *Orthalicus* and *Liguus*, but the exact origin of these species is still in question. Craig (1972) suggested populations of *Orthalicus* arrived directly across the Gulf of Mexico from Central America, but the mode of transportation and whether dispersal occurred on a single or multiple occasions was not known. No one knows when the Stock Island tree snail arrived in the Lower Keys.

Historically, the Stock Island tree snail was believed to have a very limited distribution, being found only in tropical hardwood hammocks on Stock Island and Key West; although it may have been found in other hammock areas in the Lower Keys. Their distribution has since been artificially extended by collectors who have introduced them to Key Largo and the southernmost parts of the mainland. *Orthalicus reses nesodryas* has a broader range, distributed throughout the Keys from Sugarloaf Key north. *Orthalicus floridensis* is the only *Orthalicus* species to occur naturally on the mainland, and is also found in the Keys.

Habitat

Originally, the Stock Island tree snail occurred exclusively in hardwood hammocks of the Keys. The Stock Island tree snail survives best in hammocks with smooth-barked native trees that support relatively large amounts of lichens and algae. In the Keys, *Orthalicus* is limited to the higher portions of the islands that support hammock forests (minimum elevations of 5 to 11 feet).

Stock Island tree snail.
Original photograph by Beth Forys.

Lower Keys hammocks consist of thick forests of tropical trees and shrubs which grow in limestone, marl, and calcareous sand soils. Canopy trees include black ironwood (*Krugiodendron ferreum*), gumbo limbo (*Bursera simaruba*) Jamaican dogwood (*Piscidia piscipula*), mahogany (*Swietenia mahagoni*), pigeon plum (*Coccoloba diversifolia*), poisonwood (*Metopium toxiferum*), and strangler fig (*Ficus aurea*). Hammock understory contains torchwood (*Amyris elemifera*), milkbark (*Drypetes diversifolia*), wild coffee (*Psychotria nervosa*), marlberry (*Ardisia escallonioides*), stoppers (*Eugenia* sp.), soldierwood (*Colubrina elliptica*), crabwood (*Gymnanthes lucida*), and velvetseed (*Guettarda scabra*).

Larger trees are more likely to support more Stock Island tree snails than smaller trees probably because they provide the snails with an increased surface area for foraging (Deisler 1987). It is not known if Stock Island tree snails prefer certain tree types or species (Deisler 1987); however, Voss (1976) suggested tree snails generally prefer trees with smooth bark over trees with rough bark, because it would require less energy to crawl over smooth bark. Voss also believed Stock Island tree snails would prefer smooth bark because it would make it easier for them to form a secure mucous seal when they were aestivating, resulting in lower mortalities from dehydration or accidental dislodgement.

Stock Island tree snails are entirely arboreal except when they move to the forest floor for nesting or traveling. Hammocks that contain well-developed soils or leaf litter are important for nesting activity and dispersal. Essential factors affecting food availability are the light intensity and moisture content of the hammock habitat.

No data are available on minimal hammock size needed to support a viable population of tree snails. Suitable habitat would have to include an area large enough to provide for foraging and nesting requirements, as well as provide for the microclimate (air temperature and humidity) needed by the Stock Island tree snail. Preferences for edge or interior hammock have been observed in *Liguus* populations on Lignumvitae Key (Tuskes 1981). Age-class differences were seen where older individuals were found in the central mature hammock, while younger individuals were found more often along the edges of the hammock. Tuskes (1981) suggested this may be an adaptation of younger snails to move to the edge to escape competition from older snails. It is not known whether Stock Island tree snails prefer interior or edge hammock areas. Recent surveys of snails in Key Largo populations have shown higher numbers of snails along the edge of the hammock than in the interior, but this result may be affected by the differences in visibility during surveying.

Behavior

Stock Island tree snails are active mainly during the May through November wet season when breeding, feeding, and dispersion takes place. Dry periods (December through April) are spent in aestivation, in which the snail forms a tight sealed barrier between the aperture and a tree trunk or branch. Snails secrete a mucus seal that cements their shell to a tree to protect them from desiccation in the dry period. Snails may come out of aestivation briefly to feed during dry-season rains or go into aestivation during summer dry spells.

Reproduction

Stock Island tree snails are hermaphroditic and cross-fertilization is common. *Liguus* individuals are able to locate each other by following mucus trails (Voss 1976), and Stock Island tree snails likely do the same. They mate and nest in late summer and early fall during the wettest part of the rainy season. They lay approximately 15 eggs per clutch in a cavity that is dug into the soil humus layer, usually at the base of a tree, and take anywhere from 24 to 105 hours to deposit their eggs (Deisler 1987, McNeese 1989). The presence of this humus layer is essential for egg laying. The eggs hatch during the onset of the rains the following spring. Upon hatching the snails immediately proceed to climb adjacent trees. Most nesting snails appear to be approximately 2 to 3 years old and are estimated to live for up to 6 years, with 2.11 years being the mean age for the Stock Island population at the time of Deisler's study (1987). Tree snail age can be estimated by counting the number of dark "suture-like" lines resulting from pigment deposition during long dry spells (the dry season).

Foraging

The rate at which Stock Island tree snails grow is dependent upon the availability of food and how quickly their food is replenished after being grazed. Food regrowth is affected by the light intensity and moisture (canopy density and climate) of the hammock habitat. They feed on epiphytic growth on hardwood tree trunks, branches, and leaves. Little is known about the feeding habits or food preferences of the Stock Island tree snail. Probable food items include a variety of fungi, algae, and lichens found on many of the native hammock trees. Mixobacteria and some small mites may serve as a secondary food source. Feeding can occur anytime during the day or night with peak feeding activity occurring from late afternoon through the night to mid-morning and during or immediately after rainfall. Stock Island tree snails often follow a random twisting path that covers the entire bark surface, but will move in a straight line if surface moisture is abundant.

Relationship to Other Species

There are two other species of *Orthalicus* in the Florida Keys: *O. floridensis* and *O. reses nesodryas*. *O. floridensis*, the Florida tree snail, is the most widespread of the *Orthalicus* and has occurred historically throughout the Keys. *Orthalicus reses nesodryas* also apparently occurs throughout the Keys, being seen most often in the Lower and Middle Keys, from Sugarloaf Key north.

It is generally thought that the two subspecies of *O. reses* do not interbreed due to differences in their anatomy (Pilsbry 1946, FWS 1982, 1996). As discussed below, individuals of *O. reses* have been introduced to other areas of the Keys and the mainland, including areas where the other species of *Orthalicus* and *Liguus* are present.

Historically, the Stock Island tree snail did not have overlapping ranges with any of the current federally listed species. Due to their introduction into other habitats, Stock Island tree snails now share habitat with other listed species. Some snails have been introduced into habitat on Key Largo that contains several other federally protected species, including the eastern indigo snake (*Drymarchon corais couperi*), Key Largo cotton mouse (*Peromyscus gossypinus allapaticola*), Key Largo woodrat (*Neotoma floridana smalli),* and Schaus swallowtail butterfly (*Heraclides aristodemus ponceanus*). Snail populations that have been introduced into the Lower Keys now share habitat with the Key deer (*Odocoileus virginianus clavium*).

The effect of the introduction of snails to these habitats is believed to be minimal, but it is essential to monitor any potential changes in the flora and faunal composition as it relates to the presence of the Stock Island tree snail. The Stock Island tree snail now occurs in the native range of *O. r. nesodryas* and *O. floridensis*. The relationship between these species needs to be examined.

Status and Trends

The Stock Island tree snail was listed as threatened by the FWS on July 3, 1978 (43FR 28932) because of population decline, habitat destruction and modification, pesticide use, and over-collecting (FWS 1982). The Stock Island tree snail has, for the most part, been extirpated from its historic range due to a number of factors including habitat destruction, pesticide use, over-collecting, and predation by fire ants and black rats. Most of the hardwood hammocks that could serve as suitable habitat for the snail on Stock Island and Key West have been destroyed or severely altered by past human activities. Remnants of hammock that remain on these Keys tend to be small in size and low in quality due to disturbance, making them unsuitable for the tree snail.

As a result of unauthorized introduction efforts, the Stock Island tree snail presently occupies six areas outside its historic range. Sites at John Pennekamp Coral Reef State Park, Key Largo Hammock State Botanical Site, and the Everglades NP/Big Cypress Preserve area are publicly owned; however, the other three areas, located in south Key Largo subdivisions, Calusa Cove Camp Ground, and Monkey Jungle, are in private ownership and subject to human disturbance.

Status of Sites within Historic Range

Until surveys conducted in 1996, the Stock Island tree snail was not thought to occur within its historic range. The tree snail has been extirpated from Stock Island (McNeese 1997); but in 1996, snail populations were discovered in Key West.

Florida's population growth has been almost exponential since the late 1800s. In 1940, there were 12,927 people in Key West, constituting 95 percent of the population in Monroe County. By 1950, the population increased to 26,433, comprising over 90 percent of the Monroe County population. The population began to level off in the 1960s with only 71 percent of the population residing in Key West and only 52 percent (27,563) in 1970 (Simpson 1983). By this time, the hammock forests in Key West had been eliminated and there was no snail habitat remaining.

Museum collections have no records of Key West specimens beyond 1938 and Pilsbry (1946) concluded that the snail was extinct from Key West. Although two snails were transplanted into Indigenous Park in Key West in 1989, they have not been found since that time. Until 1996, other surveys confirmed a lack of sightings in Key West.

The population discovered in Key West in 1997 was located in a residential subdivision, along a small street near the center of Key West. Over 65 snails were counted in two large royal poinciana trees (*Delonix regia*) and approximately 30 were found on other vegetation including *Aralia* bushes and mango trees. Most of the snails were one to two years old. The fate of these snails is not certain because the trees are frequently trimmed by the City of Key West and there are reports of heavy collecting. The FWS is coordinating with the City of Key West to help establish management procedures to protect these snails.

The Stock Island tree snail population on Stock Island exhibited a rapid decline. Initial surveys in 1982 revealed between 214 to 321 individuals. This number rapidly decreased each year to the point where no snails exist on Stock Island today (McNeese 1997). The decline is related to the loss of habitat due to construction activities associated with the construction of the Key West Golf Course and the use of various pesticides and herbicides in the area. However, the Key West Botanical Gardens on Stock Island may provide adequate habitat for small numbers of tree snails and could serve as a re-introduction site with proper management.

Status of Occupied Sites Outside of Historic Range

Populations of Stock Island tree snails were established at six locations outside of the historical range. All areas were known to support Stock Island tree snails in the recent past; however, surveys conducted by FWS and GFC biologists in 1995 and 1996 revealed either a decline in populations or no observation of live snails. More intensive surveys are required to obtain reliable population trend and status data.

John Pennekamp Coral Reef State Park, Key Largo: Approximately 33 snails were placed here in 1993. By 1995, no snails were found. About three snails were released here in 1996, but surveys conducted shortly after that revealed no snails. The absence of snails suggests inability to adapt to the habitat, interference (*e.g.*, relocating, collecting) from snail collectors, or simply dispersion. The status of this population is considered to be declining, and possibly extirpated.

Key Largo Subdivisions, Key Largo: Due to the declining population of snails on Stock Island, collectors moved an unknown number of snails to several single family lots in various Key Largo subdivisions. In one known subdivision, several lots have snails present. In December 1995, one densely populated lot was cleared. Direct snail destruction and habitat removal resulted. The adjoining lot is also being planned for clearing. A FWS survey conducted in August 1996 on this lot revealed 72 snails present. Most of these snails were young (1 to 2 years old). A different lot in the same area contains over 50 snails, most of which are older snails (5+ years old). Although other lots have not been surveyed, snails may be present. The snails in these subdivisions face imminent threats from habitat destruction, illegal collecting, biocides, and mosquito spraying. The FWS is working with Monroe County to alleviate some of these threats. Additional surveys are necessary, but the status of the snails in this area is considered to be declining.

Crocodile Lake NWR/Key Largo Hammocks State Botanical Site, Key Largo: Several snails have been observed on both the Refuge and the State Botanical Site. Their presence is due to collectors moving them. Because thorough surveys have not been conducted, the status of these snails is unknown.

Calusa Cove Campground, Key Largo: Snails were introduced here by collectors because of the large amount of undisturbed suitable habitat. In past years, this area contained the largest population of snails. Surveys conducted in 1994 and 1995 showed a drastic reduction of live snails, and several dead shells at the base of trees. A brief survey in 1996 reported a few live snails and a few snail shells, but detailed surveys have not been conducted. Monitoring of this population is necessary to track changes in their status. This property is privately owned and currently listed on the Conservation and Recreation Lands list as a priority for purchase. Because surveys have reported a decrease in the number of snails, this population is considered to be declining.

Monkey Jungle, Miami: Monkey Jungle is managed as a tourist facility and the owner has no current plans to modify any of the hardwood habitat occupied by tree snails. However, ownership and/or management plans could change at any time. Although snails are known to occur here, the date of their introduction is not known. The habitat is very sparse, consisting of only a few small tree islands surrounded by asphalt, and the quality of the habitat is low. Researchers from the University of Florida surveyed this site in February 1992 and collected approximately 460 individuals for captive propagation experiments. Of those, only 200 survived, several of which were released in 1993 at Monkey Jungle. Between 180 to 195 eggs were hatched in 1993 at the University of Florida's laboratory, but the majority of them died.

Approximately five of those were still alive in 1996, four of which were released by researchers on John Pennekamp Coral Reef State Park property. Follow-up monitoring was not conducted, so the fate of those snails is unknown. The one remaining snail was released with other Stock Island tree snails by the FWS on public property and is currently being monitored. Although the Monkey Jungle habitat suffered considerable disturbance in 1992 from Hurricane Andrew, the snail population rebounded and continues to persist today. Surveys conducted in 1996 found at least 35 snails present at Monkey Jungle. The combined threat of free roaming monkeys and the disturbance of habitat by exotic vegetation is believed to be partially responsible for the continued decline in the status of these snails.

Everglades National Park (ENP) and Big Cypress Preserve: Snails were first introduced by collectors to a small area in ENP in the late 1980s. Between 1987 to 1994, the presence of snails was reported, but by 1995, surveys revealed the snails were no longer present. The disappearance of the snails from ENP may be due to a number of causes including over-collecting, hurricanes, exotics, competition, or inability to adapt to the surroundings. A population of snails has recently been reported in Big Cypress, but surveys are necessary to confirm this. The status of the populations in ENP and Big Cypress is considered to be declining or extirpated.

Since the Stock Island tree snail's original listing as a threatened species in 1978, its populations and its habitat have drastically declined. Snails once found on Stock Island, formerly the largest and most stable population, are now extinct. According to the definitions of the ESA, this species now qualifies for reclassification as an endangered species-"any species which is in danger of extinction throughout all or a significant portion of its range." If it were not for the population recently found in Key West, which is presumably a direct transplantation from Stock Island, the snail would be considered extinct from its entire historic range. The stability and protection of those populations outside of its historic range are extremely important and will be necessary for the persistence of this species.

Threats

The greatest threat to the Stock Island tree snail is the loss and modification of its habitat, although natural disasters, such as hurricanes and drought, can have a significant effect. Increased urbanization in the Keys has led to the destruction, fragmentation, and reduction in quality of habitat throughout the historic and present range. Because of its limited range, the Stock Island tree snail faces a high risk of extinction from habitat loss or a single, natural disaster.

Other threats include habitat loss, pesticide use, collecting, and predation by black rats, birds, raccoons, and fire ants (*Solenopsis invicta*). Fire ants are becoming more abundant in the Keys and hence an increasing threat to the Stock Island tree snail as well as other species. Tuskes (1981) observed fire ants killing *Liguus* snails, despite the snails' ability to ward off other ant species. Residential and commercial construction destroys habitat important to the tree snail. The areas that currently harbor populations of tree snails are small isolated tracts of land, which makes highly susceptible to the snails threats of habitat loss, fragmentation, and reduction in quality. Destruction of habitat reduces reproduction by disrupting hammock soils and leaf litter used as nest areas. Habitat fragmentation may destroy the microclimate (air temperature and humidity) important for feeding, shelter, and reproduction.

The use of pesticides on or near snail habitat can kill snails directly or alter behavior associated with feeding and reproduction. These effects decrease the likelihood of survival and recovery of the Stock Island tree snail in the wild. Urbanization within or near snail habitat promotes the establishment of black rats and fire ants that feed on snails.

Management

Efforts to manage the Stock Island tree snail have been complicated by two problems. First, since Deisler's 1987 study, little or no information has been collected or published about the life history of the Stock Island tree snail. What little information does exist is found in letters, memos, unreleased or incomplete data from researchers, and through conversations and speculations. Second, although the status of a few snail populations has been monitored over the years, the most difficult thing to monitor is how snail collectors and other parties have been moving this species to areas within and outside of its range. Although the relocation of snails to other areas may have protected the snails from extinction, it has complicated the management and protection of this species.

Relatively few section 7 consultations have been conducted for the Stock Island tree snail. In 1980, a Biological Opinion was completed that addressed Farmers Home Administration (FmHA) financing of the Florida Keys Aqueduct Authority (FKAA) pipeline improvements in the Keys. After reviewing effects of the FKAA pipeline, the FWS concluded the proposed action was likely to jeopardize the continued existence of the Stock Island tree snail, American crocodile, Key deer, and Schaus swallowtail butterfly. This opinion was based on the likelihood that pipeline improvements would result in a loss of habitat and an increase in human disturbance that would be detrimental to the mentioned species. As an alternative, the FmHA chose to exclude certain areas from water delivery. These loan conditions were subsequently accepted by the FKAA.

In September of 1998, the FWS provided funding to the Florida Audubon Society and the Key West Garden Club to restore tropical hardwood hammock and freshwater wetlands at the Key West Botanical Gardens on Stock Island. The project will occur on a 3-acre site and includes the removal of exotic vegetation, planting of native species, and relocation of snails from other populations back to the Gardens.

There have been several cases of alleged section 9 "take" violations in Key Largo. Both Federal and State Wildlife Officers are currently investigating these incidents. Management efforts are also in progress to coordinate more efficiently with Monroe County and the city of Key West. The FWS will be developing species information, digital maps, and conservation recommendations to help provide better protection for the snail.

In 1992, researchers from the University of Florida removed the last known remaining snails from Stock Island and began an attempt to maintain and breed snails in captivity (Emmel *et al*. 1992). The first few months of the captive propagation efforts appeared to be successful, with the snails showing signs of foraging and possible mating. Additional snails (>400) were removed from Monkey Jungle and brought into captivity, but approximately half of these snails died and the other half had to be released. Several other remaining captive snails also died. By 1996, only five to six snails were alive in captivity, all of which were returned to the wild. The cause of the unsuccessful effort to captively maintain and breed this species is not known, but it is attributed to the inability to imitate natural hammock conditions in the laboratory. Based on the inability to breed tree snails, the recovery team recommended stopping all captive propagation efforts and instead, focusing on protecting remaining living wild populations. Prior to additional propagation efforts, the recovery team recommended developing a plan that outlines specific criteria for propagating this species in captivity. Future propagation efforts should be done *in situ* in order to retain the conditions of the natural habitat (FWS 1996).

Literature Cited

Craig, A.K. 1972. Observations on the arboreal snail *Orthalicus floridensis*. Quarterly Journal of the Florida Academy of Sciences 35(1): 15-20.

Deisler, J.E. 1987. The ecology of the Stock Island tree snail, *Orthalicus reses reses* (Say). Bulletin Florida State Museum Biological Science 31(3): 107-145.

Deisler J.E. 1982. The Stock Island tree snail *Orthalicus reses reses* (Say). Pages 8-9 *in* R. Franz, ed. Rare and endangered biota of Florida, volume 6, invertebrates. University Press of Florida; Gainesville, Florida.

Emmel, T.C., P.J. Eliazar and D.L. Freberg. 1992. Captive propagation and restoration ecology of the endangered Stock Island tree snail, Quarterly Project Report. U.S. Fish and Wildlife Service, Unit Cooperative Agreement #14-16-0009-1544, Research Work Order #94; Gainesville, Florida.

McNeese, P.L. 1989. A proposal for the study of the Stock Island tree snail, *Orthalicus reses reses*, at its type locality. Monroe County Environmental Resources Department; Marathon, Florida.

McNeese, P.L. 1997. Survey of Key West and Stock Island for the Stock Island tree snail *Orthalicus reses reses*. Monroe County Environmental Resources Department; Marathon, Florida.

Pilsbry, H.A. 1946. Land Mollusca of North America (north of Mexico). Monograph Academy of Natural Science, Philadelphia 3[2(1)]: 1-520.

Simpson, L. 1983. The Island of Key Largo, Florida. Mayfield Printing Company; Mayfield, Kentucky.

Tuskes, P.M. 1981. Population structure and biology of *Liguus* tree snails on Lignumvitae Key, Florida. Nautilus 95(4): 162-169.

U.S. Fish and Wildlife Service [FWS]. 1996. Multispecies Recovery Team/Keys Group meeting, April 1996.

U.S. Fish and Wildlife Service [FWS]. 1982. Stock Island tree snail recovery plan. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Voss, R.S. 1976. Observations on the ecology of the Florida tree snail *Liguus fasciatus* (Muller). Nautilus 90: 65-69.

Recovery for the Stock Island Tree Snail

Orthalicus reses

Recovery Objective: DELIST the species once recovery criteria are met.

Recovery Criteria

Surveys conducted over the past 3 years indicate the Stock Island tree snail is threatened with extinction due to a loss of more than 90 percent of its habitat to urbanization and other anthropogenic factors such as over collecting and pesticide use. The objective of this recovery plan is to delist the Stock Island tree snail by protecting and managing its habitat in the Lower Keys, restoring potential habitat, increasing the size of populations, and establishing populations in the Lower Keys. This objective will be achieved when: further loss, fragmentation, or degradation of suitable, occupied habitat in the Lower Keys has been prevented; occupied habitat on priority acquisition lists for the Lower Keys is protected either through land acquisition or cooperative agreements; potential habitat on these protected lands is managed, restored, or rehabilitated to provide habitat for the Stock Island tree snail; four stable populations of the Stock Island tree snail are established throughout the Lower Keys. These populations will be considered demographically stable when they exhibit a stable age structure, have a rate of increase (r) equal to or greater than 0.0 as a 3-year running average for 14 years, and have at least a 95 percent probability of persistence for 100 years.

Species-level Recovery Actions

S1. Determine the distribution and status of the Stock Island tree snail. The distribution of the Stock Island tree snail has changed due to relocation activity by snail collectors. Past investigations have consisted of presence/absence surveys and thorough surveys are still needed. Conduct detailed surveys to determine the distribution and status of the Stock Island tree snail.

S1.1. Survey snail populations in the Lower Keys. Snails have been observed in several areas in the Lower Keys. Survey these areas to determine their status.

S1.1.1. Determine status of snails on Stock Island. The snail population on Stock Island has decreased dramatically since the 1980s and is now considered possibly extirpated. Conduct thorough surveys of Stock Island to determine if snails are present.

S1.1.2. Determine status of populations in Key West. In 1996, populations of snails were discovered in the City of Key West. Survey other areas in Key West to determine if snails are present.

S1.2. Survey snail populations in the Middle and Upper Keys.

S1.2.1. Determine the status of snails in Key Largo subdivisions and other areas in Key Largo. Several of the Key Largo subdivisions contain populations of snails, but this area has not been thoroughly surveyed. Survey other suitable areas within these subdivisions and throughout Key Largo.

S1.2.2. Determine status of snails present in Calusa Cove. Since 1994 there has been a reduction of the number of snails here. Survey this area to determine the status of snails.

S1.2.3. Determine status of snails in John Pennekamp Coral Reef State Park. Determine the status of snails that were placed here in 1993, 1994, and 1996.

S1.2.4. Determine status of snails in Crocodile Lake NWR/Key Largo Hammocks State Botanical Site, Key Largo. Several snails have been observed on both the Refuge and the State Botanical Site. Survey these areas to determine their status.

S1.3. Determine status of snails on mainland Florida.

S1.3.1. Determine the status of snails at Monkey Jungle. The number of snails observed here has varied over the years and recent surveys conducted in 1996 indicated a decline. Survey this area to determine the status of the snail population.

S1.3.2. Determine status of snails in Everglades National Park (ENP) and Big Cypress National Preserve (BCNP). Snails have been observed in ENP and possibly in BCNP. Survey these areas to determine if snails are present.

S1.4. Maintain and improve the GIS database for snail information. Maintain GIS database on the presence of snails and suitable habitat.

S2. Protect and enhance existing populations of Stock Island tree snail. The survival of the Stock Island tree snail is dependent upon the few remaining populations left in the wild. Active protection and management of this species and its habitat are essential for the snail's survival considering all significant populations are outside of the historic range.

S2.1. Assign a biologist responsible for implementing recovery actions for the threatened or endangered species of the Lower Keys. Recovery actions implemented to recover the Stock Island tree snail will benefit other threatened or endangered species in the Lower Florida Keys, including the Key deer, marsh rabbit, tree cactus, and silver rice rat. The number of actions that will be necessary to recover threatened or endangered species in the Lower Florida Keys will require the attention of a biologist dedicated specifically to addressing the recovery needs of these species.

S2.2. Conduct Stock Island tree snail reintroductions from wild populations. Relocation and reintroduction may be the only strategy to ensure the survival of the Stock Island tree snail. To recover this species it is necessary to establish and enhance populations within the historic range and relocate populations from private to public or protected lands.

S2.2.1. Develop a standard protocol for conducting, monitoring, and evaluating all reintroduction, translocation, and supplementation efforts of Stock Island tree snails using the IUCN/SSC Guidelines for Reintroductions..Develop criteria that determine the type of release to be conducted, evaluate and select release site, identify source and health of release stock, develop and monitor short-and long-term success indicators, and develop a policy on intervention. Ensure release sites are relatively free of threats, especially mosquito spraying, pesticides, and collecting prior to any release of snails.

S2.2.2. **Relocate snails to secure areas in the Lower Keys.** Relocate imperilled snail populations located outside of the historic range to one of the release sites described below or other appropriate secure areas in the historic range. Relocation of one population will be conducted over a period of at least 2 years to ensure relocation efforts are successful before relocating other populations. The FWS will conduct or oversee all relocations and develop a management plan for each relocation site selected.

Key West Botanical Garden (Garden), Stock Island-The Garden is within this species' historical range, was previously occupied by snails, and contains suitable vegetation for the snails. Historically, this site contained a large number of snails. Since 1988, no snails have been observed. The FWS is coordinating with the Garden and the Stock Island Golf Course to develop a restoration plan for the Garden. Continual management will be needed to ensure the snails survive. Direct effects may occur from pesticides and herbicides that are applied all around the periphery of the Garden by the Stock Island Golf Course, as well as from spraying for mosquito control. In addition, the remaining vegetation is not believed to be large enough to support a sustainable, self-sufficient population of snails.

Weapons Hammock, NAS, Key West-The Weapon's Hammock is within the Lower Keys historic range, contains suitable habitat, and is on Federal property. The FWS and GFC are coordinating with NAS to develop a relocation program. This site contains enough habitat to sustain a large stable population of snails.

National Key Deer Refuge-Several suitable sites are present within refuge boundaries. Snails currently exist here and can easily be augmented.

S2.2.3. **Monitor all reintroduced/relocated populations.** Develop protocol for monitoring the flora and fauna of reintroduction sites both before and after relocation of snails. Monitor to determine survival, growth, and reproductive success of introduced snails, as well as the effects of the snail's presence on other floral and faunal species.

S2.3. **Utilize Federal regulatory mechanisms for protection. Conduct section 7 consultations on Federal activities.** Federal agencies whose actions may affect the Stock Island tree snail include COE, FEMA, Federal Housing Administration, and the Rural Electrification Administration. Determine jeopardy thresholds for the tree snail. Estimate and evaluate the type of Federal activities over the next 20 years that are likely to cause jeopardy and determine threshold levels for the total population. Coordinate with Law Enforcement to prevent take under section 9. Identify what activities could result in take of tree snails, such as tree trimming and collecting.

S2.4. **Provide information about Stock Island tree snails to Federal, State, county, and city agencies.** Distribute information regarding the presence of Stock Island tree snails, their protection under the ESA, and ways to minimize impacts. Non-Federal agencies that may influence the Stock Island Tree Snail include DEP, DCA, GFC, Department of Agriculture and Consumer Services, Monroe County Mosquito Control, Florida Keys Aqueduct Authority, and Monroe County Government.

S2.5. **Reduce disturbance or mortality of Stock Island tree snails.** Human-related mortality must be minimized if the subspecies is to survive.

S2.5.1. **Minimize the impact of mosquito spraying and other herbicide use.** Coordinate with public and private entities to avoid directly spraying snails with pesticides and herbicides, especially mosquito spray.

S2.5.2. **Reduce illegal collecting.** Unauthorized snail collecting and relocating continues to be a considerable problem. Inform snail collectors to eliminate these impacts. Coordinate with law enforcement to increase enforcement efforts.

S2.5.3. **Minimize the impacts of native and non-native predators to snails.** Black rats, birds, raccoons, and fire ants are known predators of tree snails. Reduce the negative impacts of these species.

S2.5.4. **Develop a Memorandum of Agreement (MOA) with Monroe County to ensure their actions do not harm this species.** The highest priority area for snail protection is Key Largo, especially subdivisions in North Key Largo. Many of the populations are in private ownership and will require coordination with Monroe County and the homeowner. Provide information to Monroe County on where snails are located and means to protect tree snails. Ensure mosquito spraying and pesticide use does not impact the snail. Areas with snails present should be identified and the necessary permitting offices and homeowners notified to avoid any negative impact on the snail. The ultimate goal is to relocate any imperilled snails from private property to secure sites in the Lower Keys over the next 5 years.

S3. **Determine if the total population size is large enough to prevent functional extinction and genetic extinction.** As of July 1997, the population contains a minimum of 225 individuals distributed in several disjunct sites. Conduct a model to predict the persistence of this species. Determine what effective population size is necessary to prevent inbreeding depression.

S3.1. **Investigate the genetics of snails from different sites.** Determine if the relocation and manipulation of tree snails has affected its genetic makeup.

S3.2. **Identify factors that affect the persistence of the Stock Island tree snail.** Determine what aspect of this species' ecology makes it most vulnerable to extinction (*e.g.*, predation, lack of food, inability to find mate). Investigate relationships between nuisance competitors or predators and determine their effect on the snail's persistence.

S3.3. **Determine the number of subpopulations necessary for a stable or increasing population**. There are approximately eight different areas that have small disjunct groups.

S3.3.1. **Determine subpopulations most vulnerable to extinction.** Snail populations on private property are extremely vulnerable to loss of habitat and pesticide use, especially those located in the Key Largo subdivisions. Evaluate the vulnerability of snail populations to prioritize relocation needs and recovery actions.

S3.3.2. **Determine the necessary number of subpopulations and level of exchange that will enable the snail to persist for 100 years.**

S3.4. **Determine what constitutes a stable age structure and group size for the snail.** Recent surveys have shown representatives from several age classes, suggesting some reproduction is occurring, but it is not known what comprises a stable age structure or group size. Investigate these parameters to determine what constitutes a stable population structure.

S4. **Monitor Stock Island tree snail populations.** Although some presence/absence surveys have been conducted over the years, long-term monitoring of snail populations has not been conducted. Develop a monitoring protocol to survey the status of snail populations.

S4.1. **Develop methods to monitor presence of snails, population dynamics, and habitat use.**

S4.2. **Develop methods to monitor demographic parameters.** Monitor sex ratios, age class structure, survivorship, age of dispersal, and dispersal distance of snail populations.

S4.3. **Monitor the success of tree snail reintroduction efforts.** Develop monitoring guidelines as part of the reintroduction protocol and monitor all relocated snails.

S4.4. **Determine the effects of relocated snails on flora and fauna already present.** The effect of the introduction of snails to these habitats is believed to be minimal, but it is essential to monitor any potential changes in the floral and faunal composition as it relates to presence of the Stock Island tree snail.

S5. **Increase public awareness and stewardship for the Stock Island tree snail.** Inform public, especially snail collectors, about the snail, its protections under Federal law, and its importance as an integral part of the ecosystem. Inform homeowners on how to protect and manage snails on their property. Coordinate with snail collectors to reduce the amount of illegal snail collecting or manipulation, including the unauthorized relocation of snails to various locations.

S6. **Establish reclassification and delisting criteria.** Develop measurable reclassification criteria that reflect a stable or increasing population including: total population size, number of subpopulations, age structure, habitat condition and availability, and level of threats. Evaluate and monitor the tree snail's status in relation to reclassification criteria.

Habitat-level Recovery Actions

H1. **Prevent degradation of existing habitat.** Habitat loss is the main reason for the Stock Island tree snail's decline. Most of the hardwood hammocks that could serve as suitable habitat for the snail on Stock Island and Key West have been destroyed or severely altered by past human activities. Remnants of hammock that remain on these Keys tend to be small in size and low in quality. Habitat degradation can decrease the number of snails an area can support, contributing to the overall probability of extinction.

H1.1. Acquire Stock Island tree snail habitat. Acquire tree snail habitat essential to the snail's survival. Develop an acquisition plan based on habitat in greatest need, while taking into consideration the need for reserve design (*e.g.*, corridors, core areas).

H1.1.1. Continue Federal acquisition efforts. Continue to acquire habitat within the Crocodile Lake NWR, National Key Deer Refuge, and Great White Heron NWR boundaries.

H1.1.2. Support State acquisition efforts. Continue to support the acquisition of State lands including Key Largo Botanical Site and programs such as Florida's Conservation and Recreation Lands (CARL) program.

H1.1.3. Support and encourage land acquisition by non-governmental agencies. Habitat not listed for Federal, State, or county acquisition may become available for private purchase and management by such organizations as The Nature Conservancy and Florida Keys Land Trust.

H1.2. Protect and manage Stock Island tree snail habitat. Most tree snail sites are small in size and are near high concentrations of people. Protect and manage these areas to prevent negative impacts on the tree snail. Loss or damage of these habitats may destroy the microclimate (air temperature and humidity) important for food, shelter, and reproduction.

H1.2.1. Protect tree snails on public lands. Develop a habitat management plan that outlines priority habitat for acquisition and methods to protect, restore, and minimize impacts on tree snails and their habitat. Acquire and incorporate snail habitat into Federal, State, and county land protection systems. Manage public lands for exotics, off-road vehicles, dumping, exotic predators, and vehicular traffic. Identify and minimize other causes of tree snail death or mortality on public lands.

H1.2.2. Protect tree snails on private lands where feasible. When opportunities exist, protect tree snail populations on private land through acquisition, conservation easements or agreements, and landowner outreach. Develop agreements between the FWS and private landowners to minimize impacts such as certain landscaping techniques and exotics.

H1.2.3. Protect important core areas. Several tree snail populations are concentrated in a few small areas. Protect the habitat of these core areas by coordinating with the appropriate parties to avoid any negative impact on the snail.

H1.2.4. Remove invasive exotic vegetation. Continue efforts to remove exotic plants in snail habitat, especially Australian pine (*Casuarina equisetifolia*) and Brazilian pepper (*Schinus terebinthifolius*).

H1.2.5. Prevent habitat areas from being modified. Prevent excessive watering of ornamental plants and lawns which modifies snail behavior by bringing snails out of aestivation during the winter months and exposing them to cold temperatures and desiccation.

H1.2.6. Restrict access to snail habitat on public lands. Restrict access to occupied snail habitat to prevent death and injury, over-collecting, and unauthorized relocations.

H2. Restore suitable tree snail habitat. Habitat degradation from housing and road construction, trash dumping, and invasive exotic vegetation have altered the integrity of hardwood hammock forests and facilitated the ability of exotic plants and animals to invade native habitats. As a result, habitat quality and availability have been reduced or eliminated. Identify and prioritize areas in greatest need of habitat restoration and conduct restoration efforts.

H2.1. Restore both occupied and unoccupied tree snail habitat that has been degraded to optimal conditions.

H2.2. Improve habitat by planting or encouraging native plant species. Plant native vegetation in areas that have been scarified or degraded. Encourage homeowners to plant native plant species important to the snail.

H2.3. Create habitat by refilling and revegetating areas that have been destroyed or altered.

H2.4. Restore snail habitat at Key West Botanical Garden. Remove exotic vegetation and manage habitat so snails can be relocated here according to the relocation protocol.

H3. Conduct research to determine habitat needs for the Stock Island tree snail. Specific habitat requirements are not known, but tree snails are believed to need an area large enough to provide for foraging and reproductive requirements as well as provide adequate temperature and humidity conditions.

H3.1. Investigate how snails utilize different habitat components for survival (*e.g.*, food, shelter, and reproduction). Hammocks that contain well-developed soils or leaf litter are important for reproduction and dispersal. Light intensity and moisture content influence the amount of food available. Investigate how snails rely on various habitat components.

H3.1.1. Determine minimum area required for snails to persist. No data are available on minimal hammock size needed to support a viable population of tree snails.

H3.1.2. Compare and characterize occupied tree snail habitat. Tropical hardwood hammocks in the Keys tend to have higher species diversity and structural variety than hammocks on the mainland. Several differences also exist between hammocks in the Upper Keys as compared to the Lower Keys (*e.g.*, elevation, canopy height, soil, etc.). Investigate habitat components and compare among the different snail populations (*i.e.*, compare habitat of Key West, Key Largo, and Monkey Jungle habitat).

H3.1.3. Investigate the effect of habitat change on the snail's persistence. Investigate how variables such as disturbance of leaf litter, soil composition, light intensity, and moisture content affect the ability of an area to support snails.

H3.1.4. Investigate the use of ornamental and exotic vegetation as food and habitat. Several Stock Island tree snails have been observed on a variety of ornamental and exotic plants. Determine the level of use and quality of habitat these plants provide.

H3.2. Determine an index of habitat fragmentation. It is not known whether Stock Island tree snails prefer interior or edge hammock areas. Recent surveys of snails in Key Largo populations have shown higher numbers of snails along the edge of the hammock than in the interior, but this may be an artifact of where snails were originally released by collectors. Investigate the effects of fragmentation on the snail's use of its habitat.

H3.2.1. Investigate movement patterns and the spatial utilization of habitat to determine important core areas.

H3.2.2. Determine if the amount and configuration of remaining occupied and unoccupied habitat is sufficient to support a stable population of Stock Island tree snails.

H4. Monitor the status of Stock Island tree snail habitat. Conduct yearly monitoring evaluations of the status of the tree snail's habitat. Overlay habitat quality with GIS mappings of habitat locations, including what patches are being altered or lost each year. Monitor through GIS the availability of snail habitat by updating the loss or change of habitat due to residential or commercial construction. Monitor habitat of relocated populations.

H5. Increase public awareness of Stock Island tree snail habitat and instill stewardship. Conduct workshops with the public to inform private landowners on how to establish safe management practices to protect and enhance snail habitat. Encourage private landowners to remove exotics, plant native vegetation, and restore disturbed areas. Prepare literature to provide information regarding the snail's habitat and ways to protect and conserve it.

The Plants

Thirty-five federally-threatened or endangered plant species occur in South Florida. A majority of these species occur only in South Florida, predominantly in the Lake Wales Ridge and Pine Rockland communities. Other species, like *Chrysopsis floridana* and *Warea amplexifolia* occur in South Florida but are also distributed elsewhere in Florida. None of these species occur outside of the State of Florida.

This section of the Multi-Species Recovery Plan contains accounts of the threatened and endangered plant species of South Florida. These accounts detail the biology, ecology, status and trends, and management for each of these plant species. Each account is followed by the recovery needs of the species which outline the recovery objective, criteria that will be used to determine when the objective has been achieved (called recovery criteria), and the tasks that will be necessary to achieve the objective (called recovery actions). The recovery tasks are divided into species-level recovery actions that address species-specific conservation and biology, and habitat-level recovery actions that address habitat management, conservation, and restoration needs for the species. The habitat-level recovery actions form the basis for the multi-species/community-level restoration actions that are provided in the community accounts. For species that have distributions outside of South Florida, there are two sections to the recovery objective; the first is the recovery objective for the species throughout its range; the second section identifies how South Florida will contribute to the species' recovery throughout its range.

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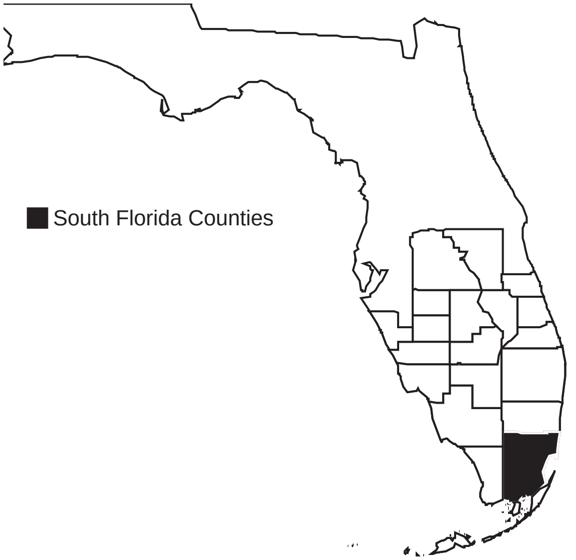
Crenulate Lead-plant

Amorpha crenulata (=*herbacea* Walt. var. *crenulata* (Rydberg) Isley)

Federal Status:	**Endangered (July 18, 1985)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of the crenulate lead-plant.



The crenulate lead-plant is a perennial, deciduous shrub that inhabits marl prairies and wet pine rocklands in a small area of Miami-Dade County. This pine rockland community is maintained by periodic fires. Greater than 98 percent habitat loss, fire suppression, drainage, and exotic pest plant invasions threaten the species, which was federaly listed as endangered on July 18, 1985.

This account represents a revision of the existing recovery plan for the crenulate lead-plant (FWS 1988).

Description

Also known as the Miami lead-plant, *A. crenulata* is a rhizomatous, deciduous, perennial shrub that grows to 1.5 m in height and is endemic to Miami-Dade County, Florida (DOT 1997). The branches of this plant are red/purple, and contain 25 to 33 leaflets borne on leaves that are 0 to 15 cm long, with petioles 1 cm long or less. The crenulate leaflets are grey/green above, paler and glandular dotted below, and 5 to 11 cm long. The racemes are terminal, 15 to 20 cm long, solitary or in clusters of two to three. The 8 mm-long flowers are held in loose clusters. The calyx is dark green or purplish, 3.2 to 4.0 mm long with the upper half glandular dotted. The showy white standard flower is 5.2 mm long, and 4.2 mm wide with long exerted stamens. The fruit is 6 to11 mm long, laterally compressed, and glandular dotted on the upper two-thirds. The seeds produced in the fruit are 5 mm long and compressed.

Taxonomy

The crenulate lead-plant was described by Rydberg in 1919, citing his type specimen as J.K. Small and Percy Wilson #1898, May 9, 1904, "In hammocks, between Coconut Grove and Cutler" (New York Botanical Garden herbarium). Small (1933) followed this treatment. Isley (1986, 1990) argues that *A. crenulata* is an isolated variant of *A. herbacea*, distinguished only by the presence of crenulate leaf margins.

He published the new combination as *A. herbacea* Walt. var. c*renulata* (Rydberg) Isley (Isley 1986). Synonyms: *Amorpha crenulata* Rydberg, *A. herbacea* auct. non. Walt.

Distribution

The crenulate lead-plant is known from a 20- square- mile area from Coral Gables to Kendall, Miami-Dade County. Its historic range was only slightly greater, extending south to Cutler (based on an entry of *Amorpha caroliniana* on an unpublished plant list by John Kunkol Small of Addison Hammock), and north to the Little River in northeast Miami-Dade County. This range encompasses an area 5 miles east to west and 12 miles north to south. Currently, eight locations are known for this plant (D. Garvue, *et al.* Fairchild Tropical Garden, personal communication 1998).

Habitat

The crenulate lead-plant occurs in plant communities that were historically associated with seasonally hydrated soils and frequent burning, including wet pinelands, transverse glades, and hammock edges. It can be found growing in poorly-drained Opalocka sands within pine rocklands or in wet prairies with Opalocka-rock outcrop complex soils. It requires open sun to partial shade. The type specimen (Small and Wilson #1898) cites the habitat as "In hammocks." No recent collections have been seen from within hardwood hammocks. Many of Small's specimen labels were pre-printed with habitat data and some species were collected and labeled as occurring in hammocks that were actually collected in habitats outside hammocks. It may be that crenulate lead-plant was never collected in hammocks.

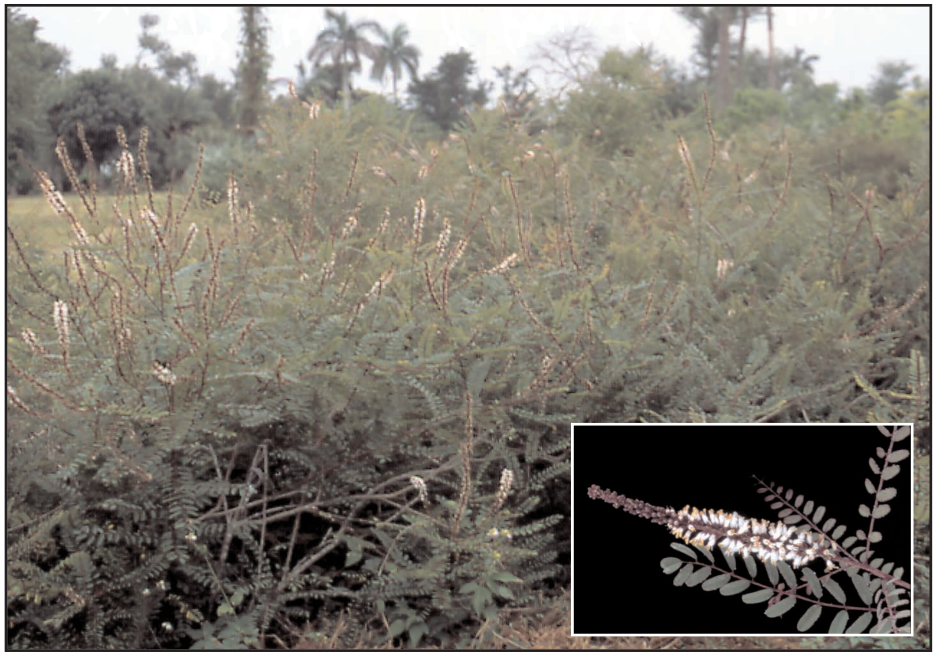
Reproduction

Little is known of the life history of crenulate lead-plant. In two years of life-history monitoring of one population, no seedlings were observed. Plants showed little to no growth and flowered primarily following human disturbance. Crenulate lead-plant is semi-deciduous, about 70 percent of plants losing most or all leaves between December and February. Pollinators or dispensers have not been observed (DERM 1993). New sprouts, when observed, have been identified as primarily adventitious roots (DOT 1997). In addition, the viability of germplasm is not known (DOT 1997). This species is relatively easy to cultivate, indicating that the lack of reproduction in the wild may not be due to a lack of viable seeds (A. Herndon, personal communication 1998).

Relationship to Other Species

The pine rocklands where the crenulate lead-plant occurs are characterized by a canopy of slash pine (*Pinus elliottii* var. *densa*), a shrub canopy of saw palmetto (*Serenoa repens*), wax myrtle (*Myrica cerifera*), poison wood (*Metopium toxiferum*), and willow bustic (*Sideroxylon salicifolium*). Common

Crenulate lead-plant.
Original photographs by Steve Shirah.



herbaceous associates include *Schizachyrium sanguineum* var. *sanguineum, S .gracile, Aster adnatus,* and *Acalypha chamaedrifolia.* Other typical species associates of crenulate lead-plant include cabbage palm (*Sabal palmetto*), southern sumac (*Rhus copallina* var. *leucantha*), bluestem (*Schizachyrium rhizomatum*), wild-petunia (*Ruellia succulenta*), *Paspalum monostachyum,* and blueheart (*Buchnera americana*).

Status and Trends

Crenulate lead-plant was listed as endangered on July 18, 1985 because of the loss of pine rockland habitat from residential and commercial development. Vegetative communities within the historic range of crenulate lead-plant have been almost entirely eliminated by agricultural, urban, and commercial development. The transverse glades where crenulate lead-plant occurs were among the first areas in Miami-Dade County to be farmed, because their marl soils were better suited to conversion to farmland than the limestone rock of the adjacent pinelands. By 1984, 98 to 99 percent of Miami-Dade County pine rocklands had been destroyed, and development continues today. In addition, fire suppression, invasion by exotic plant species, and drainage threaten the survival of the crenulate lead-plant. Flowering and seed production may not occur as a result of these disruptions.

The crenulate lead-plant is currently known from eight sites (D. Garvue *et al.,* Fairchild Tropical Garden, personal communication 1998). Four sites are located in parks owned by the Miami-Dade County Parks Department. One site is located in the Bird Road railroad right-of-way. The three remaining sites are located in the vicinity of Snapper Creek and Old Cutler Road, Red Road and SW 8th Street, and Schoolhouse Road. Fairchild Tropical Gardens, in cooperation with Miami-Dade County Parks Department, has also introduced a population of 108 plants to a pine rockland habitat adjacent to Addison Hammock at the Charles Deering Estates (J. Maguire, Miami-Dade County Parks Department, personal communication, 1998 and D. Garvue, *et al.* Fairchild Tropical Garden, personal communication 1998).

Management

The pine rocklands of Miami-Dade County have evolved and adapted to frequent fires (Snyder *et al.* 1990). Presumably, crenulate lead-plant is also adapted to the natural fire regime of the pine rocklands, but this has never been studied. Under two to three decades of fire suppression these areas mature into tropical hammocks with a few pines in the canopy (Snyder *et al.* 1990). A fundamental question concerning the fire ecology of pine rocklands is how frequently they should burn and at what season of the year. Snyder *et a*l. (1990) inferred the historic burn regimes by looking at the time it takes for the herbaceous layer to be excluded from an area by shading (maximum time between fire) and the point when enough fuel is available to carry a fire (minimum time between fires). The minimum fire regime they found was 2 to 3 years and the maximum was 15 years. This wide range in fire frequencies would result in different forest structures and dynamics. This would suggest that a mosaic of burns should be used in the management of pine rocklands. Presently the recommended burn regime is 3 to 7 years with summer fires generally preferred to winter. Summer fires are preferred because most of the lightning strikes (the historical cause of fires) occur in the summer months. In areas where fires have been suppressed for many years, the reintroduction of fire may have to be done in step-wise fashion. In some areas it may even include manual removal of some fuel to prevent a very hot fire and reduce residual smoke problems. Any prescribed fire management should include a monitoring program to determine the effectiveness of the prescription. Monitoring should include the species distribution (presence/absence), quantitative assessment of abundance or condition, and demographic information on individual plants (Menges and Gordon 1996). There should also be a component to the monitoring that captures the health of the community and species that occur in association with crenulate lead-plant. Fairchild Tropical Garden is currently doing such monitoring at several sites where crenulate lead-plant occurs (C. Kernan, Fairchild Tropical Garden, personal communication 1996).

The hydric component of historic pine rocklands may have been a contributing factor to seed recruitment and seedling success. Rehydration experiments should be undertaken to see if they positively influence plant recruitment (J. Maguire, Miami-Dade County Parks Department, personal communication 1998).

Invasive exotic species, especially *Schinus terebinthifolius*, *Neyraudia reynaudiana*, and Queensland umbrella (*Schefflera actinophylla*) threaten crenulate lead-plant and other rare pine rockland plants, but this has never been studied or documented. The control of exotic species in the pine rocklands is a very important part of maintaining the habitat, although it can be very costly once exotics are established in an area. In most cases the control of exotics includes the use of manual labor, herbicides, and prescribed fire. In heavily infested areas removal is very labor intensive, with a field crew pulling the plants by hand or cutting. Prescribed fire and herbicide treatments are then used to control the exotic plants. Once an area is cleared of exotics, proper management can reduce the costs of control and maintain the site relatively exotic free.

The management of pine rocklands in Miami-Dade County is complicated because most of the remaining habitat occurs in small fragmented areas bordered by urban development. Areas surrounding managed pine rocklands that have exotic species can act as a seed source for exotics to continue to invade the pine rockland. To effectively control invasive exotics, an active strategy is needed. This includes a multi-lingual outreach program in Miami-Dade County stressing the importance of prescribed fire management and invasive exotic control.

Literature Cited

Florida Department of Transportation. 1997. Technical memorandum: endangered and threatened species assessment for State Road 90/Tamiami Trail/S.W. 8 Street from S.R. 826/Palmetto Expressway to S.W. 27 Avenue, Miami-Dade County, Florida. Florida Department of Transportation District Six; Miami, Florida.

Garvue, D., C. Kernan, and J. Kornegay. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30. 1998.

Herndon, A. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30. 1998.

Isley, Duane. 1986. Notes about Psoralea sensu auct. *Amorpha, Baptisia, Sesbania*, and *Chamaecrista* (Leguminosae) in the southeastern U.S. Sida 11(4):429-440.

Isley, Duane. 1990. Vascular flora of the southeastern U.S. volume 3, part 2. Leguminosae (Fabaceae). University of North Carolina Press; Chapel Hill, North Carolina.

Kernan, C. 1996. Visit to Fairchild Tropical Garden research center. December 12, 1996.

Maguire, J. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30. 1998.

Menges, E.S. and Gordon, D.R. 1996. Three levels of monitoring intensity for rare plant species. Natural Areas Journal. 16:227-237.

Metro-Dade County Department of Environmental Resources Management, (DERM).1994. Management plan for the Richmond pine rocklands. Final Report to the U.S. Fish and Wildlife Service under Grant 14-16-0004-92-987.

Metro-Dade County Department of Environmental Resources Management, (DERM). 1993. Annual report on endangered pine rockland plant species. Final Report to the U.S. Fish and Wildlife Service under Grant 14-16-0004-91-951.

Rydberg, P.A. 1919. *Amorpha*. North American Flora.

Small, J.K. 1933. Manual of the southeastern flora. University of North Carolina Press; Chapel Hill, North Carolina.

Snyder, J.R., A. Herndon, and W.B. Robertson, Jr. 1990. South Florida rockland. Pages 230-274 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

U.S. Fish and Wildlife Service [FWS]. 1988. Recovery plan for five pine rockland plant species. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Recovery for the Crenulate Lead-plant

Amorpha crenulata (=*herbacea* Walt. var. *crenulata* (Rydberg) Isley)

Recovery Objective: PREVENT extinction, then stabilize.

Recovery Criteria

Amorpha crenulata will, most likely, never reach a level at which reclassification could be possible. The objective of this recovery plan is to increase existing populations and prevent extinction. *Amorpha.crenulata* may be considered stabilized when existing populations, within the historic range, are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression. These sites must also be managed to maintain areas to support *A. crenulata*. Monitoring programs should demonstrate that populations of *A. crenulata* on these sites support sufficient population sizes, are distributed throughout the historic range, and are sexually or vegetatively reproducing a sufficient rate to maintain the population. Further, seedling establishment must be documented in the wild.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be developed if new information identifies ways of re-establishing populations of this species to expand its distribution within its historic range.

Species-level Recovery Actions

S1. Conduct surveys to determine distribution of crenulate lead-plants. Crenulate lead-plants on county-owned pine rockland sites have been thoroughly surveyed in Miami-Dade County. However, other populations may be noted during pine rockland purchase and restoration program implementation. Fire may eliminate litter concealing listed species, or enable seeds in the seed bank to germinate. For that reason, pine rocklands that did not contain listed species when unmanaged should be resurveyed after fire events.

S2. Protect and enhance existing populations. It is imperative for the stabilization of crenulate lead-plants that additional populations not be lost. The existing populations should be mapped, including obtaining GPS coordinates and developing GIS coverage. Herbarium voucher specimens should be collected and archived for all populations.

S2.1. Augment natural populations of crenulate lead-plants, where appropriate. Because many pine rockland plant species are in a precarious situation, *ex situ* collections exist for *A. crenulata*. If possible, additional collections should be established. These may be used to cultivate this species and augment sparse populations in protected areas. Experiments with reintroductions will be useful in the future, and could be essential for the recovery of the crenulate lead-plant species.

S2.2. Continue work with *ex situ* propagation and seed storage banks. Seeds should continue to be banked for all the listed species possible, and should be identified precisely as to collection location. Fairchild Tropical Garden has submitted seeds of crenulate lead-plant to the National Seed Storage Laboratory at Fort Collins, Colorado to initiate studies on seed storage potential and methods. Propagation and cultivation methods have been developed by Fairchild Tropical Garden (D. Garvue *et al.,* Fairchild Tropical Garden, personal communication 1998).

S2.3. Continue to identify potential reintroduction sites and reintroduce pine rockland plants, where appropriate. Sites identified as suitable for reintroduction within the known historic range should be surveyed and prepared to receive plants. Federal lands under proper management regimes may be good recipient sites. These sites should receive reintroduction stock.

S2.4. Enforce available protective legislation. State, Federal, and local regulations should be used to protect the pine rockland ecosystem and the listed plants. Use existing standard monitoring protocols.

S2.4.1. Initiate section 7 consultation when applicable. Section 7 of the ESA applies to Federal activities which might impact listed species, especially on Federal lands (former Richmond Naval Air Station lands, and the Perrine USDA site).

S2.4.2. Encourage implementation of management plans. Federal agencies are obligated under section 7(a)(1) of the ESA to conduct positive conservation programs for the benefit of listed species. Implementation of the Richmond Pine Rocklands Management Plan (DERM 1994) would constitute such a positive conservation program and should be implemented by the U.S. Army Reserve Center in Perrine, the U.S. Coast Guard site, the Department of Correction's Miami Correctional Center, and any other Federal agency property owner in this area.

S2.4.3. Continue to enforce take and trade prohibitions. The listed pine rockland plants are protected by take and trade restrictions of the ESA and the Preservation of Native Flora Act. Since these are inconspicuous plants, take and trade are nonexistent or uncommon.

S3. Collect biological information important to species recovery. Additional information on the ecology and life history of pine rockland plants needs to be collected. Determine size and viability of all populations. Known populations of the listed pine rockland plants should be evaluated. Population viability needs to be investigated and determined for each listed plant species.

S3.1. Continue to investigate and refine the habitat needs of crenulate lead-plant.

S3.2. Determine population size and viability of all populations.

S3.3. Study the reproductive biology of crenulate lead-plant.

S3.4. Conduct genetic studies to document the genetic variation within and between populations.

S3.5. Study the fire ecology of *A. crenulata.*

S3.6. Study the response of crenulate lead-plant to habitat management treatments.

S4. Develop standardized monitoring. Standardized monitoring based upon the protocols developed by FNAI should be used for pine rockland species in order to determine the effect of management actions on these species and make the date compatible to existing databases.

S4.1. Collect existing and historical data, and place in a central location. Contact former researchers for historical data, gather information from herbaria and museums, and contact all present researchers to compile data and place in GIS database in South Florida Ecosystem Office. This location will allow all researchers access to both historic and current data, and provide the FWS with a means to monitor the success of recovery tasks.

S4.2. Monitor status and success of all populations; **change management practices if so indicated**. Because of the varying vegetation conditions and fire histories, different management may be required at different pine rockland sites. Different prescribed burn intervals may be necessary for best results. Intervals should be adjusted over the years to promote pine re-establishment and hardwood reduction.

S4.3. Convene a meeting of researchers and land managers. A meeting of current pine rockland researchers and land managers would enable the FWS to locate information sources, and begin the process of compiling those data. The meeting would also afford cooperators an opportunity to discuss monitoring and management procedures and set realistic species level goals.

S4.4. Monitor reintroduction success and modify procedures as necessary. Plant reintroductions should be monitored to determine the success of the procedure. The goal of reintroduction should be to establish a viable population. Management of the reintroduction sites should be modified as necessary to improve results. The experimental outplanting conducted by Fairchild Tropical Garden at the Deering Estate should continue to be monitored for information that will help design future reintroductions.

S5. Continue to provide public information about pine rocklands and their unique flora. Public support will increase the chances of recovery for pine rockland species. Informational and educational materials have been produced. DERM and Miami-Dade County Parks and Recreation Department's Natural Areas Management have developed flyers, displays, newsletters, and press releases, and have held workshops with the general public. Organizations best able to carry out information and education programs include: Metropolitan Miami-Dade County Parks and Recreation Department, the Florida Native Plant Society, Everglades National Park, and Miami-Dade County DERM. Support of local press coverage should continue. DERM has developed a web page that will also aid in disseminating information about this endangered plant community to the public.

Habitat-level Recovery Actions

H1. Develop a GIS database on all listed pine rockland species and their habitats, and distribute the database to researchers, land managers, and conservationists.

H1.1. Assess the available GIS data.

H1.2. Create coverage of population locations.

H1.3. Acquire recent imageries of the sites.

H1.4. Distribute the coverage.

H2. Continue to protect and prevent degradation of pine rockland plant habitat. The decline of the five listed pine rockland plants is due to the almost complete elimination or alteration of pine rocklands in South Florida. Without protection and proper management, the remaining rockland sites will be developed or will deteriorate.

H2.1. Protect pine rockland habitat. Acquisition of remaining private sites may be the only effective way to protect or conserve pine rockland habitat. Miami-Dade County's Environmentally Endangered Lands program and the State of Florida's CARL program have acquired over 450 acres of pine rocklands since 1990. It should be noted that public lands may still be subject to development for recreational, maintenance, or other purposes. Such disturbances, unless carefully planned, may directly destroy pine rockland and may secondarily result in exotic plant infestations as well as destructive human uses.

H2.2. Protect or acquire privately owned sites. Less than fee simple acquisition should be used, where appropriate, as an alternative means of protecting pine rockland habitat. Covenants, as provided for under Miami-Dade County regulations, provide tax incentives for private landowners to protect pine rockland sites. A site owned by Florida Power and Light Company may be maintained through cooperation with that utility. This avenue of protection should also be pursued with the railroad company that owns the site of one of the three largest populations. Miami-Dade County DERM is developing a private lands management and grant program for pine rockland protection and restoration. This program should be implemented as soon as possible.

H2.3. Implement additional management to meet habitat needs.

H2.3.1. Eliminate human-caused degradation. Preventing trash dumping or other destructive human activities in pine rocklands is important. In order to accomplish this task, fencing and access restrictions may be necessary. Mowing of the crenulate lead-plant habitat at A.D. Park should be halted and the habitat allowed to recover.

H2.3.2. Control invasive plant species, particularly exotics. Burma reed, or persistent hardwoods need to be controlled and may require special techniques including herbicide, fire, mechanical, and hand clearing at most sites. Other management needs indicated by ongoing research should also be implemented. The two crenulate lead-plants at Matheson Hammock are being suppressed by a closed hardwood canopy.

H3. Restore areas to suitable habitat.

H3.1. Eliminate physical degradation of habitat and restore to optimal conditions. Physical degradation of pine rocklands continues to occur, and hurricane Andrew in 1992 killed most of the adult pines in the Richmond tract and elsewhere in Miami-Dade County. The continued degradation of these areas should be curtailed and restoration of uneven-aged pine stands should be undertaken. Tubelings, or direct seeding experiments may be used to accomplish this task. In order to use direct seeding techniques, collection of local pine seeds must continue.

H3.2. **Develop best management practices for pine rocklands.** This would include development of fire management strategies that would best benefit pine rockland species. Studies specifically on the response of crenulate lead-plant to alternative fire management treatments should be implemented.

H3.3. **Implement necessary management.** Without active fire and exotic plant management, pine rocklands will continue to disappear or degrade. Because of the highly fragmented and restricted nature of remaining pine rocklands, intensive management may be necessary at many of the remaining sites. The existing management plans for sites that include crenulate lead-plant should continue to be implemented and modified as necessary for the benefit of this species.

H3.4. **Continue to expand prescribed burning.** Prescribe fire should be conducted at crenulate lead-plant sites at the appropriate times of the year to lower fuel loads. Growing season burns should then be employed after fuel levels are under control. The response to crenulate lead-plant to prescribed burns should be studied. Special consideration must be incorporated when planning prescribed fire for pine rocklands invaded by Burma reed. Incorporate appropriate actions to minimize additional Burma reed infestations in these areas. Due to the highly urbanized lands surrounding some of the pine rockland sites, burning involves risks of smoke damage and annoyance, or worse, losing control of the fire. The Florida Division of Forestry has expertise in carrying out controlled burns in Miami-Dade County, and should be contacted to assist with burns. Fire management is necessary for all Federal and County lands. Miami-Dade County is composing a Strategic Fire Management Plan. This plan should be implemented once approved.

H4. Monitor habitat and ecological processes.

H4.1. **Monitor sites with crenulate lead-plant populations to determine success.** A protocol developed by Fairchild Tropical Garden for monitoring the plant communities at crenulate lead-plant sites should be implemented.

H4.2. **Investigate fire history and incorporate into management strategies.** Look at fire history for pine rocklands in Miami-Dade County, incorporate into GIS database and analyze relative to healthy populations. This exercise will provide adequate information on fire history and intervals in urbanized and non-urbanized settings and enable assessment of the appropriateness of proposed management regimes in Miami-Dade County.

H4.3 **Rehydrate soils where feasible.** A monitoring protocol should be developed and implemented that examines the relationship between hydric soils and the recruitment and survival of seedlings at these sites.

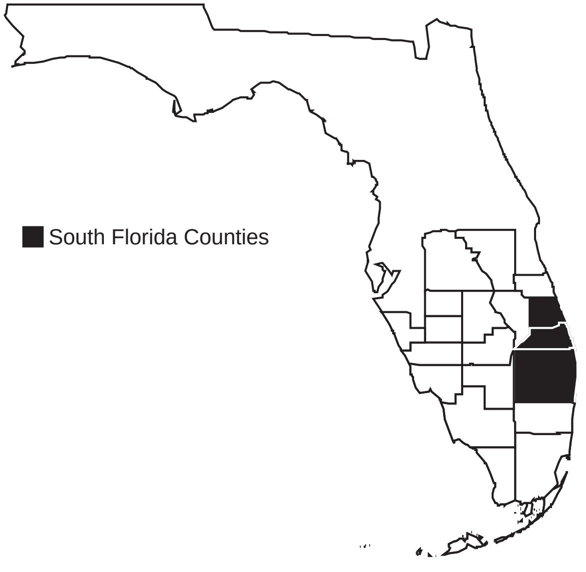
H5. Continue implementation of the fire education program and modify as necessary any fire management education program that has been developed. Future modifications to this program may include tri-lingual language (Spanish, English, and Haitian Creole).

Four-petal Pawpaw

Asimina tetramera Small

Federal Status:	**Endangered (Sept 26, 1986)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of the four-petal pawpaw.



Asimina tetramera, the four-petal pawpaw, is an aromatic shrub belonging to the Annonaceae or custard apple family. This pawpaw is found in coastal sand pine scrub habitats in Martin and Palm Beach counties in southeast Florida. Much of the sand pine scrub habitat has been destroyed and converted for residential housing and commercial activities. This declining species continues to be threatened by further loss of habitat.

This account represents a revision of the existing recovery plan for the four-petal pawpaw (FWS 1988).

Description

Asimina tetramera is a 1 to 3 m tall aromatic shrub that has one to several stems arising from a deep taproot. Leaves are oblong to oblanceolate, 5 to 10 cm long, arranged alternately on the stem, and are yellow-green to deep green. The leaves are narrow at the base (A. Cox, Florida International University, personal communication 1995), have broadly acute or blunt tips, and lack stipules.

The flowers are maroon and fetid. They occur singly in the leaf axil; however, if the plant is burned or damaged, two or three flowers may develop. Perianth parts are typically in whorls of three, but may vary. The petals usually form whorls. The stamens are spirally arranged on an elevated torus or ball-shaped receptacle, surrounding one to many separate carpels. After fertilization, the receptacle expands as fruit develops.

The fruit is an aggregate of developing carpels, or monocarps, on the expanding receptacle. The monocarps are indehiscent and berry-like. An individual flower may produce from one to eight monocarps with one to nine seeds each (A. Cox, Florida International University, personal communication 1995). The fruit are oblong and greenish-yellow, emitting a banana-like aroma when ripe (A. Cox, Florida International University, personal communication 1995). The laterally flattened seeds are dark brown and shiny (Austin and Tatje 1979, Kral 1983).

Many flowers of *A. tetramera* are four-merous, with sepals, inner petals and outer petals arranged in groups of four (Kral 1960). Some flowers may have a combination of three- and four-merous parts. Four-merous flowers are more common on *A. tetramera* than on the other *Asimina*.

Taxonomy

The four-petal pawpaw was discovered at Rio, Florida, in 1924 and subsequently named *Pityothamnus tetramerus* (Small 1926, 1933). However, the new genus was rejected by other taxonomists (Kral 1960). According to Kral (1960), *Asimina tetramera* is grouped with *A. pygmaea*, *A. longifolia*, and *A. nashii*. These species have several common characteristics, including flower development on new growth, sparsely and omentulose young shoots, and glabrous petioles, peduncles and leaf surfaces.

Kral (1960) concluded *A. tetramera* more closely related to *A. pygmaea* than to the other *Asimina* species based on floral similarities. Both species have strongly recurved inner petals, are maroon, have a pungent aroma and flower between April and July. However, several differences separate these two species: the gynoecium of *A. tetramera* is larger than *A. pygmaea*, adult plants of *A. tetramera* are larger than adult plants of *A. pygmaea*, and *A. tetramera* is limited to sand pine scrub ridges in Martin and Palm Beach counties, while *A. pygmaea* occurs in mesic slash pine or long leaf pine habitats and savannas.

Distribution

Historically, *A. tetramera* occurred in sand pine scrub habitat on the coastal dune system in Martin and northern Palm Beach counties (Kral 1960). Most of the suitable habitat in the historic range of this species has been destroyed or converted. At present, the species is only found north of Palm Beach Gardens (A. Cox, Florida International University, personal communication 1996a) to the Savannas State Reserve in Martin County and in a few locations in northern St. Lucie County (Figure 1).

Habitat

Asimina tetramera is found only in sand pine scrub vegetation on old, coastal dunes (Austin and Tatje 1979). The species grows in excessively-drained, quartz sand of both the Paola and the St. Lucie soil series (Austin *et al*. 1980; A. Cox, Florida International University, personal communication 1995); however, it shows a preference for the Paola soils (Farnsworth, 1988).

Asimina tetramera is found in various seral stages of sand pine scrub, ranging from open [no canopy] to mature [closed canopy] (A. Cox, Florida International University, personal communication 1997). *A. tetramera* is adapted to infrequent, intense fires, perhaps every 20 to 80 years (FWS 1988). Abundant flowering and fruitset occur in years following fire and diminish with maturation of the community and subsequent canopy closure (A. Cox, Florida International University, personal communication 1996b).

Four-petal pawpaw.
Original drawing by Ann Murray; original flower photograph by Steve Shirah.

Reproduction

Reproduction in *A. tetramera* is sexual. The perfect flowers open before all the parts are fully developed, and mature from the base of the stem toward the developing tip. They are protogynous, meaning that the stigmatic surface becomes receptive before anther maturation and pollen release. The petals fall from the flowers within one day of pollen release, and carpel development and receptacle enlargement follow successful pollination and fertilization. Flowers that are not pollinated fall soon after pollen release (A. Cox, Florida International University, personal communication 1995).

Beetles are the most likely pollinators, although Dipterans (flies), Hymenopterans (wasps), and other insects have been observed visiting flowers. Gopher tortoises (*Gopherus polyphemus*), and small mammals such as the Florida mouse (*Podomys floridanus*) (Jones 1989) eat the fleshy fruit and may disperse seeds. Ingestion by animals is not necessary for seed germination (A. Cox, Florida International University, personal communication 1998).

Asimina tetramera seeds germinate from September to March. Old, stored, or dried seeds will not germinate (FWS 1988, A. Cox, Florida International University, personal communication 1995). Germination may take from 1 to 8 months after the seed is planted. The root system establishes several months before shoot emergence, and two to seven leaves are produced the first year (A. Cox, Florida International University, personal communication 1996b).

Asimina tetramera plants are deciduous, or partly so, with new leaves emerging in April and continuing to develop into summer. Buds are borne in the axils of the leaves as shoots develop. Flowers occur on new growth, and flower maturation proceeds from the base of the shoot toward the tip. Damaged stems sprout, producing new growth and may flower as late as September (A. Cox, Florida International University, personal communication 1995). Flowering peaks in April and May, and continues throughout the summer, with fruit ripening in 2 to 3 months (A. Cox, Florida International University, personal communication 1995).

Relationship to Other Species

The four-petal pawpaw occurs with sand pine (*Pinus clausa*) and scrub oaks (*Quercus myrtifolia, Q. geminata, Q. chapmanii*), which may shade *A. tetramera* in areas where fire has been excluded. However, *A. tetramera* is not extirpated by shading but the internodes elongate, the leaves become larger, and flowering is reduced. *Asimina tetramera* is found in association with rosemary (*Ceratiola ericoides*), saw palmetto (*Serenoa repens*), wax myrtle (*Myrica cerifera*), shiny blueberry (*Vaccinium myrsinites*), and other scrub species (Austin and Tatje 1979).

Female zebra swallowtail butterflies (*Eurytides marcellus*) lay their eggs on new growth of *Asimina* species. Developing larvae eat the leaves and flowers and may damage developing shoots (Damman 1987, 1989). The damage may encourage new growth throughout the summer and extend the breeding season of the butterflies (A. Cox, Florida International University, personal communication 1996a).

A shelf fungus (*Phylloporia frutica*) invades *A. tetramera* at sites of injury close to the ground and the fruiting bodies appear at branch junctions of the plant. Field observations indicate this does not kill the pawpaw, since new shoot growth frequently occurs below the fruiting body. However, plants with fungus may have reduced flowering and fruit set (A. Cox, Florida International University, personal communication 1995).

Status and Trends

Asimina tetramera was listed as endangered because the majority of its habitat has been lost to urban development (51 FR 34419). It now exists in fragmented populations within the historic range. Continued urban expansion is eradicating those few plants still left on unprotected private lands (FWS 1988).

Early surveys of *A. tetramera* placed the population at approximately 100 individuals (Austin and Tatje 1979). However, a 1988 Florida Natural Areas Inventory (FNAI) survey found *A. tetramera* on 16 sites in Palm Beach and Martin counties and located between 800 to 900 individual shrubs (Farnsworth 1988). The additional shrubs found in the survey do not represent a population increase, they were additional populations that were not previously located (A. Cox, Florida International University, personal communication 1996a). More recent survey efforts on two protected parcels in Palm Beach County located additional plants after prescribed fire had thinned vegetation and provided greater access to likely *A. tetramera* habitat (S. Farnsworth, Palm Beach County Department of Environmental Resource Management, personal communication 1998) . The population is believed to be declining (FWS 1990), although this will need to be verified by additional surveys and monitoring (A. Cox, Florida International University, personal communication 1996b).

Most *A. tetramera* populations currently exist on protected sites. In Martin County these include Jonathan Dickinson SP and Savannas State Reserve. In Palm Beach County *A. tetramera* is found in Carlin Park, Juno Beach Park, a proposed (unnamed) park, Juno Hills and Jupiter Ridge natural areas, BLM's Jupiter Inlet tract, and the Florida Power and Light headquarters office grounds. Although there many of the known localities for this species are protected, the species may not be adequately preserved in the northern part of its range, as only four plants in this region lie on protected land.

Of the protected areas, Jonathan Dickinson SP is the largest site in Martin County, with 220 plants. The proposed park with 224 plants is the largest site in Palm Beach County (A. Cox, Florida International University, personal communication 1996a).

Management

Individuals of *A. tetramera* plants appear to be long-lived and are not affected by occasional freezes. Above-ground growth is lost periodically to fire, and other natural conditions; however, the plants resprout from the rootcrown just below ground (Kral 1960). In addition, the new stems produce flowers and fruits more vigorously than older stems. The optimum frequency of fire has not been determined (Austin *et al.* 1980, FWS 1988, Kral 1983).

Maintaining the coastal scrub habitats that support *A. tetramera* is essential to its survival. Research is in progress at Jonathan Dickinson SP to determine the response of *A. tetramera* to prescribed fire and alternative methods of management, such as chopping and biomass removal (A. Cox, Florida International University, personal communication 1996b). This research may yield information relating to the fire frequency, alternatives to fire, and the reproductive responses of *A. tetramera* to these management applications. Research is also in progress to determine the population trend of this species (A. Cox, Florida International University, personal communication 1996b).

At present, sites in Palm Beach and Martin counties in private ownership could be destroyed. Several sites in Martin County should be purchased, especially a large site in Jensen Beach. If these lands were acquired, *A. tetramera* populations would then be preserved in the northern, central and southern portions of the existing range.

Literature Cited

Austin, D.F., B.E. Tatje, and C.E. Nauman. 1980. Status report on *Asimina tetramera.* Unpublished report prepared for: U.S. Fish and Wildlife Service, Endangered Species Field Station; Jacksonville, Florida.

Austin, D.F., and B.E. Tatje. 1979. Four-petal pawpaw. Pages 5-6 in D.B. Ward, ed. Rare and endangered biota of Florida, vol. 5: plants. University Presses of Florida; Gainesville, Florida.

Cox, A. 1995. Letter. 28 September 1995.

Cox, A. 1996a. Letter. 29 February 1996.

Cox, A. 1996b. Letter. 02 October 1996.

Cox, A. 1997. Telephone conversation. 16 January 1997.

Cox, A. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30, 1998.

Damman, H. 1987. Leaf quality and enemy avoidance by the larvae of a pyralid moth. Ecology 68(1):88-97.

Damman, H. 1989. Facilitative interactions between two lepidopteran herbivores of *Asimina*. Oecologia 78:214-219.

Farnsworth, S. 1988. Summary four-petaled pawpaw report. Unpublished report. Florida Natural Areas Inventory; Tallahassee, Florida.

Farnsworth, S. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 1998.

Jones, C.A. 1989. First record of pawpaw consumption by the Florida mouse. Florida Scientist 52(1):7.

Kral, R. 1960. A revision of *Asimina* and *Deeringothamnus* (Annonaceae). Brittonia 12:233-278.

Kral, R. 1983. *Asimina tetramera*. Pp. 448-451 *in* A report on some rare, threatened, or endangered forest-related vascular plants of the south. U.S. Department of Agriculture Forest Service, Southern Region. Technical publication R8-TP2; Atlanta, Georgia.

Small, J.K. 1926. A new pawpaw from Florida. Torreya 26:56.

Small, J.K. 1933. Manual of the southeastern flora. J.K. Small; New York, New York.

U.S. Fish and Wildlife Service. 1988. Recovery plan for three Florida pawpaws. U.S. Fish and Wildlife Service; Atlanta, Georgia.

U.S. Fish and Wildlife Service. 1990. Report to Congress: Endangered and threatened species recovery program. U.S. Department of the Interior, Fish and Wildlife Service; Washington, D.C.

Recovery for the Four-petal Pawpaw

Asimina tetramera Small

Recovery Objective: **RECLASSIFY** to threatened.

Recovery Criteria

Asimina tetramera may be reclassified from endangered to threatened when enough demographic data are available to determine the appropriate numbers of self-sustaining populations and sites needed to ensure 20 to 90 percent probability of persistence for 100 years; when sites within the historic range of *A. tetramera* are adequately protected from further habitat loss, degradation, and fragmentation; when these sites are managed to maintain the coastal sand pine scrub communities to support *A. tetramera*; and when monitoring programs demonstrate that these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed periodically based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. **Determine current distribution of *A. tetramera*.** Some portions of *A. tetramera*'s range have been well surveyed yet a total distribution has not been ascertained for this species. A thorough survey is needed to determine the distribution for this species.

S1.1. **Conduct surveys for additional populations of *A. tetramera*.**

S1.1.1. **Continue surveys in Palm Beach and Martin counties.** Although the range of this species has been surveyed, sites may still be located that have *A. tetramera* populations.

S1.1.2. **Continue surveys on protected lands.** New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. **Maintain distribution of known populations and suitable habitat in GIS database.** Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate with the Florida Natural Areas Inventory to update their database.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Atlantic Coastal Ridge has been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. Acquire or otherwise protect privately-owned habitat through acquisition, conservation easements, or agreements with landowners.

S2.2. Protect populations of *A. tetramera* on public lands. Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. Use local or regional planning to protect habitat. Utilize available Regional and county planning processes to encourage protection of suitable, unoccupied, and occupied habitat of *A. tetramera*.

S2.4. Continue *ex situ* conservation. *Ex situ* collecting can preserve genetic diversity, preventing loss of the species, and determine ecological characteristics and habitat management needs. These collections will be instrumental in the recovery of *A. tetramera*. Since long-term seed storage is impossible for this species, cultivated populations are very important. *Asimina tetramera* is easily grown from seed, but cannot be grown from cuttings. Seeds should be periodically planted to maintain populations for study and to be used as seed sources for reintroduction.

S2.5. Enforce available protective measures. Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *A. tetramera* occurs.

S2.5.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. Enforce take and trade prohibitions. This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from state lands.

S2.6. Augment natural populations of *A. tetramera.* Augmentation of populations on protected land is appropriate because there is little prospect for protecting additional sites.

S2.6.1. Establish a protocol for reintroduction. Records for source plants, techniques for establishing new populations, and protocols for monitoring are needed.

S2.6.2. Locate potential (re)introduction sites. Survey habitat within the historic range of *A. tetramera* and identify protected lands, both public and private, that will be suitable for (re)introduction.

S2.6.3. (Re)introduce plants to protected sites. Plant seeds from nearby stable populations to re-establish plants in suitable habitat.

S3. Continue research on life history characteristics of *A. tetramera*. To effectively recover this species more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality. Observations of the relationship of flowering to fire, pollination, seed production, and seedling biology will help to guide reintroduction efforts.

S3.2. Once demographic data are known, conduct a population viability and risk assessment analysis to determine the number of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *A. tetramera*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring will provide information contributing to a better understanding of population increases or declines for each site. Population monitoring should be in relation to various habitat managment practices. Site-specific management guidelines should be provided to land managers. Close coordination among land managers is essential to develop appropriate management techniques.

S3.4. Assess feasibility of relocating *A. tetramera*. Removing plants threatened with destruction has only been marginally successful. Information on transplant techniques and plant survival is needed to assess whether transplanting should be pursued in the future. Seeds should be collected from reproductive plants and planted on reintroduction sites.

S4. Monitor existing populations of *A. tetramera*.

S4.1. Develop monitoring protocol to assess population trends for *A. tetramera*.

S4.1.1. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival, and mortality. Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. Monitor the effects of various land management actions on *A. tetramera*. Assess any changes in demographic characteristics of *A. tetramera* in response to land management activities, such as prescribed fire, exotic plant control, *etc*.

S4.2. Develop a quantitative description of the population structure of *A. tetramera*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) may prove helpful in future management.

S4.3. Monitor introduced plants. Monitoring of reintroduced plants will be essential for assessing the status of new plants and their contribution to the population as a whole. Compare adult survival, seed production, germination rates, seed survival, seedling survival, and growth rates between transplanted plants and natural plants. Where monitoring indicates that the introduction has been unsuccessful, reevaluate protocol and methodology.

S5. Provide public information about *A. tetramera*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *A. tetramera* and other rare species requires self-sustaining, secure, natural populations in existing native scrub habitat.

S6. Establish delisting criteria. Once reclassification is achieved, research and monitoring results may provide data necessary to develop delisting criteria.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there are two protected sites in Martin County and eight protected sites in Palm Beach County.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *A. tetramera* populations by preventing damage by off-road vehicle use, prohibiting seed collection, and providing proper management of habitat, including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and an integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. The scrub is naturally made up of a heterogeneous matrix of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible. *A. tetramera* appears to benefit from burning at irregular intervals of several decades or more.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not major threats in sand pine scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *A. tetramera*.

H1.2.3. Control access to areas where listed plants are growing. Trampling and off-road vehicles can severely threaten individual populations. Fencing may be needed for some sites, and clearing around individual *A. tetramera* plants has been suggested.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. **Restore natural fire regime.** Long periods without fire and too frequent fires may shift the species composition and alter the structure of scrub habitats. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites seed banks may exist that could include other rare endemic species.

H2.2. **Enhance sites with native plant species.** Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. On these sites, seed banks may exist for other rare endemic species, but if fire has been excluded for too long or applied too often, seed banks may not be present. Although *Asimina tetramera* does not have a seed bank, areas of unburned vegetation may provide refugia for *A. tetramera* seed dispersal by small animals.

H3. **Continue habitat-level research projects.** A current study at Jonathan Dickinson State Park is looking at the response of *A. tetramera* to various land management practices, such as prescribed fire regimes, mechanical chopping, and biomass removal. Researchers are hoping to provide answers to optimal disturbance interval, under conditions which mechanical alternatives will work, and the reproductive responses of *A. tetramera* to management applications.

H4. **Monitor habitat/ecological processes.** Monitor the effects of land management actions, such as prescribed fire, mechanical disturbance, *etc*., on the habitats where *A. tetramera* occurs.

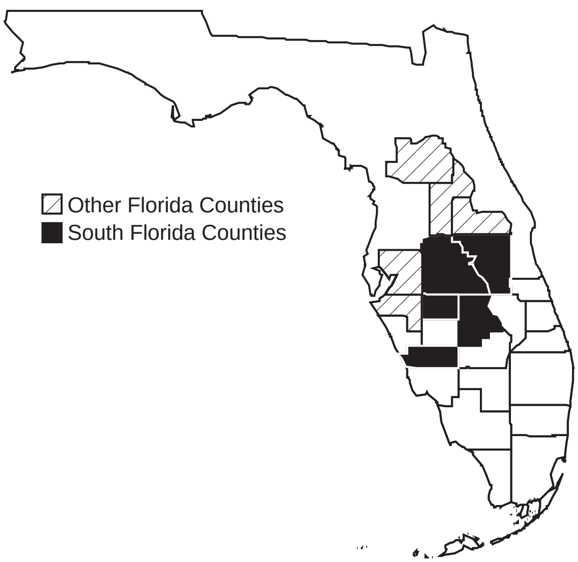
H5. **Provide public information about xeric vegetative communities and their unique biota**. Educational efforts, especially those conducted by private conservation organizations, have been successful in providing important information about xeric plant communities to the public. The State's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations and others such as the Florida Park Service, the Florida Native Plant Society, and local garden clubs play crucial roles in increasing public appreciation of xeric plant communities and *A. tetramera*.

Florida Bonamia

Bonamia grandiflora (A.Gray) Heller

Federal Status:	**Threatened (November 2, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status: Contribution (May 1999)	
Geographic Coverage: South Florida	

Figure 1. County distribution of the Florida bonamia.



Bonamia grandiflora is a member of the morning glory family (Convolvulaceae), and is the only species of its genus in the continental Unitd States. This endemic scrub, with its large, attractive flower, is found only on scrub areas of central and South Florida. Destruction of Florida's scrub habitat for residential housing and agricultural expansion has dramatically reduced the size and number of *B. grandiflora*'s population, resulting in its Federal listing as a threatened species.

This account represents South Florida's contribution to the existing recovery plan for the Florida bonamia (FWS 1996).

Description

Bonamia grandiflora is a perennial vine with appressed hairs and long prostrate stems a meter or more in length. It has a long, relatively slender tap root. The leathery sessile or subsessile leaves are up to 4 cm in length and ovate in shape. The flowers are solitary and sessile in the leaf axils. The funnel-shaped corolla is 7 to 10 cm long and 7 to 8 cm across. It has a deep blue or bluish-purple color with a white throat. The flowers open in the morning and are wilted by early afternoon (G. Romano, University of Florida, personal communication 1996). The fruits are capsules, normally containing four seeds. The seeds are smoothish, pale brown or greenish-brown, 5 to 8 mm long, and oblong (G. Romano, University of Florida, personal communication 1995). The outer face is convex, and the inner two faces are flat, forming an angle (Wunderlin *et al*. 1980). *B. grandiflora* is the only morning glory vine found in scrub areas with a large blue flower (Wunderlin *et al.* 1980), but could be confused with *Stylisma villosa*.

Taxonomy

Bonamia grandiflora was originally named by Asa Gray in 1880 as *Breweria grandiflora.* In 1897, Hans Hallier transferred it to the genus *Bonamia.* There have been no other taxonomic treatments of the species since then (Myint and Ward 1968).

Distribution

Bonamia grandiflora formerly occurred in central Florida from Volusia and Marion counties south to Highlands and Charlotte counties (Wunderlin *et al*. 1980). The plant was historically collected in Sarasota, Manatee, and Volusia counties in 1878, 1916, and 1900, respectively (Wunderlin *et al*. 1980). It is currently found in Charlotte, Hardee, Highlands, Hillsborough, Lake, Manatee, Marion, Orange, Osceola, and Polk counties (FWS 1996) (Figure 1).

Habitat

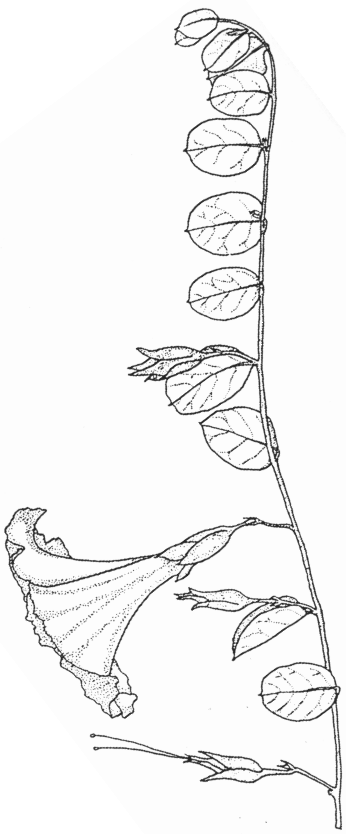
Bonamia grandiflora is a scrub endemic of central Florida. All of its known populations occur within or near scrub or on the edge of scrub habitat in the white sands associated with the ancient Pleistocene dune systems of the central ridge system (Ward 1979). These sands are of the St. Lucie-Paola complex, highly porous, acidic (4.5 to 6.0) and containing few nutrients (Wunderlin *et al.* 1980). This substrate is associated with a sand pine scrub vegetation consisting of evergreen scrub oak (*Quercus myrtifolia* and *Q. germinata*) and sand pine *(Pinus clausa*) with openings between the trees and shrubs occupied by lichens and herbs. The openings are cleared by infrequent fires or by mechanical disturbance. *Bonamia grandiflora* is also known to live in disturbed areas near roadways and clearings caused by logging operations (50 FR 42068). This species is not found on altered soils such as the clay applied to logging roads (Miller 1989).

As the scrub community reaches maturity, encroachment and shading from overstory pines and oaks cause the decline of this species as well as other associated endemics (Wunderlin *et al.* 1980). It seems that this species prefers an open canopy in full sunlight in order to avoid competition from the surrounding shrubs. For example, in Ocala NF, the *Bonamia* grows in a variety of growth stages of sand pine, but flowers profusely only in the open, sunny conditions of regeneration stands, and sparsely if at all in older stands.

Reproduction

Bonamia grandiflora grows for 3 or more years (50 FR 42068, Wunderlin *et al.* 1980), flowering from spring to summer (Small 1933). It has a mixed mating system; it is highly self-compatible, it can self-pollinate, and it can produce seeds without fertilization (G. Romano, University of Florida, personal communication 1998). Pollinators are essential, however, to ensure substantial seed production by self- as well as cross-fertilization. *Bonamia grandiflora* shows some inbreeding depression in selfed fruits and seeds but it does not appear to be enough to hinder the present populations (G. Romano, University of Florida, personal communication 1998). The seeds of *Bonamia* become dormant, but may not require dormancy to germinate, particularly if the seeds are planted immediately. Hartnett and Richardson (1989) observed that populations of this species have large seed banks of dormant seeds, mostly within 1 cm of the surface, distributed rather homogeneously, with no relation to the distribution of mature plants. The seedlings germinate throughout the summer until September.

Florida bonamia.
Original drawing by Bruce Edward Tatje; original flower photograph by Steve Shirah.



The necessity of fire for germination has not been studied; however, germination occurs on sites with sparse vegetation that have not burned recently (G. Romano, University of Florida, personal communication 1996).

Seedling survival rates are not known but are currently being investigated (G. Romano, University of Florida, personal communication 1996). Due to the nature of *Bonamia*'s growth, identifying seedlings from older individuals' stems that are actually connected to other stems below-ground can be difficult. However, it is possible to distinguish these two life phases. Hartnett and Richardson (1989) excavated several plants and found that the clumps of prostrate stems seen at the surface are all connected to a "large central and somewhat woody rootstock." They had no difficulty distinguishing such well-established older individuals from young single-stem plants that had grown from seed.

According to Hartnett and Richardson (1989), fire stimulates seed production and germination as well as regrowth from clonal stems. The first season after a fire, clonal stem production is the greatest and then declines. However, seed production is greatest during the second season after a fire. The lag is probably due to the increased energy needed for regrowth following fire; seed production is postponed to conserve energy. New seed production replaces the seed banks that are often destroyed by fire.

Relationship to Other Species

Federally listed species found in association with *B. grandiflora* are the Highlands scrub hypericum (*Hypericum cumulicola)*, papery whitlow-wort (*Paronychia chartacea*), and the scrub plum (*Prunus geniculata*) in Highlands and Polk counties. The scrub lupine (*Lupinus aridorum*) is associated with *B. grandiflora* in Orange County (50 FR 42068).

Status and Trends

Bonamia grandiflora was federally listed as threatened on November 2, 1987, due to habitat destruction, excessive collection, and habitat degradation due to invasive exotics, off-road vehicles, and lack of proper management (52 FR 42068). By the time of listing, much of its suitable habitat had been destroyed. In Highlands County, about 64 percent of the xeric vegetation (scrub, scrubby flatwoods, and southern ridge sandhills) present before settlement was destroyed by 1981, and an additional 10 percent of the xeric vegetation was moderately disturbed, primarily by construction of roads for housing subdivisions (Peroni and Abrahamson 1985). Remaining tracts of scrub are rapidly being developed for citrus groves and housing. Habitat destruction is similar in Polk County, the leading county in the state for citrus production (Fernals 1981). Farther north, most of the former habitat of the plant in northwest Osceola, western Orange, and central Lake counties has been converted to agricultural or urban uses. The five known sites for the plant in Orange County are all on small remnants of scrub vegetation or vacant lots surrounded by houses or orange groves west and southwest of Orlando, one of the fastest growing urban areas in the United States. Because *B. grandiflora* is limited to small areas of scrub surrounded by residential housing and cultivated lands, habitat destruction or degradation often occurs because of trash dumping, invasion by exotics and weeds (*e.g*. cogon grass, *Imperata* sp.) and off-road vehicle use.

Bonamia grandiflora is dependent on the sunny cleared areas left by periodic fires or physical disturbance (52 FR 42068). Historically, lightning fires swept through the scrub and surrounding communities, burning large tracts of land. Today, fragmentation of habitat and fire suppression have interrupted the natural burn regime. Reduced fire frequency has left many of the scrub sites overgrown and unsuitable for highly specialized scrub endemics that require open sunny patches. *Bonamia grandiflora* can be found growing along roadsides that are often the only available openings. However, these areas cannot be considered a safe refuge for rare species. Roadsides are often filled with invasive exotics that compete with scrub endemics. In addition, road maintenance activities such as mowing, herbicide spraying, and soil disturbance can adversely affect native species.

Bonamia grandiflora is striking when flowering and grows in accessible areas. This morning glory may be adversely affected because of excessive scientific collecting. Horticulturists may also desire this flower as an ornamental. Collecting is regulated in Ocala NF, but regulations have been difficult to enforce.

Bonamia grandiflora may also be affected by fungus. G. Romano (University of Florida, personal communication 1996) reported that in one location all plants bloomed, but few produced viable seed. She found that fungus infested the fruit capsules and prevented development of the seed. This fungus did not appear in the same site the following year. The frequency and long-term effects of fungal infestations are unknown for this species.

Except for a fairly large reservoir of *B. grandiflora* in the Ocala NF, Marion County, this species appears to be in decline. South of Marion County, most sites where this species occurs are small remnants of a once larger xeric community. In Lake and Orange counties, this species is severely affected by habitat loss and degradation. In Orange County, *B. grandiflora* is found with the endangered *Lupinus aridorum. Bonamia. grandiflora* is found in Manatee County though this area has not been adequately surveyed for scrub endemics (K. DeLaney, Environmental Research Consultants, Inc., personal communication 1995). In South Florida, this species is found on scattered scrub sites in Charlotte, Hardee, Highlands, Osceola, and Polk counties. This species may be more abundant in Hardee and Charlotte counties since little survey effort has been expended in these counties (K. DeLaney, Environmental Research Consultants, Inc., personal communication 1995). *B. grandiflora* has disappeared from many of its historical locations (Ward 1979).

Bonamia grandiflora is protected on several sites due to the intense land acquisition efforts on the Lake Wales Ridge in recent years. However, even protected sites cannot ensure the preservation of this species. For example, the species is no longer found at Archbold Biological Station despite its history of conscientious land management practices (Christman and Judd 1990). The species at The Nature Conservancy's Tiger Creek Preserve seems to be in decline as well (G. Romano, University of Florida, personal communication 1996).

Bonamia grandiflora is protected at the following sites: Wingate Creek State Preserve in Manatee County, Turkey Lake Park, Lakes Cane and Marsh Park in Orange County, Lake Louisa SP in Lake County, Crooked Creek owned by the Lake County Water Authority, Ocala NF, and Tiger Creek Preserve, Saddle Blanket Lakes Preserve, Lake Wales Ridge SF, Flamingo Villas, and Sun Ray Preserve in Polk and Highlands counties. There are no protected sites for this species in Osceola, Charlotte, and Hardee counties.

Management

The sand pine scrub community historically burned every 20 to 70 years, and like many other scrub plants, *B. grandiflora* needs fires or mechanical disturbances to reduce competition and maintain a healthy population. Periodic fire also stimulates flowering and seed production of mature plants, stimulates germination of seed, and causes turnover of stored seed banks. This species resprouts after fire. *Bonamia grandiflora* can also withstand mechanical site preparation or low-intensity mowing, but the timing of the mowing is very important. If mowed repeatedly while growing or blooming, energy stores would be used for regrowth and not reproduction. Postponing reproduction for a full growing season could have long-term detrimental effects. However, mowing may be a useful management tool if used after seed set or before leaf out (G. Romano, University of Florida, personal communication 1997).

The USFS, Lake George Ranger District, has developed *B. grandiflora* management recommendations that provide for open, sunny habitat and prevention of cogon grass (*Imperata* spp.) invasion. The only available method to control cogon grass is by spot herbicide application, but this treatment may kill a few *B. grandiflora* plants. Efforts should be made to use grass-specific herbicides and spray during *B. grandiflora*'s dormancy when possible to minimize accidental mortality of this threatened species.

Literature Cited

Christman, S.P., and W.S. Judd. 1990. Notes on plants endemic to scrub. Florida Scientist 53:52-73.

DeLaney, K. 1995. FWS Multi-Species Recovery Team Meeting. December 6-8, 1995.

Fernals, E.A. 1981. Atlas of Florida. Florida State University Foundation; Tallahassee, Florida.

Hartnett, D.C., and Richardson, D.R. 1989. Population biology of *Bonamia grandiflora* (Convolvulaceae): Effects of fire on plant and seed bank dynamics. American Journal of Botany 76(3):361-369.

Miller, L. 1989. Bonamia grandiflora: road survey, Lake George and Seminole Ranger Districts, Ocala National Forest, July and August 1989. Manuscript report, Lake George Ranger District, Ocala National Forest; Silver Springs, Florida.

Myint, T., and D.B. Ward. 1968. A taxonomic revision of the genus *Bonamia* (Convolvulaceae). Phytologia 17:121-239.

Peroni, P.A., and W.G. Abrahamson. 1985. A rapid method of determining losses of native vegetation. Natural Areas Journal 5:20-24.

Romano, G. 1996. Letter. December 5, 1996.

Romano, G. 1997. Letter. February 13, 1997.

Romano, G. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 29, 1998.

Small, J.K. 1933. Manual of the southeastern flora. University of North Carolina Press; Chapel Hill, North Carolina.

U.S. Fish and Wildlife Service [FWS]. 1996. Revised recovery plan for nineteen Florida scrub and high pineland plant endemics. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Ward, D.B. 1979. *Bonamia grandiflora*. Pages 71-72. in D.B. Ward and R.K. Godfrey (eds.), Rare and endangered biota of Florida, vol. 5: Plants. University Presses; Gainesville, Florida.

Wunderlin, R., D. Richardson, and B. Hanson. 1980. Status report on *Bonamia grandiflora*. Unpublished report prepared for U.S. Fish and Wildlife Service; Jacksonville, Florida.

Recovery for the Florida Bonamia

Bonamia grandiflora (A. Gray) Heller

Recovery Objective: DELIST the species once recovery criteria are met**.**

South Florida Contribution: STABILIZE and increase the population.

Recovery Criteria

The South Florida Recovery objective can be achieved when: sites, within the historic range of *B. grandiflora*, are adequately protected from habitat loss, degradation, and fragmentation; when these sites are managed to maintain the seral stage of xeric oak scrub communities to support *B. grandiflora*; and when monitoring programs demonstrate that these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species. Currently, most protected *B. grandiflora* individuals are protected on the Ocala National Forest. To adequately conserve the species, protected sites are needed throughout its entire range, including South Florida.

Species-level Recovery Actions

S1. Determine current distribution of *B. grandiflora.* Some portions of *B. grandiflora*'s range have been well surveyed (Ocala NF and the southern Lake Wales Ridge), yet a distribution has not been ascertained for this species. Lack of survey knowledge in much of its range makes defining distribution difficult.

S1.1. Conduct surveys for additional populations of *B. grandiflora*.

S1.1.1. Survey scrub habitat in Osceola, Charlotte, Hardee, and Hendry counties. Adequate survey work has not been performed off the Lake Wales Ridge. Sites on private property should be surveyed and we should work with landowners to protect them.

S1.1.2. Continue surveys in Polk and Highlands counties. The Lake Wales Ridge has probably been adequately surveyed, though new sites for *B. grandiflora* may still be found.

S1.1.3. Continue surveys for *B. grandiflora* on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. Maintain distribution of known populations and suitable habitat in GIS database. Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. **Protect and enhance existing populations.** Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. **Acquire or otherwise protect privately owned habitat through acquisition, conservation easements, or agreements with landowners.**

S2.2. **Protect populations of *B. grandiflora* on public lands.** Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. **Use local or regional planning to protect habitat.** Utilize available regional and county planning processes to encourage protection of suitable habitat, both unoccupied and occupied of *B. grandiflora*.

S2.4. **Continue *ex situ* conservation.** *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *B. grandiflora*.

S2.4.1. **Conserve germ plasm.** The seed for this species is not presently in long-term storage.

S2.4.2. **Maintain *ex situ* collection**. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *B. grandiflora* as part of the National Collection.

S2.5. **Enforce available protective measures.** Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *B. grandiflora* lives.

S2.5.1. **Initiate section 7 consultation when applicable.** Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. **Enforce take and trade prohibitions.** This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from state lands.

S3. **Conduct research on life history characteristics of *B. grandiflora*.** Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species more specific biological information is needed.

S3.1. **Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality.**

S3.2. **Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.**

S3.3. **Conduct research to assess management requirements of *B. grandiflora*.** Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring information will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S4. **Monitor existing populations of *B. grandiflora*.**

S4.1. **Develop monitoring protocol to assess population trends for *B. grandiflora*.**

S4.1.1. **Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival and mortality.** Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. **Monitor the effects of various land management actions on *B. grandiflora*.** Assess any changes in demographic characteristics of *B. grandiflora* in response to land management activities, such as prescribed fire, exotic plant control, *etc.*

S4.2. **Develop a quantitative description of the population structure of *B. grandiflora*.** This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) should also be included.

S5. **Provide public information about *B. grandiflora*.** It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *B. grandiflora* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. **Prevent degradation of existing habitat.** Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both development and fire suppression have decreased the available habitat. To date, there are five protected sites for *B. grandiflora* in Polk and Highlands counties; however there are no protected sites in Charlotte, Hendry, Hardee, or Osceola counties.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *B. grandiflora* populations by preventing damage from off-road vehicle use, and from over collection, and by providing proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *B. grandiflora*.

H1.2.3. Control access to areas where listed plants are growing. Collection, trampling, and off-road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *B. grandiflora* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc.*, on the habitats where *B. grandiflora* occurs.

H5. Provide public information about scrub and its unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The

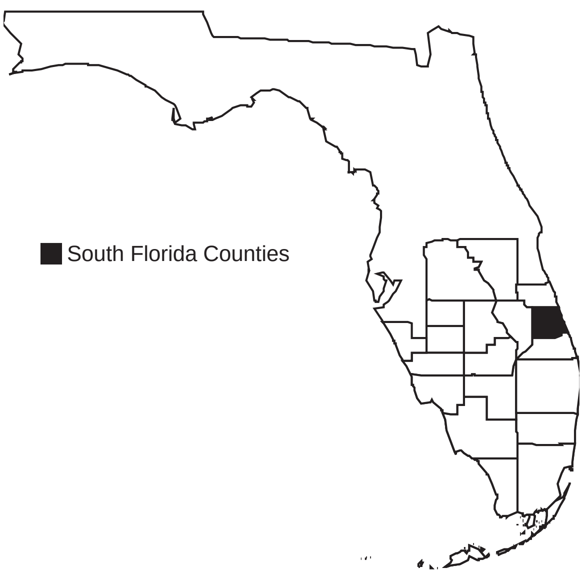
Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the SFWMD, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Fragrant Prickly-apple

Cereus eriophorus var. *fragrans* (Small) L. Benson

Federal Status:	**Endangered (Nov. 1, 1985)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of the fragrant prickly-apple.



Cereus eriophorus var. *fragrans* is a rare, slender, columnar cactus restricted to 11 small disjunct sites in eastern St. Lucie County. A 1996 survey documented the presence of 320 plants. Habitat loss and fragmentation remains a serious threat for plants on private lands. On public lands this species is protected from destruction, but in many areas it is experiencing a precipitous decline in abundance.

This account represents a revision of the existing recovery plan for the fragrant prickly-apple (FWS 1988).

Description

Cereus eriophorus var. *fragrans* is a solitary tree cactus that may have from one to eight, spiny, cane-like, stout, and succulent stems. The columnar stems are 2.5 to 5.0 cm in diameter, and have 10 or 12 ridges alternated with deep, sharp grooves (Benson 1982). Stems may be erect, or for longer stems, the plant may recline over neighboring vegetation. The branching can be extensive, and the roots of this cactus are coarse, fibrous, and shallow (Small 1920). The spine-bearing regions (areoles) are aligned along its ridges about 2 cm apart. Each areole bears 9 to 13 spines, which are mostly grayish and yellowish at the tip, with one spine longer (2 to 4 cm) than the rest.

Cereus eriophorus var. *fragrans* has initial flower buds that are 1 cm long, white, and exceedingly hairy. Buds often appear on the plant one to two months prior to flower growth. About 9 days after initiation of flower growth, the flower opens (Rae 1995). The flowers are fragrant, showy, solitary, and open only at night. The buds are 12 to 20 cm long when about to open and 7.5 to 10 cm in diameter when open. The ovary bears many lanceolate scales while the flower tube has only a few scattered scales. A tuft of long white hairs (10 to 15 mm long) protrudes from the axil beneath each scale. The sepals are narrowly linear, with green outer sepals and nearly white inner ones. There are numerous spatulate petals, white or pinkish, with unevenly toothed margins. The stamens are numerous and are composed of white filaments and yellow anthers. The style is elongate with 9 to 12 stigmas (FWS 1988). The fruits are attached at the narrower end. They average 4 to 6 cm in diameter and are a dull red. The fruit does not split and has long tufts of white hairs that remain persistent with the scale bases (Leon and Alain 1953). The fruits are swollen at the base and finely pitted; each contains approximately 1,500 black seeds that are about 3 mm long (Rae 1995).

Taxonomy

Cereus eriophorus var. *fragrans* (as well as the two other varieties mentioned below) have recently been placed within the genus *Harrisia*. However, the former classification *C. e.* var. *fragrans*, and its common name, fragrant prickly-apple, was used in the federal regulations to list the species (50 CFR 17.12) and the recent taxonomic change has not yet been adopted in the most recent list of endangered and threatened wildlife and plants (December 1998). To maintain consistency between this recovery plan and 50 CFR 17.11 and 17.12, we have opted to continue using *C. e.* var. *fragrans* (and the *Cereus* genus for other species) until it is officially changed in the Federal regulations.

Cereus eriophorus var. *fragrans* has two congeners also found in South Florida: *C. gracilis* var. *simpsonii*, Simpson prickly-apple cactus and *C. gracilis* var. *aboriginum*, aboriginal prickly-apple cactus. *Pilosocereus robinii*, Key tree-cactus, was formerly in the genus *Cereus*. There has been some taxonomic confusion between the fragrant prickly-apple and Simpson's prickly-apple, leading to questions of historical range (Austin 1984). The best character separating these species appears to be spine length. *C. e.* var. *fragrans* has one longer (2 to 4 cm) spine per cluster of shorter spines, whereas *C. g.* var. *simpsonii* has only the shorter spines.

Distribution

Cereus eriophorus var. *fragrans* occurred from Merritt Island, Brevard County south to the St. Lucie River in St. Lucie County. Today, it is known only from three geographically-isolated populations all on the Atlantic Coastal Ridge of St. Lucie County, Florida (Rae 1994a, 1995, 1996) (Figure 1). These populations have been further subdivided by habitat fragmentation and loss; they now occur on 11 disjunct sites on the coastal ridge. The ridge habitat where this plant occurs is approximately 11 km long by 0.2 km wide.

Habitat

Cereus eriophorus var. *fragrans* prefers early-successional sand pine scrub habitat (Rae 1994b). The known sites are limited to St. Lucie sand which is excessively well drained (Watts and Stankey 1980), where the water table is normally deeper than 3 m. Water capacity, fertility, and organic matter content are all very low. The most common plant species in this community include *Polygonella fimbriata*, *P. ciliata, P. gracilis*, *Quercus geminata*, *Q. myrtifolia*, *Sabal palmetto*, and *Opuntia humifusa*. Much of the Atlantic Coastal Ridge was

Fragrant prickly-apple.
Original photograph by John Rae.

cleared in the 1880s for pineapple plantations, but commercial pineapple cultivation was abandoned by 1920. The vegetative community has yet to regain its previous level of diversity or productivity. The vegetative succession has been arrested and the plant community has not succeeded to the climax sand pine habitat type (Rae 1994a, 1995). This cactus prefers partial shade, which is often provided by surrounding plants that shelter it from sun for a portion of the day (Rae 1994b).

Reproduction

Cereus eriophorus var. *fragrans* reproduces sexually and by regeneration by vegetative reproduction. Plants flower from April to September with two distinct peaks. The first peak is in the spring with flowering starting in April and reaching a peak in May. Some sporadic flowering occurs in the summer. In September and October, another minor peak in flowering occurs. Flowering is uncommon in the late fall, and no flowering occurs from January through March. Fruit set follows flowering with a major peak in May and a minor peak in September. A large standing crop of fruit remains on plants for approximately 8 months of the year.

According to Rae (1995), mature plants are greater than 4.1 dm in length. The smallest plant to flower was 1.45 dm in stem length and the smallest plant to set fruit was 4.1 dm in length. In his study, 63 percent of the mature plants flowered. At two sites in the Savannas State Preserve, in St. Lucie County, 38 and 60 percent of flowers successfully produced fruits and 44 and 61 percent of mature plants successfully set fruit. A positive relationship was observed between total length of the stems and branches of a plant and the total annual production of fruit.

The means of seed dispersal are uncertain, but there is evidence that birds consume the fruit of *C. eriophorus* var. *fragrans*. Additionally, most individuals of this species are found within the dripline of other plants, suggesting avian seed dispersal. Rodents or gopher tortoises may also distribute the seeds. In addition to sexual reproduction, long stems will occasionally snap off of existing plants. After falling to the ground, stems may reroot at several places creating a small group of genetically identical plants (Rae 1994a).

Vegetative growth of this perennial species is slowest from November to March. Growth accelerates in April and May, with the fastest growth occurring from July through September. The growth rate drops off rapidly after September (Rae 1994a, 1995).

Relationship to Other Species

The plant species most commonly associated with *C. e.* var. *fragrans* are *Sabal palmetto*, *Smilax laurifolia*, and *Cassytha filiformis* (Rae 1995). *Schinus terebinthifolius,* an invasive exotic, is often found associated with this species. Surrounding vegetation is often used for support by *C. e.* var. *fragrans* for its long stems. Other plants may serve as "nurse plants" for the seedlings, protecting them from direct sun, but this has not been studied. As the plant grows, the nursery plant may die, leaving the cacti exposed to a greater intensity of sunlight. Overgrowth and shading by sand live oaks (*Quercus geminata*) and other species may cause reproductive failure and premature death. Growth and productivity seems to be greater for plants in areas that are partially shaded.

Status and Trends

Cereus eriophorus var. *fragrans* was listed as endangered on November 1, 1985, following substantial losses of suitable habitat (50 FR 45621). Historically, this species occurred from Merritt Island south to the St. Lucie River in coastal hammocks (Small 1917, 1918, 1922, 1925, 1932, 1935). All the identified sites were on the Atlantic Coastal Ridge bordering the Indian River or on spoil islands in the Indian River.

More recently, surveys of the historic range of *C. e.* var. *fragrans* resulted in the discovery of a population of five to eight plants north of Sebastian Inlet, Brevard County, and one individual on Turtle Mound, Volusia County (Poppleton 1981). Poppleton also found a population in Indian River County just south of the Brevard County line. Austin (1984), however, believed that cacti found previously on Merritt Island in Brevard County (Small 1927, Norman 1976, Poppleton and Shuey 1977), and Turtle Mound and south of Coronado in Volusia County (Small 1929) were misidentified and that they were *C. g.* var. *simpsonii*. A population of *C. e.* var. *fragrans* from Malabar, Brevard County, was extirpated prior to 1979 (Austin *et al*. 1980). A thorough botanical search of all spoil islands from Brevard to Martin counties by DEP personnel from 1986 to 1988 failed to find any specimens.

The primary threat to *C. e.* var. *fragrans* is the destruction of sand pine scrub habitat as a result of seaside residential, commercial, and sand mine development. In addition to habitat loss, collecting by cactus enthusiasts may have resulted in the loss of additional plants. Many of the *C. e.* var. *fragrans* individuals are found on or near the right-of-way of the Florida East Coast Railroad. Herbicides used in maintaining railroad rights-of-way may affect cacti near the tracks. Off-road vehicle use in *C. e.* var. *fragrans* habitat is also known to impact plants. Today, the only protected habitat for this species is in Savannas State Preserve in St. Lucie County.

The ecology of *C. e.* var. *fragrans* in the Savannas State Preserve is being studied by Rae (Francis Marion University, personal communication 1995). According to Rae (1994a; J. Rae, Francis Marion University, personal communication 1997), the number of individuals of this species on his study plots declined by 41 percent between 1988 and 1993. The reason for such a decline is unknown. A severe unknown stress on the populations has lead to high mortality (average, 10.7 percent/year) and general recruitment failure (average, 1.0 percent/year). Most deaths appear to occur during the summer months. Later surveys indicated an additional decline of 40 percent between 1993 to 1996 (Rae 1996). These recent deaths may be partially due to changing vegetation patterns, as observed when adjacent vegetation overgrows and shades the cacti.

Management

Cereus eriophorus var. *fragrans* has specific micro-habitat requirements. Plants growing in mostly sunny areas between vegetation and open sandy areas are reproductively successful, while plants growing in the shade rarely flower or produce fruit (Rae 1995). To maximize available habitat for this species, both shade and sun are needed. As one or the other increases, it may be necessary to manage vegetation in proximity to individual cacti by pruning or planting nurse plants.

Lacking adequate reproduction in the wild, it may be necessary to germinate seeds and subsequently transplant seedlings. However, efforts to germinate seeds have failed. Germination failure may be due to one of several factors, including low seed viability, inadequate micro-habitat conditions, or pollination failure (J. Rae, Francis Marion University, personal communication 1998).

To protect *C. e.* var. *fragrans*, land management is critical (Rae 1994b). Management for this species at Savannas State Preserve should include fencing and patrolling to eliminate poaching and damage by off-road vehicles, selective canopy thinning, and control of invasive and exotic plants. Additional research on the effects of land management practices on this species will help guide development of appropriate habitat management strategies for *C. e*. var. *fragrans.* Annual population censuses, experimental introductions and reintroductions following successful propagation may also be important in the successful management of this species.

Literature Cited

Austin, D.F. 1984. Resume of the Florida taxa of *Cereus* (Cactaceae). Florida Scientist 47(1):68-72.

Austin, D.F., C.E. Nauman, and B.E. Tatje. 1980. Endangered and threatened plant species survey in southern Florida and the National Key Deer and Great White Heron National Wildlife Refuges, Monroe County, Florida. Final Report on contract 14-16-004-78-105 to U.S. Fish and Wildlife Service; Jacksonville, Florida.

Benson, L. 1982. The cacti of the United States and Canada. Stanford University Press; Stanford, California.

Leon, H. and H. Alain. 1953. Flora de Cuba, Vol. III. Dicotiledoneas: Malpighiaceae a Mystaceae. Contribuciones Ocasionales del Museo de Historia Natural del "Colegio de la Salle," Vedado, La Habana, Cuba. Numero 13.

Norman, E.M. 1976. An analysis of the vegetation at Turtle Mound. Florida Scientist 39(1):19-31.

Poppleton, J. 1981. The occurrence and ecology of potentially endangered, threatened, and rare plants on Merritt Island, St. John's and Pelican Island National Wildlife Refuges. Part 1, Status Reports. On file at U. S. Fish and Wildlife Service, South Florida Field Office; Vero Beach, Florida.

Poppleton, J.E. and A.G. Shuey. 1977. Vegetation of central Florida's east coast: a checklist of the vascular plants. Florida Scientist 40:362-389.

Rae, J.G. 1994a. Element stewardship Abstract for *Cereus eriophorus* var. *fragrans*. Unpublished report prepared for the Florida Department of Agriculture and Consumer Services; Tallahassee, Florida.

Rae, J.G. 1994b. General management plan, *Cereus eriophorus* var. *fragrans*. Unpublished report prepared for the Florida Department of Agriculture and Consumer Services; Tallahassee, Florida.

Rae, J.G. 1995. Aspects of the population and reproductive ecology of the endangered fragrant prickly-apple cactus (*Cereus eriophorus* var. *fragrans* (Small) L. Benson). Castanea 60(3):255-269.

Rae, J.G. 1996. Distribution of the fragrant prickly-apple cactus. Final report to the Florida Department of Agriculture and Consumer Services; Tallahassee, Florida.

Rae, J.G. 1997. Telephone conversation. January 22, 1997.

Rae, J.G. 1998. Comments on draft species account. January 20.

Small, J.K. 1917. The tree cactus of the Florida Keys. Journal of the New York Botanical Garden 18:199-203.

Small, J.K. 1918. A winter collecting trip in Florida. Journal of the New York Botanical Garden 19:69-77.

Small, J.K. 1920. *Harrisia fragrans*. In: Britton, N.L., and J.N. Rose, The Cactaceae: descriptions and illustrations of plants of the cactus family. pp. 149-150. Dover Publishing Company Incorporated; New York, New York.

Small, J.K. 1922. The botanical fountain of youth. Journal of the New York Botanical Garden 23:117-133, 139-155.

Small, J.K. 1925. Gathering cacti in the eastern coastal plain. Journal of the New York Botanical Garden 26:241-258, 265-285.

Small, J.K. 1927. Among floral aborigines. Journal of the New York Botanical Garden 28:1-20, 25-40.

Small, J.K. 1929. From Eden to Sahara Florida's Tragedy. Sage Press; Lancaster, Pennsylvania.

Small, J.K. 1932. Harrisia fragrans. Addisonia 17:29-30.

Small, J.K. 1935. Chronicle of the cacti of Eastern North America. Journal of the New York Botanical Garden 36:1-11, 25-36.

U.S. Fish and Wildlife Service [FWS]. 1988. Recovery plan for the fragrant prickly-apple cactus. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Watts, F.C. and D.L. Stankey. 1980. Soil survey of St. Lucie County area, Florida. U.S. Department of Agriculture, Soil Conservation Service.

Recovery for the Fragrant Prickly-apple

Cereus eriophorus var. *fragrans* (Small) L. Benson

Recovery Objective: **PREVENT** extinction, then stabilize.

Recovery Criteria

Cereus eriophorus var. *fragrans* may never reach a level at which reclassification could be possible. The objective of this recovery plan should be to increase existing populations and prevent extinction. Current research shows a drastic decline over the last few years in all of the sites being monitored. Determining the cause and extent of this decline is crucial. *Cereus eriophorus.* var. *fragrans* may be considered stabilized when existing populations, within the historic range, are self-sustaining and are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression. These sites must also be managed to maintain xeric coastal scrub to support *C. e.* var. *fragrans*.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be defined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. **Determine distribution of *C. e.* var. *fragrans*.** Known *C. e.* var. *fragrans* populations occur on well-drained soils indicative of xeric upland plant communities. Much of the xeric upland habitat of Indian River and St. Lucie counties remains botanically unsurveyed and threatened with destruction. Efforts to survey and assess the xeric vegetative communities for *C. e.* var. *fragrans* are needed to ensure the survival of this species.

S1.1. **Inventory known populations.** Conduct a thorough ground survey to determine the distribution of *C. e*. var. *fragrans*. Collect and archive herbarium voucher specimens for all populations. Locate and tag all individual plants. Record population sizes. Initiate a quarterly monitoring program. Use existing standardized monitoring protocols developed by the FNAI to record baseline data regarding the biology and ecology of this species.

S1.2. **Search for additional populations.** Resurvey historic locations. Conduct thorough ground surveys to locate unrecorded individuals and populations of *C. e*. var. *fragrans*.

S1.3. **Map distribution of known populations and suitable habitat.** Map populations, including obtaining GPS coordinates and developing GIS coverages.

S2. Protect and enhance existing populations. Of the three populations known, one occurs on private land in residential areas and two occur in Florida's Savannas State Preserve. Additional protection at each of these sites is needed.

S2.1. Acquire or otherwise protect habitat. Protect habitat through cooperative agreements, lease agreements, acquisition by conservation organizations or government agencies, or by measures other than simple fee title.

S2.2. Use local or regional planning to protect habitat. Utilize available regional and county planning processes to encourage protection of suitable unoccupied and occupied habitat of *C. e.* var. *fragrans*.

S2.3. Augment existing populations of *C. e.* var. *fragrans*. Even though existing populations may persist and possibly expand without human intervention if habitat is protected and appropriately managed, some sites may require augmentation, especially where natural regeneration is unlikely or has not been documented.

S2.3.1. Characterize the habitat and identify suitable sites for experimental outplantings. Experience with garden populations of *C. e*. var. *fragrans* will provide seedling production methods, and perhaps some insight into how seeds or seedlings would fare in the wild. Based on horticultural information available on this species, seedling production, followed by transplanting onto suitable sites, appears to be the most feasible method for introducing *C. e*. var. *fragrans* to the wild.

S2.3.2. Conduct experimental outplantings. Study the feasibility of restocking and reintroducing *C. e*. var. *fragrans* into historically appropriate and protected natural habitats.

S2.3.3. (Re)introduce plants to protected sites. Following successful implementation of **S2.3.3,** use plants under cultivation to (re)establish plants in suitable habitat. Use protocols established by the conservation community and modify, if needed, based on (re)introduction results.

S2.3.4. Monitor experimental outplantings. Monitoring of reintroduced plants is essential for assessing the success of recovery efforts. Growth and survivorship will be measured.

S2.4. Continue *ex situ* conservation. *Ex situ* collections can help preserve genetic diversity, prevent loss of the species, and determine ecological characteristics and habitat management needs. These collections will be instrumental in the recovery of *C. e.* var. *fragrans*.

S2.4.1. Conserve germ plasm. Fairchild Tropical Garden maintains an *ex situ* conservation collection of this species. This collection needs to be expanded in order to build a genetically representative conservation collection. Continue to identify germination and cultivation protocols. Identify seed storage potential and methods.

S2.4.2. Continue propagation and development of successful horticultural methods. This species is currently cultivated at Bok Tower Gardens and Fairchild Tropical Gardens. Cultivated collections maintain genetic diversity and provide valuable information regarding the reproductive biology of rare species.

S2.4.3. **Maintain *ex situ* collections.** Currently, The Center for Plant Conservation sponsors the establishment of garden populations of endangered plants at member botanical gardens. Fairchild Tropical Gardens continues to work with the genus *Cereus,* including *C. e.* var. *fragrans.* Bok Tower Gardens also cultivates this species. The wild plants bear fruits freely, and each fruit apparently contains at least 700 seeds. Dissemination of seed for propagation for display in other botanical gardens or for commercial propagation would probably not adversely affect the wild populations.

S2.5. **Enforce available protective measures**. Use local, State, and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *C. e*. var. *fragrans* occurs.

S2.5.1. **Initiate section 7 consultation when applicable.** Initiate section 7 consultations when Federal activities may affect this species. However, since all known populations occur on either private or State-owned lands, we anticipate few, if any, consultations regarding *C. e*. var. *fragrans*.

S2.5.2. **Enforce take and trade prohibitions.** *C. e.* var. *fragrans* is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from land owned by the Federal government; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by State regulations regarding removal of plants from State lands. Violation of these State prohibitions (including Florida criminal trespass law) is also a violation of the ESA.

S3. **Conduct research on the biology of *C. e.* var. *fragrans*.** Much of the basic biology and ecology of this species remains poorly understood. If we are to effectively recover the species, more specific biological information will be needed.

S3.1. **Study the reproductive biology of *C. e.* var. *fragrans*.** Evaluate pollination ecology, seed germination, seedling survivorship in varying habitats, seed dispersal, age at sexual maturity, and species-specific diseases. Most of this information is poorly understood and will be essential for the successful recovery of this species.

S3.2. **Study the response of *C. e.* var. *fragrans* to habitat management treatments.** Little is known regarding how *C. e.* var. *fragrans* responds to various land management actions such as vegetative control or use of prescribed fire. Determine if fire, vegetative cutting, or other means will be required to manage vegetative communities at any of the protected sites where *C. e.* var. *fragrans* occurs.

S3.3. **Conduct genetic studies to document genetic variation within and between populations**. Conservation and recovery of *C. e*. var. *fragrans* will require knowledge of genetic diversity. Outplanting will require knowledge of genetic stock to ensure compatibility of donor and recipient populations.

S4. **Monitor *C. e.* var. *fragrans* populations.** Maintain an inventory of naturally reproducing populations to help determine habitat characteristics and natural environmental changes affecting *C. e*. var. *fragrans.*

S4.1. Initiate quarterly monitoring program. Use existing monitoring protocol developed by the Florida Natural Areas Inventory to record baseline data regarding the biology and ecology of this species, including existing individuals and individual plants that may be reintroduced in the future.

S4.2. Collect and archive existing and historical data. A number of individuals and institutions maintain data for this species. To effectively monitor this species all data must be archived to a central location.

S5. Provide public information about the fragrant prickly-apple cactus. It is important, and perhaps crucial, to the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and landowners be appropriately informed about this species. Informing the conservation organizations such as the Cactus and Succulent Society is appropriate, but care is needed to avoid unnecessarily revealing localities and to avoid stimulating demand for the species.

Efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *C. e*. var. *fragrans* and other rare species requires a self-sustaining, secure, number of natural populations.

S6. Establish delisting criteria. Once reclassification is achieved, research and monitoring results may provide data necessary to develop delisting criteria.

Habitat-level Recovery Actions

H1. Protect, manage and enhance habitat. None of the habitat for *C. e.* var. *fragrans* on private land is secure at this time. Efforts to protect these sites are essential since many of the remaining plants occur on private land.

H1.1. Acquire habitat. Fee title acquisition or less-than-simple-fee title acquisition should be sought for remaining or suitable but unoccupied *C. e*. var. *fragrans* habitat. Some of these sites are targeted for acquisition and inclusion in the Savannas State Preserve, including portions of three populations already partially protected on State property. Where State acquisition is not possible, pursue protection through conservation easements or other appropriate means.

H1.2. Develop and implement management plans on public lands. Manage habitat to maintain cactus populations by preventing damage from off-road vehicle use, and reduce or eliminate threats due to fire (both uncontrolled and controlled), herbicide application, and invasive and exotic vegetation.

H1.2.1. Control off-road vehicle use. Eliminate off-road vehicle use through controlled entry and use.

H1.2.2. Control invasive and exotic plants. Seedling and young *C. e.* var. *fragrans* require nurse plants to provide shade to enhance their survival. In some cases, exotic or invasive native species serve this role well. However, if invasive or exotic plants continue to shade cacti, they may outcompete them for light. Selective removal of competing vegetation may be required once *C. e*. var. *fragrans* no longer require large amounts of shade.

H1.2.3. Reduce impacts associated with herbicide application. Negotiate best management practices with railroad to eliminate adverse effects due to herbicide application on their rights-of-way.

H1.2.4. Define and implement habitat management techniques. Determine land management techniques most beneficial to *C. e.* var. *fragrans* and implement these actions.

H1.2.5. Restore habitat. Based on soil surveys, identify unoccupied but potentially suitable habitat and manage as in **H1.** above.

H2. Monitor habitat and ecological processes. Little is known regarding response of *C. e.* var. *fragrans* to land management actions used in coastal xeric communities. The effects of fire, vegetative cutting, or other measures must be monitored to determine biological and ecological consequences.

H3.1. Determine effects of fire. Determine the effects of fire on adult plants, seedlings, and seeds.

H3.2. Determine effects of vegetative thinning. Evaluate the effects of canopy thinning on the survival, growth, and reproduction of this species.

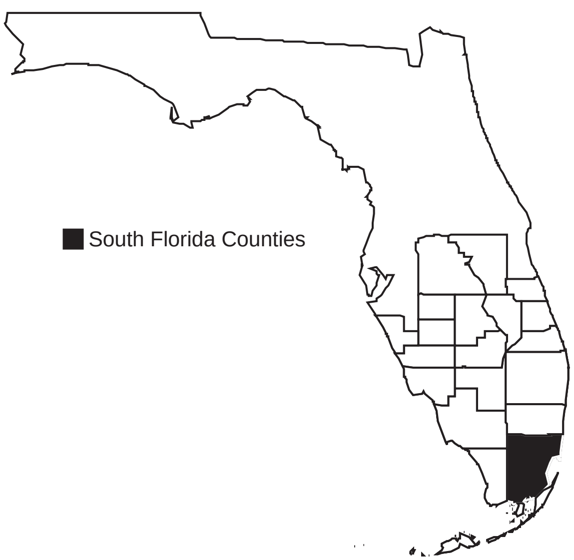
H3. Continue public information efforts about xeric vegetative communities and their unique biota. Educational efforts, especially those conducted by private conservation organizations, have been successful in providing important information about xeric plant communities to the public. The State's system of biological preserves depends on funding, and their future success is based on the public's understanding and support. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, Fairchild Tropical Garden, and Archbold Biological Station, future efforts by these organizations, the Florida Park Service, Florida Native Plant Society, and local garden clubs will play an important role in the conservation of xeric plant communities and *C. e.* var. *fragrans*.

Deltoid Spurge

Chamaesyce deltoidea (Engelman ex Chapman) Small ssp. *deltoidea*

Federal Status:	**Endangered (July 18, 1985)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of deltoid spurge.



Deltoid spurge is a prostrate, perennial herb belonging to the Euphorbiaceae or spurge family. This species is known from pine rocklands in Miami-Dade County, Florida. This plant was listed as a result of habitat destruction, which had reduced the deltoid spurge's range by 98 percent from urban expansion in the area. It requires relatively high light levels and little to no organic litter accumulation. Periodic fires are required to maintain a low litter level and an open understory. Habitat loss, fire suppression, and exotic plant invasions threaten the recovery of the deltoid spurge.

This account represents a revision of the existing recovery plan for the deltoid spurge (FWS 1988).

Description

Chamaesyce deltoidea ssp. *deltoidea* is a small, monoecious, prostrate to decumbent herb occurring in mats over exposed limestone. The stems are terete (circular although slightly oblong) in cross section, brown, and 0.3 to 0.6 mm in diameter. The leaves are smooth above to slightly hairy below, with an obtuse apex, cordate base, margins entire; stipules laciniate, brown to reddish brown with light tips, and smooth. The inflorescence is found singly, in leaf axils, with a short peduncle (1 mm long). The cyathium is 1.2 mm long, 1.0 mm wide and smooth (glabrous). It is green and ovate in shape with four glands and minute appendages. The fruit is a capsule, 1.0 mm long and 1.0 mm wide, and completely glabrous. The pedicel is also glabrous. It is fully exerted at maturity. There are three seeds, 1.0 mm long and 0.5 mm wide, ovate in shape and glabrous. The seeds are laterally four-ridged and yellowish-white (Remus 1979).

The leaves and stems of the subspecies *Chamaesyce deltoidea* ssp. *adhaerens* are appressed to the ground surface and the plants form mats. In some cases the stems will ascend and form tufts (Herndon 1993). The inflorescence is solitary, terminal, pedunculate (1.5 mm long), and glabrous proximally to pilose distally. The main distinction between the two subspecies is their pubescence. The pubescence of the subspecies *C. deltoidea* ssp. *adhaerens* is appressed on the leaves and on the stems it is spreading or appressed (Herndon 1993). The pubescence for *C. deltoidea* ssp. *deltoidea* is sparse, appressed on the leaves and the stems are glabrous or thinly pubescent (Herndon 1993).

Taxonomy

Deltoid spurge was first described as *Euphorbia deltoidea* by Engelman (Chapman 1883). In 1903, Small transferred the species to the genus *Chamaesyce*, a natural genus distinguished from *Euphorbia* by having the main stem abortive just above the cotyledons, making the aerial portion of *Chamaesyce* homologous to the inflorescence of *Euphorbia* subgenus *Esula* (Webster 1967). Burch (1966) treated *C. deltoidea* as a complex of three taxa endemic to South Florida: *C. deltoidea, C. adhaerens* Small, and *C. serphyllum* Small, treating deltoid spurge as *C. deltoidea* (Engelman ex Chapman) Small subsp. *deltoidea* var. *deltoidea* without comment. In Herndon's (1993) revision of the *C. deltoidea* complex, he recognized four subspecies endemic to South Florida: ssp. *deltoidea*, ssp. *adhaerens*, ssp. *pinetorum,* and ssp. *serphyllum*. The taxonomy of this complex is difficult and some follow Burch's 1966 treatment and others follow Herndon's 1993 treatment. The final rule as listed in the Federal Register applies to the taxa *deltoidea* and *adhaerens*, which are restricted to Miami-Dade County, Florida. According to this, all members of the *C. deltoidea* complex that are restricted to Miami-Dade County are considered endangered species by the FWS. For purposes of clarity, Herndon's treatment will be used for this recovery plan.

Synonyms: *Euphorbia deltoidea* Engelman ex Chapman; *Chamaesyce deltoidea* (Engelman ex Chapman) Small ssp. *deltoidea* var. *deltoidea*; *Chamaesyce adhaerens* Small; *Chamaesyce deltoidea* (Engelm. ex Chapman) ssp. *deltoidea* var. *adhaerens* (Small) Burch.

Distribution

Deltoid spurge is a Miami-Dade County endemic that was historically known to occur in pine rocklands from the Goulds area north to the center of the city of Miami (Figure 1). The northern portion of its range has been completely modified by urban expansion. The deltoid spurge is now known only from south Miami to the Homestead area (DERM 1994).

The deltoid spurge is the most northerly member of the *C. deltoidea* complex; the other member of the species complex, *C. deltoidea* ssp. *adhaerens*, occurs in the southern Biscayne pine rocklands, in the area known as the Redlands of Miami-Dade County (Herndon 1993).

Habitat

The deltoid spurge tends to occur in areas with an open shrub canopy, exposed limestone (oolite), and minimal litter (pine needles, leaves, and other organic

Deltoid spurge. *Original photograph by Joy Kline.*

materials). It is most often found growing at the edges of sand pockets with plants growing both in sand (sometimes in association with the endangered *Polygala smallii*) and on oolitic limestone. The soils in which it grows are classified as Opalocka-Rock Outcrop soils. The subspecies *C. deltoidea* ssp. *adhaerens* occurs in fine, reddish sandy loam over limestone. Dense colonies are sometimes found in pinelands that have undergone a slight mechanical disturbance, where little or no topsoil is formed and where productivity is low. The shrub canopy in this disturbed habitat is often poorly developed providing high light levels and low organic litter accumulation rates. The pine rocklands are often considered a fire subclimax, and are maintained with periodic fires (3 to 7 years). These periodic fires keep the shrub canopy down and eliminate the litter accumulations.

Reproduction

Studies into the life history of the deltoid spurge have only recently begun and little is known about its reproduction. It is a perennial that flowers from April through November, peaking in July. Its extensive root system gives evidence that it is a long-lived plant (DERM 1994).

The reproductive ecology in *Chamaesyce* has been poorly studied but it is known to be highly variable (Ehrenfeld 1976, 1979; Webster 1967). Some species are completely reliant on insects for pollination and seed production while others are self-pollinating. Pollinators may include bees, flies, ants, and wasps (Ehrenfeld 1979). Seed capsules of many *Euphorbiaceae* are explosively dehiscent, ejecting seeds a short distance from the parent plant. The seeds of some species are dispersed by ants (Pemberton 1988).

Relationship to Other Species

The pine rocklands where the deltoid spurge occur, are characterized by a canopy of slash pine (*Pinus elliottii* var. *densa*), a shrub canopy of saw palmetto (*Serenoa repens*), wax myrtle (*Myrica cerifera*), poisonwood (*Metopium toxiferum*), willow bustic (*Sideroxylon salicifolium*), and dozens of other shrub species. Common herbaceous associates include *Schizachyrium sanguineum* var. *sanguineum, Schizachyrium gracile, Aster adnatus,* and *Acalypha chamaedrifolia.*

Status and Trends

The subspecies *C. deltoidea* ssp. *deltoidea* is the most numerous of the deltoid spurge complex. In a 1994 report, Miami-Dade County DERM estimated the population size to be 10,000 individuals. *C. deltoidea* ssp. *deltoidea* is known from 19 sites, including the Richmond pine rocklands (DERM 1994). Twelve of these sites are in public ownership. The primary threat to this subspecies is poor management of the publicly owned sites. Although exotics were removed from over 800 acres of pine rocklands since 1994, active fire management still needs improvement. In addition, monitoring of these sites has not documented any population trends.

The subspecies *C. deltoidea* ssp. *adhaerens* is the rarest of the deltoid spurge complex. There are 12 sites known and only six are on protected lands (K. Bradley, Institute for Regional Conservation, personal communication 1996). Some management is in place at the protected sites. Goulds and Black Creek Forest are being managed. Also extensive management of the Camp Owaissa Bauer pineland began in 1998 under a state pollution recovery trust fund (J. Maguire, 1998). Along with the loss of pine rocklands to development many of the small fragments have been degraded as a result of fire suppression and the associated hardwood succession and organic litter accumulation.

Several exotic plants are significant problems in pine rocklands. Burma-reed (*Neyraudia reynaudiana*) is the most problematic. This large, fire-adapted exotic grass is now present in almost every pine rockland fragment in Miami-Dade County and forms dense stands in deltoid spurge habitat. Brazilian pepper (*Schinus terebinthifolius*), earleaf acacia (*Acacia auriculiformis*), natalgrass (*Rhynchelytrum repens*), and molasses grass (*Melinis minutiflora*) are also significant problems.

Management

The pine rocklands of Miami-Dade County have evolved and adapted to frequent fires (Snyder *et al*. 1990). In two to three decades of fire suppression these areas mature into tropical hammocks with a few pines in the canopy (Snyder *et al*. 1990). A fundamental question about the fire ecology of pine rocklands is how frequently they should burn and during what season. Snyder *et al*. (1990) inferred the historic burn regimes by looking at the time it takes for the herbaceous layer to be excluded from an area by shading (maximum time between fire) and the point when enough fuel is available to carry a fire (minimum time between fires).

The minimum fire regime they found was 2 to 3 years and the maximum was 15 years. This wide range in fire frequencies would result in different forest structures and dynamics. This would lead us to believe that a mosaic of burns should be used in the management of pine rocklands.

Presently, the recommended burn regime is 3 to 7 years with summer fires generally preferred to winter. Summer fires are preferred since most lightning strikes (the historical cause of fires) occur in the summer months. In areas where fires have been suppressed for many years, the reintroduction of fire may have to be done in step-wise fashion. In some areas it may include winter burns, or the manual removal of some fuel to prevent a hot fire. Any prescribed fire management should include a monitoring program to determine the effectiveness of the prescription. Monitoring should include the species distribution (presence/absence), quantitative assessment of abundance or condition, and demographic information on individual plants (Menges and Gordon 1996). There should also be a component to the monitoring that captures the health of the community and species that occur in association with the deltoid spurge (C. Kernan, Fairchild Tropical Garden, personal communication 1996).

Invasive exotic species, especially *Schinus terebinthifolius*, and *Neyraudia reynaudiana*, threaten the deltoid spurge and other rare pine rockland plants. The control of exotic species in the pine rocklands is a very important part of habitat maintenance, although it can be very costly once exotics are established in an area. In most cases the control of exotics includes the use of manual labor, herbicides, and prescribed fire. In heavily infested areas removal is labor intensive, with a field crew pulling the plants by hand or cutting. Prescribed fire and herbicide treatments are then used to control the exotic plants. Once an area is cleared of exotics, proper management can reduce the costs of control and maintain the site relatively exotic free.

The management for pine rocklands in Miami-Dade County is complicated because most of the remaining habitat occurs in small fragmented areas bordered by urban development. Areas surrounding the managed pine rockland that have exotic species can act as a seed source for exotics to continue to invade the pine rocklands. To effectively control invasive exotics, an active strategy is needed. This should include a multilingual outreach program in Miami-Dade County stressing the importance of invasive exotic control in areas surrounding managed pine rockland areas.

The Richmond pine rocklands, owned mostly by Federal and county agencies, is the largest and most important area of pine rockland in Miami-Dade County outside of Everglades NP (J. Maguire, Miami-Dade County DERM, personal communication, 1995). This 10 km^2 area contains 345 ha of pine rockland forest and has populations of two listed plants (*C. deltoidea* ssp. *deltoidea* and *Polygala smallii*). The Miami-Dade County DERM has completed a management plan for the Richmond pine rocklands under a grant from the FWS. The restoration and management of the Richmond pine rocklands is being lead by the Miami-Dade County Park and Recreation Department's Natural Areas Management Section and DERM. They have been replanting pines lost as a result of Hurricane Andrew, cutting and applying herbicide treatments to exotic plants, and using prescribed fire where possible. In areas where management has been completed, the restoration has been successful.

Literature Cited

Burch, D. 1966. Two new species of *Chamaesyce* (Euphorbiaceae), new combinations, and a key to the Caribbean members of the genus. Annals of the Missouri Botanical Gardens 53:90-99.

Bradley, K. 1996. FWS Multi-Species Recovery Team meeting. 11-12 March 1996.

Chapman, A.W. 1883. Flora of the southern United States, 2nd ed. Ivison, Blakeman, Taylor, and Company; New York, New York.

Ehrenfeld, J. 1976. Reproductive biology of three species of *Euphorbia* subgenus *Chamaesyce* (Euphorbiaceae). American Journal of Botany 63(4):406-413.

Ehrenfeld, J. 1979. Pollination of three species of *Euphorbia* subgenus *Chamaesyce*, with special reference to bees. American Midland Naturalist 101(1):87-98.

Herndon, A. 1993. A revision of the *Chamaesyce deltoidea* (Euphorbiaceae) complex of southern Florida. Rhodora 95:38-51.

Herndon, A. 1998. Life history studies of Plants endemic to southern Florida, October 1, 1995 to April 30, 1998. Final Report to the National Park Service under Cooperative Agreement No. CA5280-5-9019.

Kernan, C. 1996. Meeting. 12 December 1996.

Long, R.W. and O. Lakela. 1971. A flora of tropical Florida. University of Miami Press; Miami, Florida.

Maguire, J. 1995. Letter. 21 November 1995.

Maguire, J. 1998. Letter. 3 February 1998.

Menges, E.S. and Gordon, D.R. 1996. Three levels of monitoring intensity for rare plant species. Natural Areas Journal 16:227-237.

Miami-Dade County Department of Environmental Resource Management [DERM]. 1994. Annual Report. Endangered pine rockland plant species recovery project. Unpublished report prepared for the U.S. Fish and Wildlife Service; Jacksonville, Florida.

Pemberton, R.W. 1988. Myrmechorchory in the introduced range weed, leafy spurge (*Euphorbia esula* L.). American Midland Naturalist 119(2):431-435.

Remus, J. 1979. Status of two endangered Florida species of *Chamaesyce* (Euphorbiaceae). Florida Scientist 42(3):130-137.

Small, J.K. 1933. Manual of the southeastern flora. University of North Carolina Press; Chapel Hill, North Carolina.

Small, J.K. 1903. Flora of the southeastern United States. Published by the author; New York, New York.

Snyder, J.R., A. Herndon, and W.B. Robertson, Jr. 1990. South Florida rockland. Pages 230-274 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

U.S. Fish and Wildlife Service [FWS]. 1988. Recovery plan for five Florida pine rockland plant species. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Webster, R.L. 1967. Genera of Euphorbiaceae. Journal of the Arnold Arboretum. 48.

Recovery for the Deltoid Spurge

Chamaesyce deltoidea (Engelman ex Chapman) Small ssp. *deltoidea*

Recovery Objective: STABILIZE then reclassify to threatened.

Recovery Criteria

Chamaesyce deltoidea ssp. *deltoidea* may be considered stabilized when existing populations, within the historic range of *C. deltoidea* ssp. *deltoidea*, are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression. These sites must also be managed to maintain pine rocklands to support *C. deltoidea* ssp. *deltoidea*.

Once the existing populations are stabilized, *C. deltoidea* ssp. *deltoidea* may be considered for reclassification to threatened. Reclassification will be considered when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations required to ensure 20 to 90 percent probability of persistence for 100 years; when these populations, within the historic range of *C. deltoidea* ssp. *deltoidea* are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression; when these sites are managed to maintain the pine rocklands to support *C. deltoidea* ssp. *deltoidea*; and when monitoring programs demonstrate that populations of *C. deltoidea* ssp. *deltoidea* on these sites support sufficient population sizes, are distributed throughout the historic range, and are sexually or vegetatively reproducing at sufficient rates to maintain the population.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its distribution within its historic range.

Species-level Recovery Actions

S1. Conduct surveys to determine distribution of pine rockland plants. Pine rockland plants were thoroughly surveyed in Miami-Dade County; however, the status of *C. deltoidea* is not known over its entire range.

S1.1. Inventory known populations. Conduct thorough ground surveys to determine the distribution of *C. deltoidea*. Collect and archive herbarium voucher specimens for all populations. Initiate a quarterly monitoring program. Use existing standardized monitoring protocols developed by the Florida Natural Areas Inventory to record baseline data regarding the biology and ecology of *C. deltoidea*.

S1.2. Resurvey historic locations. Conduct thorough ground surveys to locate unrecorded individuals and populations of *C. deltoidea*.

S1.3. **Map distribution of known populations and suitable habitat.** Map populations, including obtaining GPS coordinates and developing GIS coverages.

S2. **Protect and enhance existing populations.** It is imperative for the recovery of pine rockland plants that additional populations not be lost.

S2.1. **Augment natural populations of listed pine rockland plants, where appropriate.** *Ex situs* collections exist for many rare pine rockland species. These collections should be used to cultivate pine rockland plants and augment sparse populations in protected areas. These experiments with reintroductions will be useful in the future, and could be essential for the recovery of pine rockland plant species. The principles of restoration genetics should be understood and applied when carrying out this task.

S2.1.1. **Continue work with *ex situ* propagation and seed banks.** Seeds should continue to be banked for all the listed species possible, and should be identified precisely as to collection location. A genetically representative *ex situ* conservation collection does not exist for *C. deltoidea.* Initiate work with *ex situ* propagation and seed storage banks. Identify seed storage potential and methods. Identify germination and propagation protocols.

S2.1.2. **Identify potential reintroduction sites and reintroduce *C. deltoidea*, where appropriate.** Sites identified as suitable for reintroduction within the known historic range of *C. deltoidea* should be surveyed and prepared to receive plants. Study the feasibility of translocating propagules into historically appropriate and protected natural habitats. Federal lands under proper management regimes may be good recipient sites. Use reintroduction protocols established by the conservation community.

S2.1.3 . **Monitor the experimental outplantings.** Monitoring of reintroduced plants is essential for assessing the success of recovery efforts. Growth and survivorship should be measured.

S2.2. **Enforce available protective legislation.** State, Federal, and local regulations should be used to protect the pine rockland ecosystem and the listed plants.

S2.2.1. **Initiate section 7 consultation when applicable.** section 7 of the Endangered Species Act applies to Federal activities which might impact listed species, especially on Federal lands (Everglades NP).

S2.2.2. **Encourage implementation of management plans.** Federal agencies are obligated under section 7(a)(1) of the ESA to perform positive conservation programs for the benefit of listed species. The implementation of management plans to benefit pine rocklands in Everglades NP and southern Miami-Dade County are positive conservation programs.

S2.2.3. **Continue to enforce take and trade prohibitions.** The listed pine rockland plants are protected by take and trade restrictions of the ESA, the Preservation of Native Flora Act, and the regulations of Everglades NP. Since these are inconspicuous plants, take and trade are nonexistent or uncommon.

S3. Collect biological information important to species recovery. Additional information on the ecology and life history of pine rockland plants needs to be collected. The size and viability of known populations of *C. deltoidea* needs to be evaluated.

S3.1. Investigate the reproductive biology of *C. deltoidea.* A better understanding of the genetics and reproduction of this species is needed.

S3.2. Identify demographics and gene flow in *C. deltoidea.* Determine the size and viability of all populations. Conduct studies to document the genetic variation within and between populations.

S3.3. Study the response of *C. deltoidea* to habitat management treatments. Study the fire ecology of *C. deltoidea.*

S3.4. Characterize the habitat and identify suitable sites for experimental outplantings. Apply and modify, if need be, reintroduction protocols established by the conservation community.

S4. Monitor *C. deltoidea* populations. Use existing standardized monitoring protocols developed by the Florida Natural Areas Inventory to record baseline data regarding the biology and ecology of *C. deltoidea.* Determine the effects of management actions on *C. deltoidea*. Initiate quarterly monitoring programs.

S4.1. Collect existing and historical data and place in a central location. Contact former researchers for historical data, gather information from herbaria and museums, and contact all present researchers to compile data and place in GIS database in the FWS South Florida Ecosystem Office. This location will allow all researchers access to both historic and current data, and provide the FWS with a means to monitor the success of recovery tasks.

S4.2. Convene a meeting of all researchers. A meeting of current pine rockland researchers and land managers would enable the FWS to locate information sources, and begin the process of compiling those data. The meeting would also afford cooperators an opportunity to discuss monitoring and management procedures and set realistic species level-goals.

S4.3. Monitor status and success of all populations and change management practices if so indicated. Because of the varying vegetation conditions and fire history, different management may be required at different pine rockland sites. Different prescribed burn intervals may be necessary for best results. Intervals should be adjusted over the years to promote pine re-establishment and hardwood reduction.

S4.4. Monitor reintroduction success and modify procedures as necessary. Plant reintroductions should be monitored to determine the success of the procedure. The goal of reintroduction should be to establish a viable population. Management of the reintroduction sites should be modified as necessary to improve results.

S5. Continue implementation of the fire education program and modify as necessary any fire management education program that has been developed. Future modifications to this program may include tri-lingual distribution (Spanish, English, and Haitian Creole).

Habitat-level Recovery Actions

H1. Continue to protect pine rockland plant habitat in order to prevent degradation. The decline of the five listed pine rockland plants is due to alteration of pine rocklands in South Florida.

H1.1. Protect pine rockland habitat. Acquisition of remaining private sites may be the only effective way to protect or conserve pine rockland habitat. Miami-Dade County's Environmentally Endangered Lands program and the State of Florida's CARL program have acquired over 182.25 ha of pine rocklands since 1990. It should be noted that public lands may still be subject to development for recreational, maintenance, or other purposes. Such disturbances, unless carefully planned, may directly destroy pine rocklands and may secondarily result in exotic plant infestations as well as destructive human uses.

H1.2. Protect or acquire privately owned sites. Less-than-fee-simple acquisition should be used, where appropriate, as an alternative means of protecting pine rockland habitat. Covenants, as provided for under Miami-Dade County regulations, provide tax incentives for private landowners to protect pine rockland sites. A site owned by Florida Power and Light Company may be maintained through cooperation with that utility. This avenue of protection should also be pursued with the railroad company that owns pine rockland habitat that supports other listed species. Miami-Dade County DERM is developing a private lands management and grant program for pine rockland protection and restoration and this program should be implemented as soon as possible.

H1.3. Develop and implement best management practices for pine rocklands. This would include development of fire management strategies that would best benefit pine rockland species. Without active fire and exotic plant management, pine rocklands will continue to disappear or degrade. Because of the restricted nature of pine rocklands, intensive management may be necessary at many of the remaining sites.

H1.4. Continue to expand prescribed burns. Fire should be conducted at appropriate times of year to lower fuel loads. Growing season burns should be employed most often after fuel levels are under control. Special consideration must be included when planning prescribed fire for pine rocklands invaded by Burma reed or Cogon grass (*Imperata cylindrica*). Incorporate appropriate actions to minimize additional Burma reed or Cogon grass infestations in these areas. Due to the highly urbanized lands surrounding some of the pine rockland sites, burning involves risks of smoke damage and annoyance, or worse, losing control of the fire. The Florida Division of Forestry has expertise in carrying out controlled burns in Miami-Dade County and should be contacted to assist with burns. Miami-Dade County DERM is developing a private lands management and grant program for pine rockland protection and restoration and this program should be implemented as soon as possible.

H1.5. Implement additional management to meet habitat needs.

H1.5.1. Eliminate human-caused degradation. Preventing trash dumping or other destructive human activities in pine rocklands is important. In order to accomplish this task, fencing and access restrictions may be necessary.

H1.5.2. **Control invasive plant species, particularly exotics.** Burma reed, Cogon grass, and persistent hardwoods need to be controlled and may require special techniques including herbicide, fire, mechanical, and hand clearing at most sites. Other management needs indicated by ongoing research should also be implemented.

H2. Restore areas to suitable habitat.

H2.1. Eliminate physical degradation of habitat and restore to optimal conditions. Physical degradation of pine rocklands continues to occur. Hurricane Andrew, in 1992, killed most of the adult pines in southern Miami-Dade County. The adult pines on Long Pine Key in Everglades NP were not as severely damaged (Herndon, 1998). The continued degradation of these areas should be curtailed and restoration of uneven-aged pine stands undertaken. Tubeling or direct seeding experiments may be used to accomplish this task. In order to use direct seeding techniques, collection of local pine seeds must continue.

H2.2. Continue to refine management practices for pine rocklands. Management plans for sites including *C. deltoidea* should be implemented and modified as necessary for the benefit of this species.

H2.3. Continue to conduct prescribed burns. Prescribed burns should be conducted at sites where *C. deltoidea* occurs at appropriate time of the year to lower fuel loads. Growing season burns should then be employed after fuel loads are under control. The response to *C. deltoidea* to prescribed burns should be studied.

H3. Conduct habitat-related research.

H3.1. Continue to investigate and refine the habitat needs of each species. The habitat needs of these species have been studied, but are still not completely understood. The pollination, germination, and growth requirements have not been fully investigated. Research should address how light levels affect survival, and how fire management affects light levels, reproduction, and regeneration of these species.

H3.2. Investigate fire history and incorporate into management strategies. Look at fire history for pine rocklands in Miami-Dade County and Everglades NP, incorporate into GIS database and analyze relative to healthy populations. This exercise will provide adequate information on fire history and intervals in urbanized and non-urbanized settings to enable assessment of the appropriateness of proposed management regimes.

H3.3. Monitor sites with *C. deltoidea* ssp. *deltoidea* to determine success. A protocol developed by Fairchild Tropical Garden for monitoring pine rockland plant communities should be implemented at sites where *C.deltoidea* ssp. *deltoidea* occur.

H3.4 Develop a GIS database on the five listed pine rockland species and their habitats. Distribute the database to researchers, land managers, and conservationists.

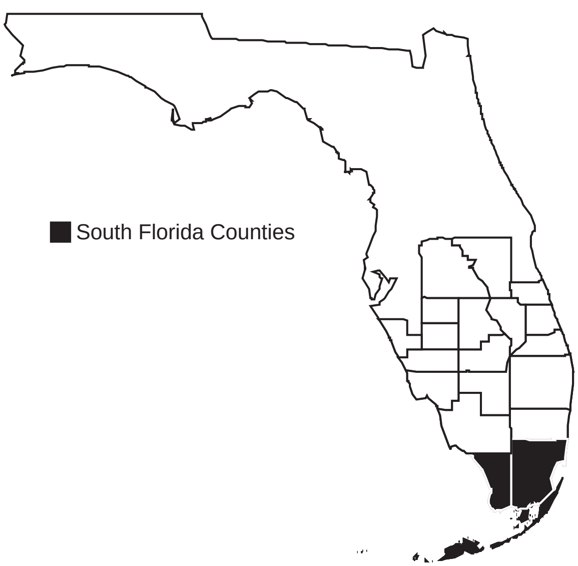
H3.2.1. Assess the availability of GIS data. Create coverage of population locations, acquire recent imageries of the sites, and distribute the coverages to researchers, land managers, and conservationists.

Garber's Spurge

Chamaesyce garberi (Engelman ex Chapman) Small

Federal Status:	**Threatened (July 18, 1985)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of Garber's spurge.



Garber's spurge is a short-lived, perennial herb belonging to the Euphorbiaceae or spurge family. This species is known from pine rocklands, coastal flats, coastal grasslands, and beach ridges in Miami-Dade and Monroe counties, Florida. It requires open sunny areas and needs periodic fires to maintain habitat suitability, although this has not yet been verified by studies. It is found throughout its historic range and is abundant in some areas, but the populations are relatively disjunct. Habitat loss and exotic plant invasion threaten its recovery.

This account represents a revision of the existing recovery plan for the Garber's spurge (FWS 1988).

Description

Garber's spurge is a prostrate to erect herb with pubescent stems. The leaves are ovate in shape and 4 to 9 mm long, with entire or obscurely serrate leaf margins. The cyathia are about 1.5 mm long and borne singly at the leaf axils. The appendages are minute or completely absent. The fruit is a pubescent capsule 1.5 mm wide. The seeds either are smooth or have transverse ridges, but are not wrinkled; this is not, however, a distinctive character for this species.

Taxonomy

Garber's spurge was first described by Engelman as *Euphorbia garberi* Engelman in 1883 (Engelman in Chapman 1883). In 1903, Small transferred it to the genus *Chamaesyce* (Small 1903), a natural genus distinguished from *Euphorbia* by having the main stem abortive just above the cotyledons, making the aerial portion of *Chamaesyce* homologous to the inflorescence of *Euphorbia* subgenus *Esula* (Webster 1967). Herndon (1989, 1993) includes *Chamaesyce porteriana* Small var. *keyensis* Small within *C. garberi,* citing that the erect growth form of *C. porteriana* var. *keyensis* was within the range of variation for *C. garberi*. Herndon also notes that three somewhat distinct forms of Garber's spurge occur, although these have never been described and may be simple morphological variations (A. Herndon, personal communication 1998).

Synonyms: *Euphorbia garberi* Engelman ex Chapman; *Chamaesyce porteriana* Small var. *keyensis* (Small) Burch; *C. acidioides* Small; *C. brachypoda* Small; *C. mosieri* Small.

Distribution

Garber's spurge is endemic to South Florida (Figure 1). It is abundant on Cape Sable and is probably found throughout the Keys in small numbers. Historically, it occurred from Perrine, Miami-Dade County, west to Cape Sable, Monroe County, and to the Sand Keys west of Key West, Monroe County (Small 1933, Long and Lakela 1971).

Habitat

Garber's spurge occurs at low elevations either on thin sandy soils composed largely of Pamlico sands or directly on limestone. It is found in a variety of open to moderately shaded habitat types. In pine rocklands, it grows out of crevices in oolitic limestone. On Cape Sable, Everglades NP, it has been reported from hammock edges, open grassy prairies, and backdune swales. In the Florida Keys, it grows on semi-exposed limestone shores, open calcareous salt flats, pine rocklands, calcareous sands of beach ridges, and along disturbed roadsides.

Reproduction

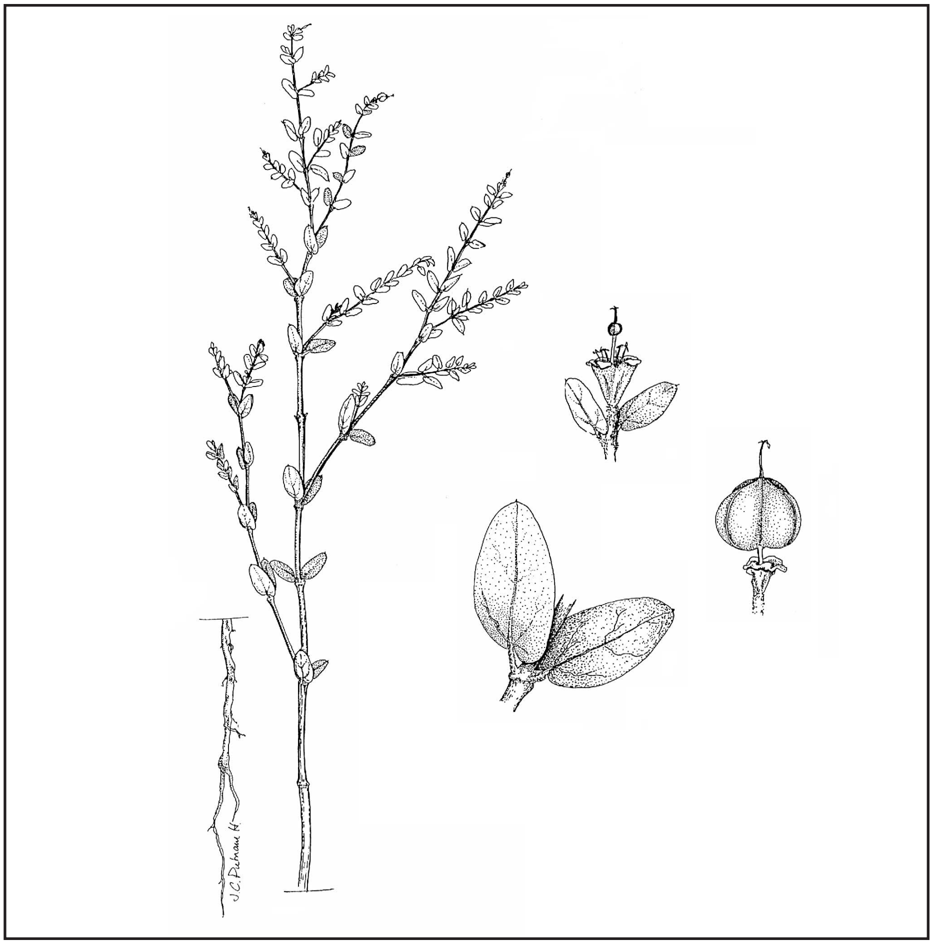
Reproductive ecology in *Chamaesyce* has been poorly studied, but is known to be highly variable (Ehrenfeld 1976 and 1979; Webster 1967). Some species are completely reliant on insects for pollination and seed production while others are self-pollinating. Pollinators may include bees, flies, ants, and wasps (Ehrenfeld 1979). The seed capsules of many *Euphorbiaceae* are explosively dehiscent, ejecting seeds a short distance from the parent plant. Some seeds are dispersed by ants (Pemberton 1988).

Relationship to Other Species

Garber's spurge occurs in association with *Randia aculeata*, *Lantana involucrata*, *Sideroxylon salicifolium*, and *Brysonima lucida* and many more scrub understory species. Relationships to pollinators and seed dispersers are not known.

Status and Trends

Garber's spurge was listed in 1985 because of habitat loss from increased residential and commercial development (50 CFR 29349). A complete status survey has not been performed for Garber's spurge since 1980. In the status survey Austin *et al*. (1981) found five sites; three on Cape Sable (Everglades NP), one on Long Pine Key (Everglades NP), and one on Big Pine Key. Only the Long Pine Key site has been resurveyed, and it was found to contain approximately 150



Garber's spurge.
Original drawing by Ann Murray.

plants (DERM 1994). Cape Sable, in Everglades NP, has an invasive exotics problem that the Park has not, until recently, been able to address (D. Jones, Everglades National Park, personal communication 1997a). The extent of the exotic plant cover was partially assessed in 1996 (Seavey *et al.* 1996). The Park began an exotics control program in 1997. The status of the three Garber's spurge populations on the Cape is not known. A new population was found in 1988 at the Charles Deering Estate, Miami-Dade County, after a burn. It had 250 to 500 plants in 1991, but the population size appears to be getting smaller (K. Bradley, Institute for Regional Conservation, personal communication 1996). Since Herndon's (1993) inclusion of *C. porteriana* var. *keyensis* under Garber's spurge, two other sites have been added, Bahia Honda State Park and Long Key SRA. The population sizes and trends at these sites are unknown.

Habitat for the Garber's spurge has been lost to development, fire suppression, and invasive exotics. In addition, the remaining habitat is relatively fragmented and most populations are small. These small, disjunct populations are more susceptible to extirpation from a single disturbance, natural or manmade, without the chance of recruitment from a nearby population. Fire suppression and the invasion of exotic plants can result in over-shading of the understory, reducing the quality of the habitat. Over time this could lead to the extirpation of Garber's spurge at these sites.

Management

Garber's spurge occurs in a few protected areas where it is being managed. The National Key Deer Refuge uses prescribed fire to manage pineland habitats on the refuge. The main focus of their management is for the key deer, but it may benefit Garber's spurge. In Everglades NP, fire is used as a management tool in pine rocklands. However, management at Cape Sable has been limited by the available manpower and funding.

Garber's spurge occurs in a variety of habitats in the Florida Keys and Miami-Dade County and will require management practices specific to each habitat. Although there are differences between the habitats, they are all early successional and require some type of disturbance (*i.e.* fire or wash over). The habitats in the Florida Keys have a slower growth rate than similar habitats in Miami-Dade County and require less frequent disturbance.

Presently, many of the publicly owned lands in the Florida Keys and Everglades NP use prescribed fire as a management tool. Fire management in Everglades NP has shifted to an early wet season burn schedule (D. Jones Everglades NP, personal communication 1997b). In Miami-Dade County pinelands, a fire frequency of 3 to 7 years is generally recommended. However, in the Florida Keys there is very little information available to determine how frequently disturbances are needed. Any prescribed fire management, especially in the Florida Keys, should include a monitoring program to determine the effectiveness of management. Monitoring should include the species distribution (presence/absence), quantitative assessment of abundance or condition, and demographic information on individual plants (Menges and Gordon 1996). There should also be a component to the monitoring that captures the health of the community and species that occur in association with Garber's spurge (C. Kernan, Fairchild Tropical Garden, personal communication 1996).

Invasive exotic plant species, especially Brazilian pepper, Burma reed, and Cogon grass (*Imperata cylindrica*) threaten many of the listed pine rockland species and other rare pine rockland plants. The control of exotic species is a very important part of maintaining the habitat, although it can be very costly once exotics are established in an area. The Florida Keys Invasive Exotics Task Force organized a mapping project where approximately 25 people mapped exotic species from Key West to Key Largo. The group used aerial photographs to map the distribution and degree of infestation of Australian pine, Brazilian pepper, Asiatic colubrina, Burma reed, and melaleuca on the roads and islands in the Florida Keys from Key West to North Key Largo. Everglades NP, Big Cypress National Preserve, Biscayne NP, and others have cooperated on a similar vegetative mapping project using aerial photographs (Welch *et al.* 1995). High resolution vegetation maps were prepared for Long Pine Key, East Everglades (partial), and Taylor Slough (partial) (D. Jones, Everglades NP, personal communication, 1998). This information will give a better understanding of the degree of infestation and help identify areas of high priority for exotics plant control.

Literature Cited

Austin, D.F. and C.E. Nauman. 1981. Status report on *Chamaesyce garberi*. Unpublished report to the U.S. Fish and Wildlife Service; Jacksonville, Florida.

Bradley, K. 1996. FWS Multi-Species Recovery team meeting 11 March, 1996.

Chapman, A.W. 1883. Flora of the southern United States. Ivison, Blakeman, Taylor, and Company; New York, New York.

Ehrenfeld, J. 1976. Reproductive biology of three species of *Euphorbia* subgenus *Chamaesyce* (Euphorbiaceae). American Journal of Botany 63(4):406-413.

Ehrenfeld, J. 1979. Pollination of three species of Euphorbia subgenus *Chamaesyce*, with special reference to bees. American Midland Naturalist 101(1):87-98.

Garvue, D., C. Kernan, and J. Kornegay. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30. 1998.

Herndon, A. 1981. *Galactia smallii*: A new name for *Galactia prostrata* Small. Rhodora 83:471-472.

Herndon, A. 1989. A Revision of the *Chamaesyce garberi* complex of southern Florida, USA. American Journal of Botany 76(6):245.

Herndon, A. 1993. Notes on *Chamaesyce* (Euphorbiaceae) in Florida. Rhodora. 95:353-368.

Herndon, A. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30. 1998.

Herndon, A. 1998. Life history studies of plants endemic to southern Florida, October 1, 1995 to April 30, 1998. Final Report to the National Park Service under Cooperative Agreement No. CA5280-5-9019.

Jones, D. 1997a. Telephone conversation. 20 January, 1997.

Jones, D. 1997b. Comments on draft species account. August 1997.

Jones, D. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30. 1998.

Kernan, C. 1996. Visit to Fairchild Tropical Gardens research center. 12 December, 1996.

Long, R.W. and O. Lakela. 1971. A flora of tropical Florida. University of Miami Press; Miami, Florida.

Menges, E.S. and Gordon, D.R. 1996. Three levels of monitoring intensity for rare plant species. Natural Areas Journal. 16:227-237.

Miami-Dade County Department of Environmental Resource Management (DERM). 1994. Annual Report. Endangered pine rockland plant species recovery project. Unpublished report prepared for the U.S. Fish and Wildlife Service; Jacksonville, Florida.

Pemberton, R.W. 1988. Myrmechorchory in the introduced range weed, leafy spurge (*Euphorbia esula* L.). American Midland Naturalist 119(2):431-435.

Seavey, R., J. Seavey, and T. Terry. 1996. The exotic plants of Cape Sable: an eradication and management plan. Report submitted to Everglades National Park, South Florida Research Center.

Small, J.K. 1903. Flora of the southeastern United States. Published by the author; New York, New York.

Small, J.K. 1933. Manual of the Southeastern Flora. University of North Carolina Press; Chapel Hill, North Carolina.

U.S. Fish and Wildlife Service [FWS]. 1988. Recovery plan for five Florida pine rockland plant species. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Webster, R.L. 1967. Genera of Euphorbiaceae. Journal of the Arnold Arboretum. 48.

Welch, R., M. Remillard and R.F. Doren. 1995. GIS database development for South Florida's National Parks and Preserves. Photogrammetric Engineering and Remote Sensing 61:1371-1381.

Recovery for the Garber's Spurge

Chamaesyce garberi (Engelman ex Chapman) Small

Recovery Objective: STABILIZE, then delist.

Recovery Criteria

Chamaesyce garberi may be considered stabilized when existing populations, within the historic range of *C. garberi*, are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression. These sites must also be managed to maintain pine rocklands to support *C. garberi.*

Once the existing populations are stabilized, *C. garberi* may be considered for delisting. Delisting will be considered when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations required to ensure 95 percent probability of persistence for 100 years; when these populations, within the historic range of *C. garberi,* are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression; when these sites are managed to maintain the pine rocklands to support *C. garberi*; and when monitoring programs demonstrate that populations of *C. garberi* on these sites support sufficient population sizes, are distributed throughout the historic range, and are sexually or vegetatively reproducing at sufficient rates to maintain the population.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information on the species. Delisting criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its distribution within its historic range.

Species-level Recovery Actions

S1. Conduct surveys to determine distribution of pine rockland plants. Pine rockland plants were thoroughly surveyed in Miami-Dade County; however, the status of *Chamaesyce garberi* is not known over its entire range.

S1.1. Inventory known populations. Conduct thorough ground surveys to determine the distribution of *C. garberi*. Collect and archive herbarium voucher specimens for all populations. Initiate a quarterly monitoring program. Use existing standardized monitoring protocols developed by the Florida Natural Areas Inventory to record baseline data regarding the biology and ecology of *C. garberi*.

S1.2. Resurvey historic locations. Search for additional populations of *C. garberi* in the Florida Keys. Resurvey historic locations. Conduct thorough ground surveys to locate unrecorded individuals and populations of *C. garberi.*

S1.3. Map distribution of known populations and suitable habitat. Map populations, including obtaining GPS coordinates and developing GIS coverages.

S2. Protect and enhance existing populations. It is imperative for the recovery of pine rockland plants that additional populations not be lost.

S2.1. Augment natural populations of listed pine rockland plants, where appropriate. *Ex situ* collections exist for many rare pine rockland species. These collections should be used to cultivate pine rockland plants and augment sparse populations in protected areas. These experiments with reintroductions will be useful in the future, and could be essential for the recovery of pine rockland plant species. The principles of restoration genetics should be understood and applied when carrying out this task.

S2.1.1. Continue work with *ex situ* propagation and seed banks. Seeds should continue to be banked for all the listed species possible, and should be identified precisely as to collection location. A genetic ally representative *ex situ* conservation collection does not exist for *C. garberi.* Initiate work with *ex situ* propagation and seed storage banks. Identify seed storage potential and methods. Identify germination and propagation protocols.

S2.1.2. Identify potential reintroduction sites and reintroduce *C. garberi*, where appropriate. Sites identified as suitable for reintroduction within the known historic range of *C. garberi* should be surveyed and prepared to receive plants. Study the feasibility of translocating propagules into historically appropriate and protected natural habitats. Federal lands under proper management regimes may be good recipient sites. Use reintroduction protocols established by the conservation community.

S2.1.3 . Monitor the experimental outplantings. Monitoring of reintroduced plants is essential for assessing the success of recovery efforts. Growth and survivorship should be measured.

S2.2. Enforce available protective legislation. State, Federal, and local regulations should be used to protect the pine rockland ecosystem and the listed plants.

S2.2.1. Initiate section 7 consultation when applicable. section 7 of the Endangered Species Act applies to Federal activities which might impact listed species, especially on Federal lands (Everglades NP, National Key Deer Refuge).

S2.2.2. Encourage implementation of management plans. Federal agencies are obligated under section 7(a)(1) of the ESA to perform positive conservation programs for the benefit of listed species. Development of management plans to benefit pine rocklands in Everglades NP and areas in the Florida Keys would constitute positive conservation programs.

S2.2.3. Continue to enforce take and trade prohibitions. The listed pine rockland plants are protected by take and trade restrictions of the ESA, the Preservation of Native Flora Act, and the regulations of Everglades NP. Since these are inconspicuous plants, take and trade are nonexistent or uncommon.

S3. Collect biological information important to species recovery. Additional information on the ecology and life history of pine rockland plants needs to be collected. The size and viability of known populations of *C. garberi* needs to be evaluated.

S3.1. Investigate the reproductive biology of *C. garberi.* A better understanding of the genetics and reproduction of this species is needed.

S3.2. Identify demographics and gene flow in *C. garberi.* Determine the size and viability of all populations. Conduct studies to document the genetic variation within and between populations.

S3.3. Study the response of *C. garberi* to habitat management treatments. Study the fire ecology of *C. garberi.*

S3.4. Characterize the habitat and identify suitable sites for experimental outplantings. Apply and modify, if need be, reintroduction protocols established by the conservation community.

S4. Monitor *C. garberi* populations. Use existing standardized monitoring protocols developed by the Florida Natural Areas Inventory to record baseline data regarding the biology and ecology of *C. garberi.* Determine the effects of management actions on *C. garberi*. Initiate quarterly monitoring programs.

S4.1. Collect existing and historical data and place in a central location. Contact former researchers for historical data, gather information from herbaria and museums, and contact all present researchers to compile data and place in GIS database in the FWS South Florida Ecosystem Office. This location will allow all researchers access to both historic and current data, and provide the FWS with a means to monitor the success of recovery tasks.

S4.2. Convene a meeting of all researchers. A meeting of current pine rockland researchers and land managers would enable the FWS to locate information sources, and begin the process of compiling those data. The meeting would also afford cooperators an opportunity to discuss monitoring and management procedures and set realistic species-level goals.

S4.3. Monitor status and success of all populations and change management practices if so indicated. Because of the varying vegetation conditions and fire history, different management may be required at different pine rockland sites. Different prescribed burn intervals may be necessary for best results. Intervals should be adjusted over the years to promote pine re-establishment and hardwood reduction.

S4.4. Monitor reintroduction success and modify procedures as necessary. Plant reintroductions should be monitored to determine the success of the procedure. The goal of reintroduction should be to establish a viable population. Management of the reintroduction sites should be modified as necessary to improve results.

S5. Continue implementation of the fire education program and modify as necessary any fire management education program that has been developed. Future modifications to this program may include tri-lingual distribution (Spanish, English, and Haitian Creole).

Habitat-level Recovery Actions

H1. Continue to protect pine rockland plant habitat in order to prevent degradation. The decline of the five listed pine rockland plants is due to alteration of pine rocklands in South Florida. Without protection and proper management, the rockland sites in the Keys may undergo the same destruction.

H1.1. Protect pine rockland habitat. Acquisition of remaining private sites is an effective way to protect or conserve pine rockland habitat. Purchase of additional parcels in the Lower Keys would also benefit the Key deer. It should be noted that public lands may still be subject to development for recreational, maintenance, or other purposes. Such disturbances, unless carefully planned, may directly destroy pine rockland and may secondarily result in exotic plant infestations as well as destructive human uses.

H1.2. Protect or acquire privately owned sites. Less-than-fee-simple acquisition should be used where appropriate as an alternative means of protecting pine rockland habitat. Miami-Dade County DERM is developing a private lands management and grant program for pine rockland protection and restoration. Monroe County should develop and implement a similar program.

H1.3. Develop and implement best management practices for pine rocklands. This would include development of fire management strategies that would best benefit pine rockland species. Without active fire and exotic plant management, pine rocklands will continue to disappear or degrade. Because of the restricted nature of pine rocklands, intensive management may be necessary at many of the remaining sites.

H1.4. Continue to conduct prescribed burns. Fire should be conducted at appropriate times of year to lower fuel loads. Growing season burns should be employed most often after fuel levels are under control. Special consideration must be included when planning prescribed fire for pine rocklands invaded by Burma reed or Cogon grass (*Imperata cylindrica*). Incorporate appropriate actions to minimize additional Burma reed or Cogon grass infestations in these areas. Due to the highly urbanized lands surrounding some of the pine rockland sites in the Keys, burning involves risks of smoke damage and annoyance, or worse, losing control of the fire. The Florida Division of Forestry has expertise in carrying out controlled burns in Miami-Dade County, and should be contacted to assist with burns in Monroe County. A regional pine rockland burn plan needs to be developed between the Federal, State, and County resource agencies and funding provided.

H1.5. Implement additional management to meet habitat needs.

H1.5.1. Eliminate human-caused degradation. Preventing trash dumping or other destructive human activities in pine rocklands is important. In order to accomplish this task, fencing and access restrictions may be necessary.

H1.5.2. Control invasive plant species, particularly exotics. Burma reed, Cogon grass, and persistent hardwoods need to be controlled and may require special techniques including herbicide, fire, mechanical, and hand clearing at most sites. Other management needs indicated by ongoing research should also be implemented.

H2. Restore areas to suitable habitat.

H2.1. Eliminate physical degradation of habitat and restore to optimal conditions. Physical degradation of pine rocklands continues to occur. Hurricane Andrew, in 1992, killed most of the adult pines in Miami-Dade County. The adult pines on Long Pine Key in Everglades NP were not as severely damaged (Herndon, 1998). The continued degradation of these areas should be curtailed and restoration of uneven-aged pine stands undertaken. Tubelings or direct seeding experiments may be used to accomplish this task. In order to use direct seeding techniques, collection of local pine seeds must continue.

H2.2 Continue to refine management practices for pine rocklands. Management plans for sites including *C. garberi* should be implemented and modified as necessary for the benefit of this species.

H2.3. Continue to conduct prescribed burns. Prescribed burns should be conducted at sites where *C.garberi* occurs at appropriate time of the year to lower fuel loads. Growing season burns should then be employed after fuel loads are under control. The response to *C. garberi* to prescribed burns should be studied.

H3. Conduct habitat-related research.

H3.1. Continue to investigate and refine the habitat needs of each species. The habitat needs of these species have been studied, but are still not completely understood. The pollination, germination, and growth requirements have not been fully investigated. Research should address how light levels affect survival and how fire management affects light levels, reproduction, and regeneration of these species.

H3.2. Investigate fire history and incorporate into management strategies. Look at fire history for pine rocklands in Miami-Dade County, Everglades NP, and Monroe County. Incorporate results into GIS database and analyze fire history relative to healthy populations. This exercise will provide adequate information on fire history and intervals in urbanized and non-urbanized settings and enable assessment of the appropriateness of proposed management regimes.

H3.3. Monitor sites with *C. garberi* to determine success. A protocol developed by Fairchild Tropical Garden for monitoring plant communities at sites where C.garberi occur should be implemented.

H3.4. Develop a GIS database on the five listed pine rockland species and their habitats. Distribute the database to researchers, land managers, and conservationists.

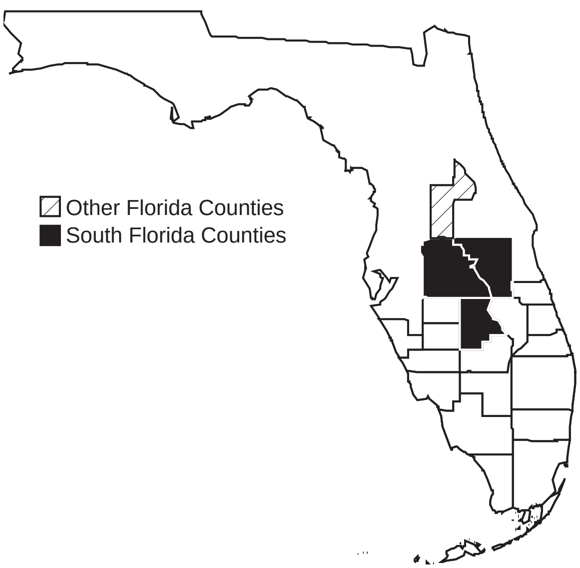
H3.2.1. Assess the availability of GIS data. Create coverage of population locations, acquire recent imageries of the sites, and distribute the coverages to researchers, land managers, and conservationists.

Pygmy Fringe-tree

Chionanthus pygmaeus Small

Federal Status:	**Endangered (January 21, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of the pygmy fringe-tree.



Chionanthus pygmaeus is a large shrub that occurs primarily in scrub as well as high pineland, dry hammocks, and transitional habitats in central Florida. Much of this species' habitat has been lost because of land clearing for citrus production and residential development. As a result, it was listed as an endangered species on January 21, 1987. Habitat acquisition and development of suitable land management actions are helping to conserve this species.

This account represents a revision of the existing recovery plan for the pygmy fringe-tree (FWS 1996).

Description

Chionanthus pygmaeus is a shrub or small tree that is often less than 1 m tall, but can grow to 4 m tall. The twigs are opposite or sub-opposite and stiff, while the leaf scars and leaves are mostly opposite but sometimes alternate. The leaves are simple, mostly 3 to 10 cm long, and lacking stipules. They have short petioles, and the somewhat leathery blades are ovate to elliptic or obovate in shape, and acute to rounded at the tip. The base of the blade is attenuated to the petiole. The upper surface of the blade is dark yellow-green and smooth, but the lower surface is paler and reticulate.

The inflorescence is a leafy-bracted panicle that appears with the new shoots from the axils of most leaf scars from the previous season. The axis (main stem) of the inflorescence is rather short with numerous opposite branches that are spreading, slender and dropping, terminating in clusters of three to six flowers. Bracts toward the base of the inflorescence are similar to, but smaller than, the leaves.

The flowers are regular, perfect, and pleasingly fragrant. The four sepals are green, united at the base, and 1.5 to 2.0 mm long. The four petals are white, united at the base to a short, campanulate throat, with narrowly linear lobes, 1.0 to 1.5 cm long and somewhat spreading. The two stamens are fused (adnate) to the corolla base. The ovary is superior with a single style. The fruit is a drupe 2.0 to 2.5 cm long, oval, and green, becoming purplish-brown when ripe.

Taxonomy

Small (1933) named this species *Chionanthus pygmaea.* Since then there have been no other taxonomic treatments. There are no scientific synonyms, but the common name used in literature is pygmy fringetree and the spelling variation pygmy fringe-tree (Wood 1985, Ward and Godfrey 1979). The gender of the name has been unclear. When he named the species, Small (1933) used the Greek suffix -*aea* which indicates the species' status as a tree. The use of this ending has been questioned and every author since, including Hardin (1974), has used the suffix -*aeus* indicating its status as a shrub.

Distribution

Chionanthus pygmaeus is known from west of Lake Apopka in Lake County, northwestern Osceola County, and the Lake Wales Ridge in Polk and Highlands counties (Figure 1). It is no longer found in its historic habitat on the Mount Dora Range. One of the largest populations is in the Carter Creek scrubs in Highlands County where it occurs with turkey oak (*Quercus laevis*), a species more typical of high pine community (FWS 1996).

Habitat

Chionanthus pygmaeus inhabits excessively drained sandy soils on the Lake Wales Ridge (and historically on the Mount Dora Range) of central Florida. These high ridges are blanketed with soils that are classified as Quartzipsamments. This species is found on the low-nutrient St. Lucie fine sand which is subject to rapid drying (Wunderlin *et al.* 1981).

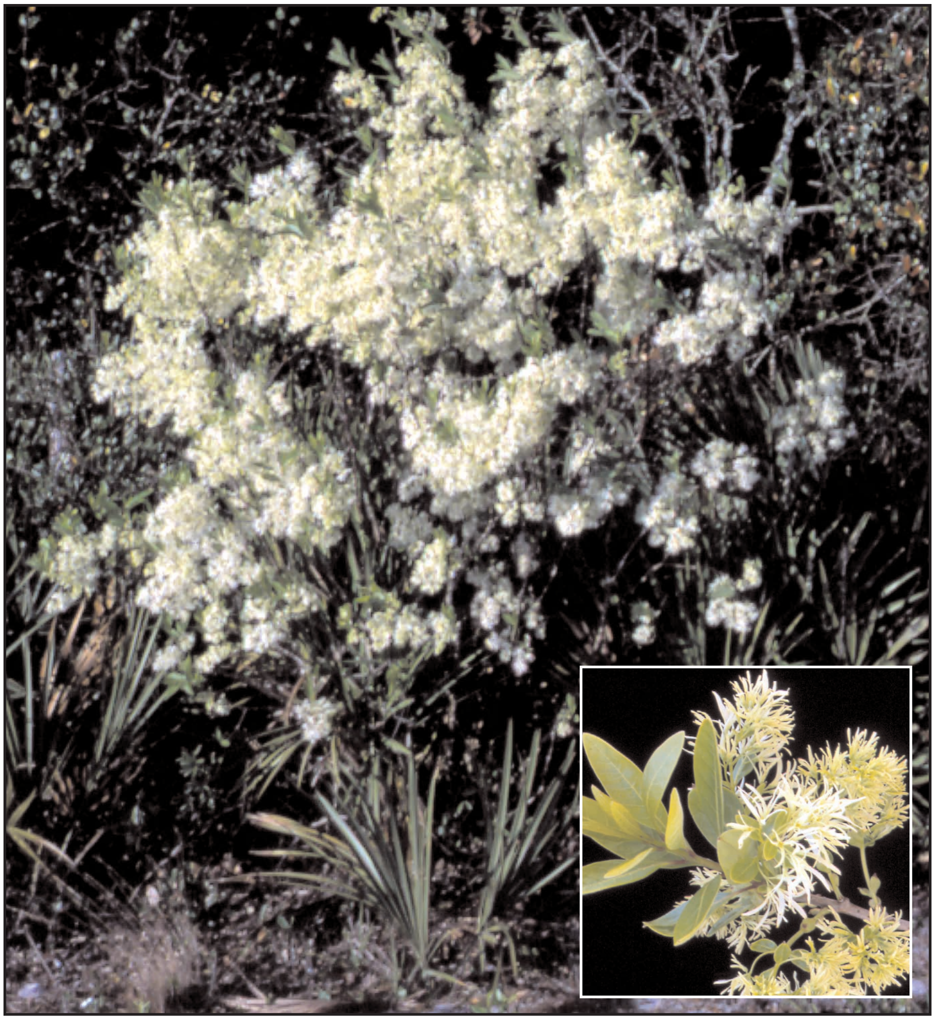
Chionanthus pygmaeus occurs primarily in scrub as well as high pine, dry hammocks, and transitional habitats. It is abundant at a few sites, where it may form thickets along with evergreen oaks and other shrubs such as *Ximenia americana, Persea humilis*, and *Carya floridana*. In some locations, it may be the dominant plant while in others it may be codominant or subdominant (Wunderlin *et al.* 1981).

Reproduction

Although the reproductive biology of *C. pygmaeus* has not been thoroughly investigated, we know that it reproduces by root sprouts and occasionally by seed (Stout *in press*). The plants appear to be functionally dioecious (Gill and Pogge 1974), and the female flowers have stunted anthers that usually do not open (Goodrum and Halls 1961).

Little is known about seed dissemination of *C. pygmaeus*, and seed production is variable from year to year, with mixed reports for success of germination. In nursery conditions the best results are obtained with cleaned, air-dried seed, but whole fruits have also germinated. Bok Tower Gardens has achieved 60 to 70 percent germination rates under greenhouse conditions (T. Race, Bok Tower Gardens, personal communication 1996).

Germination dates for *C. pygmaeus* are unknown. Leafing occurs mid-March, budding occurs in March, and anthesis is from late March to early April.



Pygmy fringe-tree.
Original photograph by Betty Wargo; original flower photograph by Steve Shirah.

Fruiting probably occurs in June, with seed dispersal in September (Gill and Pogge 1974, Ward and Godfrey 1979). Seeds (drupes) may remain on the plants well into winter (Stout *in press*). Data on the phenology of this species are sparse.

Relationship to Other Species

Chionanthus pygmaeus is similar to the widespread *Chionanthus virginicus*, whose range extends into central Florida. The two species appear to hybridize in habitats other than scrub, though the two plants are distinct species (Elfers 1989). Plants that had been thought to be *C. pygmaeus* at Fort Cooper State Park south of Inverness, Citrus County, were assigned by Elfers to *C. virginicus*. Fort Cooper State Park has no scrub; it is mostly live oak hammock or high pineland. Both species of *Chionanthus* occur at Little Manatee River SRA in Columbia County. Although a hybrid population of *Chionanthus* occurs at O'Leno State Park, Manatee County, a population of *Chionanthus* that once existed in western Hillsborough County was probably *C. virginicus* (FWS 1996).

Though the pollination biology needs further research, Wunderlin *et al.* (1981) observed that the pollen dissemination agents are mainly honey bees (*Apis mellifera*). However, Stout (*in press*), observed no diurnal pollinators during his study, but suggested that nocturnal pollination by moths may be important.

Seeds are lost to a variety of animals. Small mammals appear to partially remove the seed coat and consume the seed. Many animals, including deer (*Odocoileus virginianus*), turkey (*Meleagris gallopavo*) and quail (*Colinus virginianus*), consume the seed of *C. virginicus* (Gill and Pogge 1974, Goodrum and Halls 1961). In addition, seeds may be destroyed by weevil infestations. However, these infestations are probably not inhibiting the natural rate of germination of this species, since recruitment is believed to be inherently low in this species (Stout *in press*).

Status and Trends

Chionanthus pygmaeus was listed as threatened on January 21, 1987 (52 FR 2234). This ruling was based on loss of habitat primarily by conversion of sand scrub habitat to citrus groves or residential subdivisions. The situation in Highlands County illustrates the severity of habitat loss. In this county, 64 percent of the xeric vegetation (sand pine scrub, scrubby flatwoods, and southern ridge sandhills) present before settlement was destroyed by 1981. An additional 10 percent of the xeric vegetation was moderately disturbed by road construction (Peroni and Abrahamson 1985). The situation is similar in Polk County.

Chionanthus pygmaeus colonize and thrive in areas of bare sand that are exposed to full sun, although it also occurs and flowers in areas of deep shade and pine canopy. Fire prevention, habitat fragmentation, or other factors that may preclude the creation or maintenance of a mosaic of open, sandy patches could threaten this species. Threats from land conversion due to agriculture are obvious, as this species does not persist in citrus groves or other agricultural areas (51 FR 12444). Threat from the horticultural trade is not likely, although both native species of *Chionanthus* are valuable ornamentals. Their availability is limited by the difficulty of propagation from cuttings (Dirr 1990).

Chionanthus pygmaeus is protected at Saddle Blanket Lakes, Lake Wales Ridge SF, Lake Arbuckle Preserve, Flamingo Villas, Tiger Creek Preserve, Catfish Creek Preserve, Horse Creek, Snell Creek, and is maintained as part of the National Collection of Endangered Plant Species at Bok Tower Gardens.

Management

This species is long-lived and persists in areas that are burned on a frequency between 20 and 70 years. Very little is known about the fire ecology of *C. pygmaeus*. However, we know that it is a fire-dependent species that resprouts after fire events. This species has above-ground stems growing from rootstocks or buried stems that have survived the infrequent fires that are characteristic of the habitat (Kral 1983, Ward and Godfrey 1979). It has been observed to resprout from rootstocks following a spring burn (Stout *in press*). Fires may have an important indirect effect on *C. pygmaeus* by regulating the numbers and sizes of plants that might shade or otherwise compete with it (Kral 1983).

In the spring and summer of 1997, The Nature Conservancy burned sections of Tiger Creek Preserve that contain *C. pygmaeus*. The effects of fire on these individuals is being monitored (I.J. Stout, University of Central Florida, personal communication 1997). The effectiveness of other management techniques has not been explored with this species.

Recruitment is exceedingly slow in this species. At The Nature Conservancy's Tiger Creek Preserve (Possum Creek Trail Scrub), over 100 individuals of *C. pygmaeus* have been tagged and are being monitored (I.J. Stout, University of Central Florida, personal communication 1997). In more than 10 years of monitoring, hundreds of root sprouts have been found, but only one seedling has been located. Despite this extremely low seedling recruitment, the number of individuals at the site appears to be stable. Further research is needed on recruitment in this species. In addition, surveys for the presence of *C. pygmaeus* in South Florida are needed south of Saddle Blanket Lakes in Highlands County, as well as in DeSoto and Hardee counties.

Literature Cited

Dirr, M. A. 1990. Manual of woody landscape plants: their identification, ornamental characteristics, Yamato Scrub, a test case. Florida Scientist 52:254-271.

Elfers, S.C. 1989. A biosystematic study of *Chionanthus* in the southeastern United States. Unpublished thesis, University of Central Florida; Orlando, Florida.

Gill, J.D., and F.L. Pogge. 1974. *Chionanthus virginicus*. Pages 323-325 *in* C. S. Schopmeyer. Seeds of woody plants in the United States. Agriculture Handbook No. 450. Forest Service, U.S. Department of Agriculture; Washington, DC.

Goodrum, P.D., and L.K. Halls. 1961. Fringetree. Pages 10-11 *in* L.K. Halls and T.H. Ripley, eds. Deer browse plants of southern forests. U.S. Department of Agriculture, Forest Service, Forest Experimental Station; Atlanta, Georgia.

Hardin, J.W. 1974. Studies of the southeastern United States flora. IV. Oleaceae. Sida 5:274-285.

Kral, R. 1983. A report on some rare, threatened, or endangered forest-related vascular plants of the South. U.S. Department of Agriculture, Forest Service Technical Publication; Atlanta, Georgia.

Peroni, P.A., and W.G. Abrahamson. 1985. A rapid method for determining losses of native vegetation. Natural Areas Journal 5:20-24.

Race, T. 1996. Letter. Febuary 27, 1996.

Small, J.K. 1933. Manual of the Southeastern flora. University of North Carolina Press; Chapel Hill, North Carolina.

Stout, J. 1997. Phone call. January 10, 1997.

Stout, I.J. In press. Submitted to the Florida Committee on Rare and Endangered Plants and Animals. 2nd edition plant volume. On file in U.S. Fish and Wildlife Service, South Florida Ecosystem Office, Vero Beach, Florida.

U.S. Fish and Wildlife Service [FWS]. 1996. recovery plan for nineteen central Florida scrub and high pineland plants. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Ward, D.B., and R.K. Godfrey. 1979. Pygmy fringe-tree. *in* Ward, D.B., editor. Rare and endangered biota of Florida. Plants. vol. 5. University of Florida Presses; Gainesville, Florida.

Wood, D.A. 1985. Official lists of endangered and potentially endangered fauna and flora in Florida. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Wunderlin, R.P., D. Richardson, and B. Hansen. 1981. Status report on *Chionanthus pygmaeus*. Unpublished report for: U.S. Fish and Wildlife Service; Atlanta, Georgia.

Recovery for the Pygmy Fringe-tree

Chionanthus pygmaeus Small

Recovery Objective: STABILIZE, then reclassify to threatened

Recovery Criteria

Chionanthus pygmaeus may be considered stabilized when existing populations, within the historic range of *C. pygmaeus*, are adequately protected from further habitat loss, degradation, and fire suppression. Large areas of land are needed to support populations of this tree/shrub species. These sites must also be managed to maintain xeric oak scrub to support *C. pygmaeus.* Habitat destruction is occurring at an alarming rate. To ensure the survival of this species, actions must be taken to protect its remaining habitat. Difficulty in conserving this species may be compounded by the low seed germination rates that could affect this plant's ability to rebound from a reduction of adult individuals.

Once the existing populations are stabilized, *C. pygmaeus* may be considered for reclassification to threatened. Delisting will only be considered when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations required to ensure 95 percent probability of persistence for 100 years; when these populations, within the historic range of *C. pygmaeus,* are adequately protected from further habitat loss, degradation, and fire suppression; when these sites are managed to maintain the serial stage of xeric oak scrub to support *C. pygmaeus*; and when monitoring programs demonstrate that these sites support sufficient population sizes, are distributed throughout the historic range, and are sexually or vegetatively reproducing at sufficient rates to maintain the population.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *C. pygmaeus.* This species' distribution is somewhat questionable for taxonomic reasons and ease of overlooking individuals. A thorough survey is needed to determine the distribution for this species.

S1.1. Conduct surveys for additional populations of *C. pygmaeus*.

S1.1.1. Survey scrub habitat in Hardee County. Adequate survey work has not been performed off the Lake Wales Ridge. Sites on private property cannot be protected without survey knowledge, yet they may be difficult to survey.

S1.1.2. **Continue surveys in Polk and Highlands counties.** The Lake Wales Ridge has been well surveyed, though new sites may still be found. In Highlands County, the area south of Saddle Blanket Lakes needs more surveying.

S1.1.3. **Continue surveys on protected lands.** New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. **Maintain distribution of known populations and suitable habitat in GIS database.** Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. **Protect and enhance existing populations.** Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties has been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. **Protect populations on private land through acquisition, conservation easements, or agreements with landowners.**

S2.2. **Protect populations on public lands.** Develop management guidelines that allow for a fire regime that results in the formation of a mosaic of successional stages.

S2.3. **Continue *ex situ* conservation.** *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *C. pygmaeus*.

S2.3.1. **Conserve germ plasm.** The seed for this species is not presently in long-term storage.

S2.3.2. **Maintain *ex situ* collection**. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *C. pygmaeus* as part of the National Collection.

S2.4. **Enforce available protective measures.** Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *C. pygmaeus* lives.

S2.4.1. **Initiate section 7 consultation when applicable.** Initiate section 7 consultations when Federal activities may affect this species.

S2.4.2. **Enforce take and trade prohibitions.** This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting,or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. **Conduct research on life history characteristics.** Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species, more specific biological information is needed.

S3.1. **Continue research to determine demographic information, such as number of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality**. Information is especially needed on reproduction, pollination biology, and recruitment in this species.

S3.2. **Identify the relationship *C. pygmaeus* has with the weevils that infest its fruits.** This infestation is believed not to affect the species, but with such low recruitment, the weevils should be researched to verify their role in recruitment.

S3.3. **Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.**

S3.4. **Conduct research to assess management requirements of *C. pygmaeus*.** Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring information will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S4. **Monitor existing populations of *C. pygmaeus*.**

S4.1. **Develop monitoring protocol to assess population trends for *C. pygmaeus*.**

S4.1.1. **Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival and mortality.** Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. **Monitor the effects of various land management actions on *C. pygmaeus*.** Assess any changes in demographic characteristics of *C. pygmaeus* in response to land management activities, such as prescribed fire, exotic plant control, *etc*.

S4.2. **Develop a quantitative description of the population structure of *C. pygmaeus*.** This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) may prove to be helpful in future management.

S5. **Provide public information about *C. pygmaeus*.** It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. However, caution should be taken to avoid revealing specific locality information of *C. pygmaeus*.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *C. pygmaeus* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there are 13 protected or acquisition sites for *C. pygmaeus.*

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. Little xeric scrub habitat is remaining for this species. Any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *C. pygmaeus* populations by preventing damage from off-road vehicle use and overcollection, and by providing proper management of habitat, including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established, and agricultural conversions are becoming more prevalent. Without control, exotic/invasive plants may become a threat to the survival and recovery of *C. pygmaeus*.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *C. pygmaeus* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. **Monitor habitat/ecological processes.** Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc*., on the habitats where *C. pygmaeus* occurs.

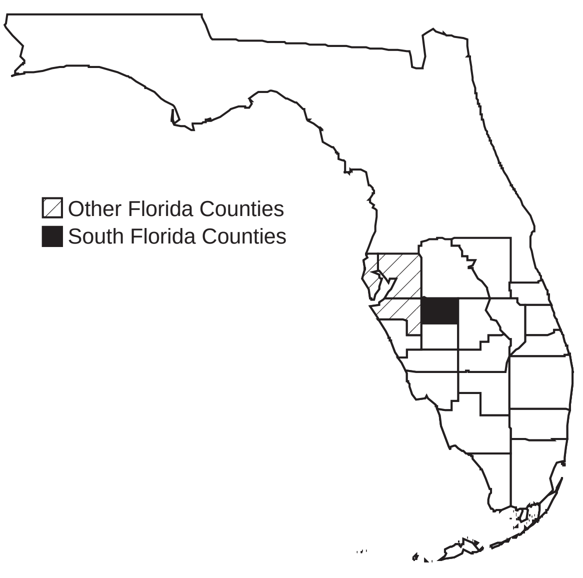
H5. **Provide public information about scrub and its unique biota**. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the SFWMD, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Florida Golden Aster

Chrysopsis (=Heterotheca) floridana Small

Federal Status:	**Endangered (May 16, 1986)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. County distribution of the Florida golden aster.



The Florida golden aster is a perennial herb in the aster family with a distribution limited to a few counties in west-central Florida. The Florida golden aster occurs in sand pine and oak scrub or in disturbed areas at the edges of scrub.

This account represents South Florida's contribution to the existing recovery plan for the Florida golden aster (FWS 1988).

Description

Chrysopsis floridana is a perennial herb with stems that are woody toward the base and non-woody above. The plants have basal rosettes (clusters of leaves at ground level) with leaves 4 to 10 cm long, 1.5 to 2.0 cm wide; the leaves of the rosette are densely short-wooly pubescent. The stem leaves are nearly the same size from the top to the bottom of the stem; they are obovate-elliptic, slightly clasping the stem, entire, and densely short-wooly pubescent. The flower heads are grouped into a more or less flat-topped cluster of 1 to 25 heads at the top of the stem. Each head is slightly over 2.5 cm in diameter. Both the central disc and the rays are golden yellow. *C. floridana* is distinguished from other members of its genus by its perennial habit, the woodiness of its stems, the wooliness and the shape of the stem and the leaves, and the way the flower heads are arranged in a flat-topped cluster (Semple 1981, Wunderlin *et al*. 1981).

Taxonomy

This species was first described by John K. Small in 1903 as *Chrysopsis floridana*. However, M. L. Fernald (1937) described this plant as *Chrysopsis mariana* var. *floridana.* V. Harms (1963) proposed the nomenclature as *Heterotheca mariana* subsp. *floridana*. R. W. Long (1970) provided another synonym, *Heterotheca floridana*. Cronquist (1980) considered it synonymous with the more common *Chrysopsis scabrella.* However, in 1981, J. C.

Semple returned *Chrysopsis floridana* to its original status as a separate species. Several other authors have also recognized it as a distinct species (Lakela *et al*. 1976, Ward 1979, Wunderlin 1982).

Distribution

Because information on distribution of *C. floridana* is derived from relatively few collections that were made prior to extensive urbanization of the Tampa Bay area, it is impossible to completely define its historic distribution. The species is presently known to occur in Pinellas, Hillsborough, Manatee, and Hardee counties (Figure 1).

Chrysopsis floridana was first collected in 1901 at Bradenton in Manatee County, Florida, by S. M. Tracy. Specimens from this collection were described in 1903 by John K. Small (Small 1903). Small subsequently collected the species in Pinellas County in 1921 and in Hillsborough County in 1924. Small's collections in 1921 included a specimen from dunes on Long Key (St. Petersburg Beach), Pinellas County, indicating that the original range of the species included dunes along the Gulf of Mexico (Wunderlin *et al*. 1981). The species was not collected again until 1953 by W. J. Dress in Hillsborough County. Ward (1979) reported that the species was restricted to two populations in Hillsborough County and that the population previously reported in Pinellas County was now a heavily urbanized area and was considered quite likely extirpated. A status survey by Wunderlin *et al*. (1981) reported the distribution of *C. floridana* was limited to several sites in central and southern Hillsborough County; population sizes ranged from one to several hundred individuals. *C. floridana* is known to occur in Lake Manatee SRA, Manatee County (Lambert and Menges 1996).

R.D. Wunderlin of the University of South Florida has herbarium specimens of *C. floridana* collected in 1987 by K. DeLaney from three sites in southeastern Hardee County, in the vicinity of Sweetwater, which places a portion of its range in the boundaries of the South Florida Ecosystem. These three sites are present in the Florida Natural Areas Inventory's database, but more recent surveys by DeLaney are not (Florida Natural Areas Inventory 1997). Wunderlin recalls that very few specimens were present at any of the sites and that there was evidence of trampling by cattle (R. Wunderlin, University of South Florida, personal communication 1997). However, more detailed information on the distribution of *C. floridana* in Hardee County, or the threats the species may face there, has not been published and is not available at this time to the FWS (K. DeLaney, Environmental Research Consultants, Inc., personal communication 1996). DeLaney reports that *C. floridana* has been eliminated from two sites he previously documented in Hardee County (K. DeLaney, Environmental Research Consultants, Inc., personal communication 1997). The FWS does not know how many sites if any remain in Hardee County (additional sites may be present in Hardee County beyond the three represented by Wunderlin's specimens).

Florida golden aster flower. *Original photograph by Steve Shirah.*

Habitat

Although a majority of South Florida's endemic scrub plants are found on the Lake Wales Ridge, *C. floridana* occurs west of the Lake Wales Ridge, on lower ridges formed during the late Miocene epoch. *Chrysopsis floridana* is associated with the excessively drained soils characteristic of sand pine scrub, such as Archbold fine sands, St. Lucie fine sands, Lakewood fine sands, Duette fine sands, and Pomello fine sands (Wunderlin *et al*. 1981, Lambert and Menges 1996). All of these soils are extremely nutrient-poor and well-drained and are composed primarily of siliceous sand.

Chrysopsis floridana prefers open, sunny areas within the sand pine scrub community. The dominant overstory trees include sand pine (*Pinus clausa*), scrub live oak (*Quercus geminata*), bluejack oak (*Q. incana*), Chapman's oak (*Q. chapmanii*), and myrtle oak (*Q. myrtifolia*). The shrub layer occurs in thickets 1 to 2 m high. The dominant species are tarflower (*Befaria racemosa*), staggerbush (*Lyonia fruticosa*), saw palmetto (*Serenoa repens*), pawpaw (*Asiminia reticulata*), and hog plum (*Ximenia americana*). The herbaceous layer usually includes wireweed (*Polygonella ciliata*), blazing star (*Liatris tenuifolia*), wiregrass (*Aristida beyrichiana*), deer's tongue (*Carphephorus corymbosus*), queen's delight (*Stillingia sylvatica*), prairie clover (*Dalea feayi*), and several species of lichens (Wunderlin *et al*. 1981).

Chrysopsis floridana was known to occur historically in scrub habitat on coastal dunes, and the species has been reintroduced to this habitat type at Ft. Desoto County Park, Pinellas County. Dominant vegetation surrounding the small patch (approximately 24 plants) of *C. floridana* includes scrub live oak, slash pine (*Pinus elliottii*), and rosemary (*Ceratiola ericoides*) (D. Chayet, Pinellas County Parks Department, personal communication 1997). More detailed analysis should identify any differences in soil, species composition, and habitat structure, between these dunes at Ft. Desoto County Park and the scrub habitats where *C. floridana* is present farther inland.

Reproduction

Chrysopsis floridana flowers in late November and December and sheds seed from December onward. This plant can spread vegetatively by forming new basal rosettes at the ends of rhizomes, but reproduction is primarily by seed (FWS 1988). The entire genus has an out-crossing breeding system. In the sand pine scrub vegetative community, *C. floridana* colonizes areas of sunny, bare sand. Lambert and Menges (1996) found that seedling emergence was increased by disturbed soil, by the absence of a litter layer and by their combination. However, seedling survival was not affected by those experimentally controlled factors. Fire did not affect seed germination or seedling survival, but did increase flowering.

Relationship to Other Species

Little information is available on the relationship of the Florida golden aster to other species. Shading by overly dense canopy species will result in reduced population size, and will ultimately eliminate *C. floridana* from the understory. No information is available on pollinators. Lambert and Menges (1996) reported that the disturbance of soil by an ant mound (species not reported) favored germination of *C. floridana*, as did rooting by armadillos (*Dasypus novemcinctus*). Gopher tortoise (*Gopherus polyphemus*) burrows are also known to provide areas of disturbed soil suitable for germination of many scrub species. *C floridana* may also be confused with *C. scabrella* in the field.

Status and Trends

Chrysopsis floridana was recognized in 1979 as an endangered species by the Florida Committee on Rare and Endangered Plants and Animals (Ward 1979), but this provided no legal protection for the species. *Chrysopsis floridana* was listed as endangered under the Endangered Species Act on May 16, 1986 (51 FR 17977); the listing rule cited the limited distribution of the species and the threats of residential and commercial development of its habitat, mowing, intense grazing, and heavy use of off-road vehicles as the causes for endangerment. At that time, all known populations of *C. floridana* occured on lands that were in private ownership.

Chrysopsis floridana is now known to occur on several protected and managed sites. *Chrysopsis floridana* has been successfully reintroduced in sand pine scrub habitat within Boyd Hill Nature Park in Pinellas County (G. Costen, Boyd Hill Nature Park, City of St. Petersburg, personal communication, 1996) and has been grown from seed in scrub at Fort Desoto SP, which is close to the shore of the Gulf of Mexico (D. Chayet, Pinellas County Parks Department, personal communication 1997). Lambert and Menges (1996) reported that the species grew at Lake Manatee SRA, and at an unnamed site acquired by Hillsborough County. Hillsborough County has now acquired several parcels through their Environmental Lands Acquisition and

Protection Program (cost sharing with the SWFWMD or the CARL program) that support populations of *C. floridana.* Hillsborough County also has acquired lands without cost sharing, and in addition shared costs with the Florida Communities Trust. As of January 1997, the species was located on seven county properties; the largest of these are the 2,024-ha Balm-Boyette Scrub and the 520-ha Golden Aster Scrub (J. Lehman, Hillsborough County Parks and Recreation Department, personal communication 1997, DEP 1995).

Lambert and Menges (1996) reported that the population size of *C. floridana* ranged between 90 and 185 individuals in two quadrats at Lake Manatee SP between February 1990 and November 1992; they noted considerable turnover from both mortality and recruitment. Information on population sizes and trends in Hardee County has been collected, but has not yet been published (K. Delaney, Environmental Research Consultants, Inc., personal communication 1997).

Chrysopsis floridana is known to occur on railroad and highway rights-of-way in Hillsborough County, making it vulnerable to the management practices surrounding transportation corridors and possible widening of these corridors (Wunderlin *et al*. 1981, FWS 1988). Where *C. floridana* occurs on private lands, threats of human activity include mowing, dumping, vehicular traffic, and land clearing (Ward 1979, Wunderlin *et al*. 1981, FWS 1988). The FWS has no information on the distribution of *C. floridana* in Hardee County. This information is needed to determine the present land uses, assess regional and county comprehensive land use plans, and to address threats to the species in Hardee County.

Management

Because the FWS currently has no specific information on the distribution of *C. floridana* and threats to its survival in Hardee County, this section is based on our knowledge of management issues in Hillsborough, Pinellas, and Manatee counties. Obtaining information on the species' distribution, its relation to current and proposed land use patterns, and current and potential threats in Hardee County would be the highest priority for protection of that portion of the species' range within the South Florida Ecosystem.

Based on the threats observed in nearby counties, it is likely that current and future threats to scrub habitat in Hardee County will include residential and agricultural development, highway projects, mowing, lack of fire management in scrub, use of off-road vehicles, and dumping of trash in scrub. Acquisition of scrub habitat containing *C. floridana* in Hardee County would allow proper management of these tracts, as has been initiated on public lands in Hillsborough County. Because Hardee County has extensive areas of improved pasture and unimproved pasture, we consider important an assessment of the effect of cattle grazing on *C. floridana* habitat. Based on this information, we will be able to provide management recommendations to cattle ranchers to protect *C. floridana* on private property.

Controlled burning is an important management tool for recovery of *C. floridana*, because plants that occupy open sandy areas in scrub habitat rely on periodic fire to prevent canopy closure. Lambert and Menges (1996) reported a prescribed burn in Boyd Hill Nature Park during their germination experiments. It was a fast cool fire which did not open the cones of sand pines in its path. The fire did not affect germination of *C. floridana* nor seedling survival, but it did increase flowering by mature plants in the burned quadrats the following year. Lambert and Menges (1996) were unable to study the long-term effects of the fire, but based on observations from similar scrub habitats, they recommend that prescribed burning mimic the natural cycle of the cover type being managed, with frequent burns (1 to 10 years) in transitional or sandhill areas and burns every 10 or more years in scrub areas themselves. They also recommend burning in late spring and summer, when lightning-generated fires tended to occur naturally, which would also be after *C. floridana* seeds have been dispersed. Personnel from Boyd Hill Nature Park indicate that two controlled burns have occurred there since reintroduction of *C. floridana* to the park in 1989 (G. Costen, Boyd Hill Nature Park, City of St. Petersburg, personal communication 1996). They have found controlled burns can be conducted successfully despite the relatively small size (99 ha) of the park and the dense urban development surrounding the park. They attribute this to careful planning for the burns and the presence of a lake adjacent to the park, which buffers the area from the adjacent urban area. This is encouraging for the likelihood of successful prescribed burns in Hardee County, which is less urbanized than Pinellas County. Controlled burning has also been used to manage *C. floridana* habitat on property belonging to Hillsborough County (J. Lehman, Hillsborough County Resource Management, personal communication 1997) and at Lake Manatee SRA and Little Manatee River SRA, both of which are owned by DEP in Manatee County (R. Hattaway, DEP, personal communication 1997).

Land managers have expressed concerns about invasion of exotic grasses in *C. floridana* habitat, particularly since prescribed burning alone may not be sufficient to prevent this invasion. Cogon grass (*Imperata cylindrica*) is a widespread exotic species that is invading the habitat of *C. floridana* in Hillsborough County (S. Bowman, Hillsborough County Parks and Recreation Department, personal communication 1996). In addition to crowding out native vegetation, cogon grass may also alter fire intensities in areas invaded (Schmitz 1994). At Boyd Hill Nature Park, Bermuda grass (*Cynodon dactylon*) has invaded scrub habitat from an adjacent athletic field (G. Costen, Boyd Hill Nature Park, City of St. Petersburg, personal communication 1996). An effective treatment of these grasses without damage to the native scrub plants should be devised for the long-term management of scrub habitats containing *C. floridana*.

Cultivation of *C. floridana* and transplantation of cultivated specimens to natural areas has been an effective recovery action; this type of action is not limited by difficulties in cultivating the aster (Wallace 1988, T. Race, Bok Tower Gardens, personal communication 1997), but it is limited by the small number of remaining suitable scrub habitats in the limited range of the species. The species was reintroduced to Boyd Hill Nature Park in 1989 from plants cultivated at Bok Tower Gardens (G. Costen, Boyd Hill Nature Park, City of St. Petersburg, personal communication 1996). The aster was also successfully reintroduced to

Fort Desoto County Park from wild-collected seeds (D. Chayet, Pinellas County Park Department, personal communication 1997). Because the aster has a high germination and survival rate, dispersal of seed is a preferred method of introducing the aster rather than germinating plants in a greenhouse and subsequent planting in the field (T. Race, Bok Tower Gardens, personal communication 1997).

L. Markham of the University of South Florida has initiated DNA analysis on *C. floridana* to determine the amount of genetic variability across the species' range. This will provide information for decisions on land acquisition and plant introduction to ensure we are protecting the full range of genetic variability in the remaining population. There is a concern that the plants reintroduced to sites in Pinellas County are all derived from the same genetic stock, which was collected at the Shadow Run Subdivision in Hillsborough County (R. Wunderlin, University of South Florida, personal communication 1997).

In South Florida, conducting surveys to determine if the aster still exists is the most immediate recovery need for this species. Once we have identified and confirmed locations for this species in South Florida, we can develop specific management actions to recover the species.

Literature Cited

Bowman, C. Telephone communication. 19 December 1996.

Chayet, D. Telephone communication. 22 January 1997.

Costen, G. Telephone communication. 19 December 1996.

Cronquist, A. 1980. Vascular flora of the southeastern United States. vol. 1. Asteraceae. University of North Carolina Press; Chapel Hill, North Carolina.

DeLaney, K. Telephone communication. 19 December 1996.

DeLaney, K. Central Florida Rare Plant Task Force meeting. 30 January 1997.

Fernald, M.L. 1937. Plants of the inner coastal plain of Virginia. Rhodora 39:433-459.

Florida Department of Environmental Protection. 1995. Conservation and Recreational Lands (CARL) Annual Report. Florida Department of Environmental Protection; Tallahassee, Florida.

Florida Natural Areas Inventory. 1997. Letter (with enclosed Element Occurrence Records) from Ann F. Johnson to Robert Pace, U.S. Fish and Wildlife Service; Vero Beach, Florida.

Hattaway, R. Telephone communication. 3 February 1997.

Harms, V.L. 1963. Variation in the *Heterotheca* (*Chrysopsis*) *villosa* complex east of the Rocky Mountains. Unpublished Ph.D. dissertation, University of Kansas.

Lakela, O., R.W. Long, G. Fleming, and P. Genelle. 1976. Plants of the Tampa Bay area. Banyan Books; Miami, Florida.

Lambert, B.B. and E.S. Menges. 1996. The effects of light, soil disturbance, and presence of organic litter on the field germination and survival of the Florida golden aster, *Chrysopsis floridana* Small. Florida Scientist 59(2):121-137.

Lehman, J. Telephone communication. 22 January 1997.

Long, R.W. 1970. Additions and nomenclatural changes in the flora of southern Florida. Rhodora 72:17-46.

Race, T. Telephone communication. 28 January 1997.

Schmitz, D.C. 1994. The ecological impact of non-indigenous plants in Florida. *in* D.C. Schmitz and T.C. Brown, project directors. An assessment of invasive non-indigenous species in Florida's public lands. Technical Report No. TSS-94-100. Florida Department of Environmental Protection; Tallahassee, Florida.

Sempel, J.C. 1981. A revision of the golden aster genus (Nutt.) Ell. nom. cons. (Compositae-Astereae). Rhodora 83(835):323-384.

Small, J.K. 1903. Flora of the southeastern United States. Published by the author; New York, New York.

U.S. Fish and Wildlife Service. 1988. Florida golden aster recovery plan. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Wallace, S.R. 1988. Letter from Susan R. Wallace, Bok Tower Gardens, to David J. Wesley, U.S. Fish and Wildlife Service; Jacksonville, Florida. 23 May 1988.

Ward, D.B. (editor). 1979. Rare and endangered biota of Florida, volume five: Plants. University Presses of Florida; Gainesville, Florida.

Wunderlin, R.D. 1982. Guide to the vascular plants of central Florida. University Presses of Florida; Gainesville, Florida.

Wunderlin, R.D. Telephone communication. 31 January 1997.

Wunderlin, R., D. Richardson and B. Hansen. 1981. *Chrysopsis floridana*. Status report prepared for U.S. Fish and Wildlife Service. Jacksonville Field Office; Jacksonville, Florida.

Recovery for the Florida Golden Aster

Chrysopsis (=Heterotheca) floridana Small

Recovery Objective: **RECLASSIFY** to threatened.

South Florida Contribution: **CONDUCT SURVEYS** to ascertain presence in South Florida.

Recovery Criteria

The best scientific information available raises questions about whether the Florida golden aster occurs within the geographic boundaries of the South Florida Ecosystem. Unless new information demonstrates that this species occurs in South Florida, no recovery criteria will be developed or proposed as part of this recovery plan.

Species-level Recovery Actions

S1. Determine the distribution for *C. floridana* in South Florida.

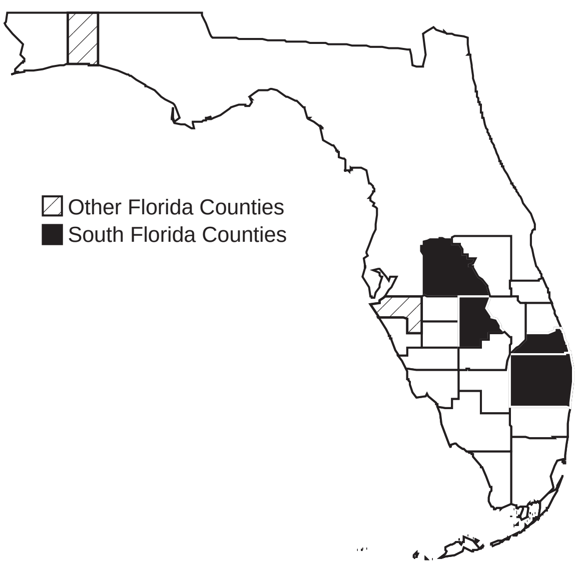
S.1.1. Conduct surveys for *C. floridana* in suitable sand pine and oak scrub habitat in Hardee County.

Florida Perforate Cladonia

Cladonia perforata Evans

Federal Status:	**Endangered (April 27, 1993)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of Florida perforate cladonia.



Cladonia perforata is a member of the family Cladoniaceae, commonly called the reindeer lichens. Unlike the more common and widely distributed species of the Cladoniaceae with which it occurs, *C. perforata* is restricted to the high, well-drained sands of rosemary scrub in Florida. *Cladonia perforata* was listed as endangered because of the significant loss of scrub habitat in Florida. This species is known to occur on approximately 27 sites in Florida; all but two sites are in the South Florida Ecosystem. Sixteen of the sites are protected, and others are proposed for acquisition in the future.

This account represents a revision of the existing recovery plan for the Florida perforate cladonia (FWS 1996).

Description

Cladonia perforata is easily recognized in the field by the conspicuous holes or perforations below each dichotomous branch point and its wide, smooth, yellowish gray-green branches.

Unlike other fruticose lichens whose branches develop from the primary or vegetative body, the branches of members of *Cladonia* and *Cladina* are developmentally derived from spore-producing structures called apothecia, present as colored, expanded tips of fertile branches. These specialized, hollow branches are called podetia and are structurally characteristic of this group. *Cladonia perforata* differs from other fruticose terrestrial Cladoniaceae in several podetial characters, including color, shape and texture, in addition to having specific habitat requirements. *Cladonia perforata* has rather wide (up to 6 mm), pale yellowish gray-green podetia, punctuated in the axils by 1 to 1.5 mm perforations. The branching pattern is complex and consists of roughly subequal dichotomies near the tips and, more commonly, sympodia (unequal branchings with the smaller branch deflected to one side) below (Evans 1952), resulting in a more-or-less compressed tuft. Its outer surface is mostly uniformly smooth. Individual podetia are typically 4 to 6 cm long (Evans 1952), although specimens of up to 8 cm across and several cm high have been observed (R. Yahr, Archbold Biological Station, personal communication 1995). No primary thallus is known. The oldest parts of the podetia degenerate, leaving no means of determining ages. No studies of growth rates in *C. perforata* have been completed. In boreal areas, growth studies of *Cladonia* species suggest that one branching occurs each year (Thomson 1967); however, in more tropical areas, more than one branching per year may be possible. *Cladonia perforata* is suspected to reproduce only by vegetative fragmentation; no spore-producing organs (apothecia) have been described (Thomson 1967).

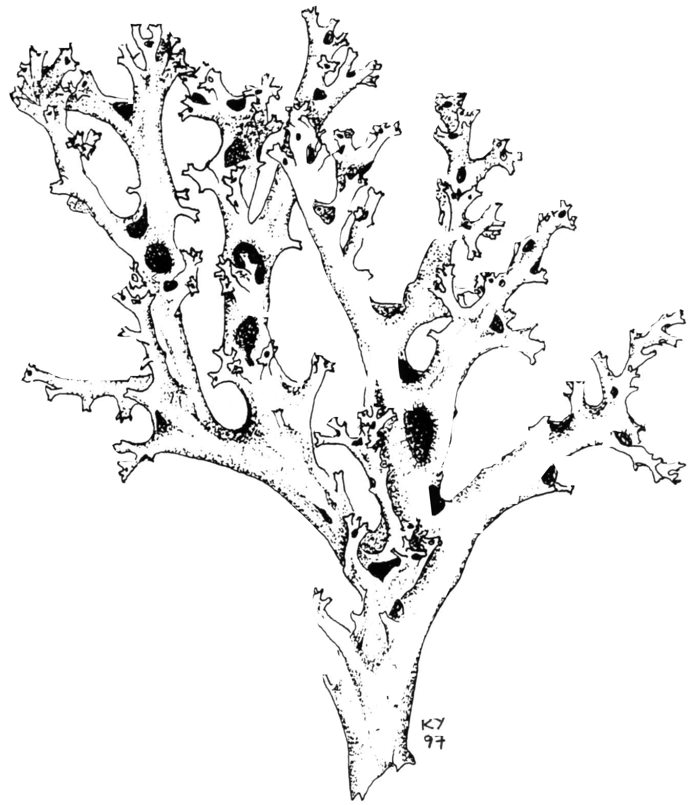
Cladonia uncialis is a closely related and similar-looking species, although its occurrence in Florida is disputed by Moore (1968). Its podetia are wide and perforate, though not at every dichotomy, and are glossy with greenish areolae (Evans 1952). The other fruticose, terrestrial species of *Cladonia* and *Cladina* which commonly co-occur with *C. perforata* can easily be distinguished from it. Although *Cladonia leporina* may sometimes have small perforations in the podetia and is occasionally confused with *C. perforata*, *C. leporina* is a darker yellow-green color, has narrower podetia with rough surfaces and can often be found with conspicuous red apothecia. *Cladonia pachycladodes* is similar in color to *C. perforata* but is more of a light bluish-grey color and has finer branches, drooping at the tips. *Cladonia subsetacea, Cladina evansii*, and *Cladina subtenuis* all have much narrower, filiform podetia, usually less than 1mm wide.

Taxonomy

The Cladoniaceae is represented in Florida by the two large, widespread, and closely related genera *Cladonia* and *Cladina*. Moore (1968) considers this conspicuous and diverse group to be one of the most important in the Florida lichen flora, represented by a total of 33 species, three of which are endemic to the state. George Llano first collected *C. perforata* Evans in 1945 from Santa Rosa Island, Florida, and in 1952, Alexander Evans described the species from this type (Buckley and Hendrickson 1988). Both Llano's and Evans' collections of *C. perforata* were purportedly from Escambia County, but Wilhelm and Burkhalter (1990) determined the actual locality to be in Okaloosa County. No other names have been applied to the species.

Distribution

In northern biomes such as boreal forests and the tundra, members of *Cladonia* and *Cladina* form continuous mats which cover the ground and provide important forage for caribou and reindeer. In temperate and subtropical regions, open rock outcrops or patches of bare ground or sand provide habitat for reindeer lichens (Thomson, 1967). Florida scrub, which is characterized in part by persistent, open patches of sand, supports a relatively rich assemblage of these terrestrial lichens. Up to eight species of reindeer lichens commonly occur in Florida scrub. *C. perforata* is the most unique member of the scrub-lichen community, by virtue of its restricted and unusual disjunct distribution and overall global rarity.



Florida perforate cladonia. *Original drawing by Rebecca Yahr*.

In 1991, the Florida Natural Areas Inventory surveyed 111 sites throughout central and coastal Florida to determine the status of *C. perforata*. A total of only 12 sites were located, six of which were at Archbold Biological Station (FWS 1993). Two additional sites were later located at Archbold Biological Station (R. Yahr, Archbold Biological Station, personal communication 1995). With one Eglin Air Force Base site in Okaloosa County, and several other more recently discovered south-central and coastal Florida locations, approximately 27 sites for *C. perforata* are currently known from four disjunct geographic regions; the counties within these regions are shown in Figure 1. The farthest and most disjunct region, supporting the only remaining North Florida site, is defined by Santa Rosa Island in Okaloosa County. This region is about 644 km northwest of the next closest region. Central Florida's Lake Wales Ridge supports the bulk of the known sites for *C. perforata*. South-coastal Martin and Palm Beach counties support three sites, and southwest Florida's Manatee County has one disjunct site for this lichen (K. DeLaney, Environmental Research Consultants, Inc., personal communication 1995).

The type locality, which was reported from Escambia County on the west side of Santa Rosa Island, was likely reported in error according to Wilhelm and Burkhalter (1990), who rediscovered *C. perforata* on the eastern end of the island. The western part of the island has scrub that should be surveyed. The current patchy distribution of *C. perforata*, represented by the fragmented scrubs on high white-sand ridges of central Florida may reflect all or only part of its historic range.

Habitat

Several of the fruticose, terrestrial *Cladonia* and *Cladina* species form a conspicuous and characteristic part of Florida's white sand scrub communities (Moore 1968). Typical habitat for *C. perforata* is found on the high sand dune ridges of Florida's peninsula, including the Atlantic Coastal and the Lake Wales Ridges. In these areas *C. perforata* is restricted to the highest, xeric white sands in sand pine scrub, typically in the rosemary phase (Abrahamson *et al*. 1984). Such rosemary scrubs, frequently referred to as "rosemary balds," are particularly well-drained and structurally open. Specific aspects of *C. perforata* microhabitat require further investigation and, presently, can only be roughly generalized with the following associated plant species: scrub oaks (*Quercus inopina, Q. geminata, Q. myrtifolia*), which are clumped and scattered throughout, sand pine (*Pinus clausa*), which dominates the tree-layer (although the canopy may be sparse or absent), and Florida rosemary (*Ceratiola ericoides*), which dominates the shrub layer. *Cladonia perforata* typically occurs in open patches of sand between shrubs in areas with sparse or no herbaceous cover.

In Highlands and Polk counties on the Lake Wales Ridge, *C. perforata* occurs at relatively higher elevations than surrounding areas, on excessively well-drained, nutrient-poor, white sands of the St. Lucie series, with pH ranging from 5.0 to 6.0 (Buckley and Hendrickson 1988, R. Yahr, personal communication 1995). At Archbold Biological Station, *C. perforata* occurs in the most xeric microsites even within rosemary scrub (E. Menges, Archbold Biological Station, personal communication 1995). A small site in xeric scrubby flatwoods on Lake Wales Ridge SF (formerly Lake Arbuckle SF) was recently discovered (R. Yahr, Archbold Biological Station, personal communication 1998). Other Lake Wales Ridge SF sites are on open rosemary scrubs or under dense sand pine in rosemary scrub. In the coastal scrubs of Jonathan Dickinson State Park in Martin County, *C. perforata* is reported from open areas in oak-dominated sand pine scrub and scrubby flatwoods. The Okaloosa County sites are on undifferentiated coastal beach sands in white-sand scrub; *C. perforata* was collected from an Okaloosa County site dominated by rosemary and "downslope into margins of gallberry swales" *(Johnson and Blythe 1986; collection deposited at Archbold Biological Station*).

Reproduction

Reproduction in the Cladoniaceae is typically by means of sexually produced spores or dispersal of vegetative fragments, either via soredia (microscopic clumps of algal cells surrounded by fungal threads which emerge from the lichen surface as a powder) or simple fragmentation (Thomson 1967). However, neither spore-producing structures nor soredia are known from *Cladonia perforata* (Thomson 1967). Presumably, the main form of reproduction is via vegetative fragmentation.

Relationship to Other Species

Cladonia perforata is a habitat-specialist, usually restricted to openings in very xeric sites. It can occur in monospecific mats or in mixed-species mats with *Cladonia leporina, Cladonia prostrata, Cladonia pachycladodes, Cladina evansii, Cladonia subsetacea*, and/or *Cladina subtenuis*. However, these other co-occurring *Cladonia* and *Cladina* species appear to be less restricted to rosemary scrub and can also be found in lower, less well-drained communities like scrubby flatwoods and flatwoods, in addition to other xeric upland habitats such as sandhills, from which *C. perforata* is notably lacking.

In addition to the more common reindeer lichen species that co-occur with *C. perforata*, associated vascular plant species may include *Serenoa repens, Sabal etonia, Lyonia ferruginea, L. fruticosa, Bumelia tenax, Asimina obovata, Persea humilis, Licania michauxii*, *Hypericum cumulicola, Polygonella basiramia, Opuntia humifusa, Lechea cernua,* and *Selaginella arenicola* (Buckley and Hendrickson 1988). *Cladonia perforata* occurs most commonly with Florida rosemary and sand pine, typically in patches of bare sand with other *Cladonia* and *Cladina* species, sometimes forming mixed-species tangled clumps. It can, however, occasionally occur in dense, long-unburned sand pine scrub on a mat of pine needles, as observed at the southernmost portion of Archbold Biological Station, on an adjacent privately owned parcel, and under dense sand pines on the Lake Wales Ridge SF (R. Yahr, Archbold Biological Station, personal communication 1995). However, Menges and Kohfeldt (1995) found that *C. perforata* decreases in dominance in sites that have gone unburned for more than 20 years. This decrease in dominance on unburned sites may be a result of a combination of factors that influence microhabitat, such as decreased insulation or increased litter accumulation.

Status and Trends

The loss of scrub habitat is the primary reason *C. perforata* is listed as endangered (58 FR 25754). Less than 15 percent of the historic distribution of scrub habitat persisted as of 1992 (FWS 1992), and land conversion to citrus and residential development continues to diminish scrub habitat almost daily. As with all species restricted to the developable upland landscape, including species of the scrubs of the Lake Wales Ridge, nearby parallel central ridges, and the Atlantic Coastal Ridge, habitat loss is the most critical concern.

In addition to habitat loss, *C. perforata* is also threatened by trampling, off-road vehicles, hurricane washover, and improper land management (Buckley and Hendrickson 1986, R. Yahr, Archbold Biological Station, personal communication 1995). Sixteen of the 27 known sites for *C. perforata* occur on dedicated conservation lands and are protected. In Highlands County eight sites are protected on Archbold Biological Station and one site is protected at the Lake Apthorpe Preserve (managed cooperatively by The Nature Conservancy and GFC). In Polk County, two sites on the Lake Wales Ridge SF were discovered by R. Yahr in 1996 (C. Weekley, DACS, personal communication 1998). In Martin County, one site occurs at Jonathan Dickinson

SP. There are three protected sites in Palm Beach County: two at the Jupiter Inlet tract, owned and managed by the BLM, and one recently discovered site on the Jupiter Ridge Natural Area (Steve Farnsworth, Palm Beach County DERM, personal communication 1998). A 1997 survey revealed approximately 5,000 lichen fragments on this site. The Okaloosa County site, on Eglin Air Force Base, occurs on a beach with restricted vehicular access, but completely open to foot traffic. In addition to the already-protected sites for *C. perforata,* the Trout Lake site in Polk County is proposed for inclusion in the State's Preservation 2000 program. Other potential sites for protection include several privately held properties in Highlands County.

A low proportion of all known sites support large areas of *C. perforata*. At only two of the Archbold Biological Station sites is this lichen very abundant, making up the dominant ground cover in most of the site with densely crowded and overlapping thalli. Abundant stands are also reported from the site at Jonathan Dickinson SP and from the east end of Santa Rosa Island.

Despite the conservation status of these sites, populations of this lichen may be extremely limited in areal extent and, therefore, subject to significant losses from local events. For example, two former Okaloosa County sites supported only small fragments of *C. perforata* prior to Hurricane Opal, which severely impacted Santa Rosa Island in October 1995. One estimate suggested that more than half of the potential habitat of *C. perforata* on the east end of the island was negatively affected by the storm, with large areas swept clean of all ground lichens or inundated with salt water (R. Yahr, Archbold Biological Station, personal communication 1995). At Archbold Biological Station, *C. perforata* occurs on eight of more than 100 discrete, available habitat patches (rosemary balds). Five of these eight sites were partially burned in a prescribed fire in 1993, but in each, the lichen persisted in unburned patches, although almost certainly in lower numbers.

Throughout its distribution, *C. perforata* is considered as rare. It has a limited areal extent and its management is further complicated by its limited reproduction and dispersal capability.

Management

Florida scrub has historically experienced variable fire frequencies and patchy high-intensity fires (Myers 1990). Scrub plant communities are therefore fire-adapted, and recover relatively quickly (Abrahamson 1984). In sand pine and rosemary scrub, however, recovery of dominant species is slower than in oak-dominated scrubs (Johnson *et al*. 1986) and open spaces between shrubs persist longer. In fire-maintained systems, low-fuel, bare sand patches may serve as refugia from fire for *C. perforata* and other lichen species which cannot survive fire. These refugia provide a local source for recolonization and population recovery.

While patch-level dynamics on a long time-scale, including local extirpation and recolonization events, are probably important in the persistence of *C. perforata* in the fire-maintained landscape, improper management may threaten the species at the site level. Due to *C. perforata*'s presumed slow growth and observed slow recolonization (Menges and Kohfeldt 1995), land managers should avoid complete burns in large areas supporting *C. perforata*. Such fires likely reduce the possibility of recolonization from unburned patches within sites or from nearby sites. Additionally, complete lack of fire is also detrimental to the species. Fire suppression creates closed canopies and causes microsite characteristics to change, possibly encouraging complete burns when a fire does occur.

Management recommendations for *C. perforata* should provide for fire-return intervals long enough to restore vigorous lichen growth and to allow regeneration of mature shrub layers, since reburning rosemary scrub too frequently can deplete its soil seed banks (Johnson 1982, Gibson and Menges 1994). Archbold Biological Station's Fire Management Plan recommends a 20 to 60 year fire interval for rosemary scrub, which is designed to allow recovery of shrub canopy while maintaining the endemic-rich open sand patches (Hawkes and Menges 1996). These factors must also be balanced with caution regarding the build-up of litter and other ground fuels over very long intervals which may contribute to homogeneous burns. Perhaps more frequent burns in adjacent habitats may serve to occasionally burn small areas of rosemary and reduce fuels enough to prevent large, complete fires. Spatially patchy fires leave unburned areas within a burned matrix from which species of *Cladonia* may recolonize, and without which, *C. perforata* may be threatened with local extinctions.

Cladonia perforata population dynamics have, to date, only been inferred from observations of occupied sites. Menges and Kohfeldt (1995) found that *C. perforata* and four other terrestrial Cladoniaceae species respond to burning by slow recolonization (within four years) and, later, by steady increases in dominance up to 20 years post fire. However, in contrast to the more common *Cladonia* and *Cladina* species which continue to increase in dominance post fire for at least 60 years, Menges and Kohfeldt (1995) found that *C. perforata* increases in dominance only until an intermediate post fire time of about 20 years, and then decreases in dominance again. Until population trends are studied, it is probably important to provide a mosaic of times-since-fire in the landscape and to encourage patchy burns if fuels have become continuous due to long-unburned conditions. Because *C. perforata*, like other lichens, cannot survive fire and likely can recolonize sites slowly and from local sources, such as unburned patches within sites, it is important to avoid complete burns in sites which support this species. Although *C. perforata* is characteristically found in open sand gaps between shrubs, it can, apparently, persist in long-unburned sites (probably for more than 50 years) under a dense sand pine canopy (R. Yahr, Archbold Biological Station, personal communication 1995). Conducting a mosaic of burns over long time frames would, therefore, be an appropriate management goal for this species.

In some cases, however, prescribed fire may be infeasible due to the proximity of residential development or due to high fuel buildup which could lead to local extirpations. In these instances, it is possible that *C. perforata* would respond well to mechanical clearings adjacent to occupied patches. Evidence of this is noted by the recolonization of some areas disturbed by off-road vehicles with a dense cover of *C. perforata* (R. Yahr, Archbold Biological Station, personal communication 1995). Research on the effects of various management regimes on *C. perforata* based on such observations may be useful in the recovery of the species.

Recent patchy burns in rosemary scrub at Archbold Biological Station and the Lake Apthorpe Preserve may be successful in promoting the persistence of this species, creating or re-opening new bare sand patches adjacent to occupied, unburned areas. A monitoring project in several sites was instituted in the winter of 1996-97 by Archbold Biological Station to investigate the rate and mode of post-fire recolonization in the peninsular region of *C. perforata*'s range; compare natural recolonization of *C. perforata* with establishment via transplantations into unoccupied suitable habitat and with previously occupied, hand-cleared sites; and to test hypotheses regarding dispersal limitations for *C. perforata*'s persistence and growth in several transplant sites.

Management of *C. perforata* should include protection of all sites from vehicle or heavy foot traffic and promoting fire management planning at sites where fire is an important part of that site's ecology. Because each site has a unique set of circumstances, appropriate management plans should be tailored to accommodate these. Unpredictable events, like hurricanes and wildfires, are best mediated by having a large number of protected sites, which provide local sources for natural recolonization and population recovery. It may be possible to reintroduce *C. perforata* into severely damaged sites, if impacts have been so severe that the nearby natural population has not been able to recolonize the site.

Little is known about the life history and ecology of *C. perforata*. This causes concern regarding its recolonization potential, since relatively large, heavy fragments may not disperse far or fast. Additionally, indeterminate branching structures which vegetatively fragment lead to problems in estimating demographic trends. Counts of individual fragments are infeasible and probably not informative, since individuals cannot be defined. Some estimate of areal coverage may be the best way to describe the population size and spread.

A review of current ecological and management research on the genus may yield valuable suggestions for applied management of *C. perforata*. Studies of boreal forest terrestrial *Cladonia* species biology and ecology, for example, may offer useful information for management of Florida's terrestrial lichen communities.

Literature Cited

Abrahamson, W.G. 1984. Post-fire recovery of Florida Lake Wales Ridge vegetation. American Journal of Botany 71:9-12.

Abrahamson, W.G., A.F. Johnson, J.N. Layne, and P.A. Peroni. 1984. Vegetation of the Archbold Biological Station, Florida: An example of the southern Lake Wales Ridge. Florida Scientist 47(4): 209-250.

Buckley, A., and T.O. Hendrickson. 1986. An update of the macrolichens of Archbold Biological Station with mphasis on the tatus of *Cladonia perforata* Evans. Unpublished Archbold Biological Station records.

Buckley, A., and T.O. Hendrickson. 1988. The distribution of *Cladonia perforata* Evans on the southern Lake Wales Ridge in Highlands County, Florida. The Bryologist 91(4):354-356.

DeLaney, K. 1995 FWS Multi-Species Recovery Team meeting. December 6-8, 1995.

Evans, A. W. 1952. The Cladoniae of Florida. Transactions of the Connecticut Academy of Arts and Sciences 38:249-336.

Farnsworth, S. 1998. Comments on techical/agency draft multi-species recovery plan for South Florida. March 19, 1998.

Gibson, D.J., and E.S. Menges. 1994. Population structure and spatial pattern in the dioecious shrub *Ceratiola ericoides.* Journal of Vegetation Science 5:337-346.

Hawkes, C. V., and E.S. Menges. 1996. The relationship between open space and fire for species in a xeric Florida shrubland. Bulletin Torrey Botany Club 123(2): 81-92.

Johnson, A.F., 1982. Some demographic characteristics of the Florida rosemary *Ceratiola ericoides* Michx. American Midland Naturalist 108: 170-174.

Johnson, A.F., W.G. Abrahamson, and K.D. McCrea. 1986. Comparison of biomass recovery after fire of a seeder (*Ceratiola ericoides*) and a sprouter (*Quercus inopina*) species from south-central Florida. American Midland Natururalist 116:423-428

Menges, E. 1995. FWS Multi-Species Recovery Team meeting. December 6-8, 1995.

Menges, E.S., and Kohfeldt, N. 1995. Life history strategies of Florida scrub plants in relation to fire. Bulletin Torrey Botany Club 122:282-297.

Moore, B.J. 1968. The macrolichen flora of Florida. The Bryologist 71(3):161-266.

Myers, R.L. 1990. Scrub and high pine. Pages 150-193 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida.

Thomson, J.W. 1967. The Lichen Genus *Cladonia* in North America. University of Toronto Press.

U.S. Fish and Wildlife Service [FWS]. 1992. draft land protection Plan for the proposed establishment of the Lake Wales Ridge National Wildlife Refuge.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery plan for nineteen central Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Weekley, C. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida January 28, 1998.

Wilhelm, G.S. and J.R. Burkhalter. 1990. *Cladonia perforata,* the northwest Florida population. The Bryologist 93:66-68.

Yahr, R. 1995. FWS Multi-Species Recovery Team Meeting. December 6-8, 1995.

Yahr, R. 1998. Comments on technical draft multi-species recovery Plan for South Florida February 5, 1998,

Recovery for the Florida Perforate Cladonia

Cladonia perforata Evans

Recovery Objective: RECLASSIFY to threatened.

Recovery Criteria

Cladonia perforata may be reclassified from endangered to threatened when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations and sites needed to assure 20 to 90 percent probability of persistence for 100 years; when these sites, within the historic range of *C. perforata*, are adequately protected from further habitat loss, degradation, and fragmentation; when these sites are managed to maintain the rosemary phase of xeric oak scrub communities to support *C. perforata*; and when monitoring programs demonstrate that these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies new ways of re-establishing populations of this species to expand its distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *C. perforata*. This species' known distribution is scattered from the panhandle area of Florida south to Martin and Palm Beach counties in South Florida with large areas having no individuals. A thorough survey is needed to determine the distribution for this species.

S1.1. Conduct surveys for additional populations of *C. perforata* in South Florida.

S1.1.1. Survey scrub and high pine habitat for *C. perforata* in Osceola, Hardee, and Hendry counties. Adequate survey work has not been performed off the Lake Wales Ridge. Sites on private property cannot be protected without survey knowledge.

S1.1.2. Continue surveys in Polk and Highlands counties. The Lake Wales Ridge has been well surveyed, though new sites are still being found. This species by nature is hard to identify and dispersed sparsely. Survey work should continue for this species.

S1.1.3. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites.

S1.2. **Maintain distribution of known populations and suitable habitat in GIS database.** Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population areas and cover, and status. This information should also be used for project review and in land acquisition activities.

S2. **Protect and enhance existing populations. Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development.** The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. **Protect populations on private land through acquisition, conservation easements, or agreements with landowners.**

S2.2. **Protect populations on public lands.** Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. **Prepare post-hurricane restoration plans for the southeast Florida counties.**

S2.4. **Enforce available protective measures.** Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *C. perforata* lives.

S2.4.1. **Initiate section 7 consultations when Federal activities may affect this species.** In particular, it will be important to consult with the Florida DOT and the Federal Highway Administration to protect occupied habitat of *C. perforata* from further fragmentation and the secondary effects of road construction.

S2.4.2. **Enforce take and trade prohibitions.** This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S2.5. **Initiate *ex situ* conservation of *C. perforata*.** *Ex situ* collections can preserve genetic diversity, prevent loss of the species, and determine ecological characteristics and habitat management needs. These collections may be instrumental in the recovery of *C. perforata*, although lichens are known to be quite difficult to culture. The efforts of organizations like the Center for Plant Conservation of the Missouri Botanical Gardens, which collect, store, and maintain the germ plasm of rare species should continue to be supported. Emphasis should be placed on culturing techniques rather than trying to maintain living symbioses.

S3. **Conduct research on life history characteristics of *C. perforata*.** Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species more specific biological information is needed.

S3.1. **Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality.**

S3.2. Continue research to better understand the mechanisms of establishment of C. perforata, the effects of translocations of fragments, and the effects of fire on survival.

S3.3. Once demographic data are known, conduct population viability and risk assessment analysis to determine the spatial distribution needed to ensure persistence of the species.

S3.4. Conduct research to assess management requirements of *C. perforata*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring will provide information on the localities of *C. perforata* sites, and on the factors contributing to any declines at each site. Site-specific management guidelines should be provided to land managers.

S4. Monitor existing populations of *C. perforata*.

S4.1. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival, and mortality. Also monitor for herbivory, disease and injury.

S4.2. Monitor the effects of various land management actions on *C. perforata*. Assess any changes in demographic characteristics of *C. perforata* in response to land management activities, such as prescribed fire, exotic plant control, *etc*.

S4.3. Develop a quantitative description of the population structure of *C. perforata*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's (or fragment's) microsite (vegetation cover, litter depth, substrate, and closest neighbors) should also be included.

S5. Provide public information about *C. perforata*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. Care is needed, though, to avoid revealing specific locality information about where *C. perforata* is found.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *C. perforata* and other rare species requires a self-sustaining, secure, number of natural populations.

S6. Establish delisting criteria. Once reclassification is achieved, research and monitoring results may provide data necessary to develop delisting criteria.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there are 15 protected sites for *C. perforata* in South Florida.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. Little xeric scrub habitat is remaining for this species; any method of securing *in situ* protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *C. perforata* populations by preventing damage from off-road vehicle use and overcollection, and by providing proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. The scrub landscape is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in this species habitat as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *C. perforata*.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *C. perforata* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation. Although recently studied, questions still exist on management reactions.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc*., on the habitats where *C. perforata* occurs.

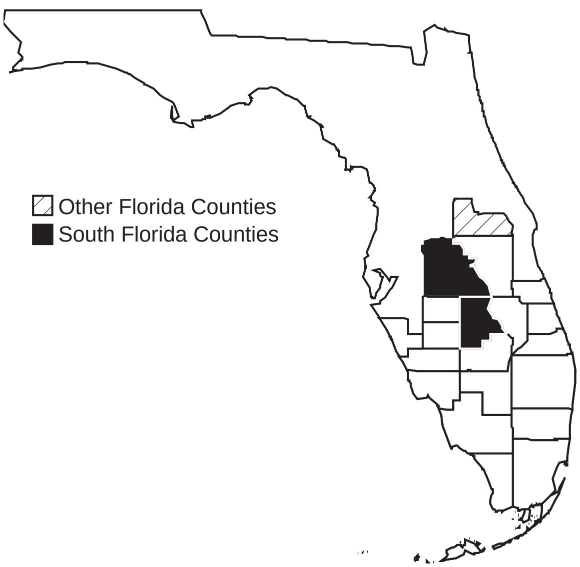
H5. Provide public information about scrub and its unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. The State's system of biological preserves depends for its funding and future success on a broad base of public understanding and support. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, the Florida Park Service, the Florida Native Plant Society and local garden clubs play crucial roles in increasing public appreciation of scrub, high pineland vegetation, and their plant species.

Pigeon Wings

Clitoria fragrans Small

Federal Status:	**Threatened (April 27, 1993)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of pigeon wings.



Pigeon wings is an erect perennial herb belonging to the pea family. The distribution of the species is limited mainly to the rapidly disappearing scrub habitat of the Lake Wales Ridge in Highlands and Polk counties. Loss of habitat to agriculture and residential development resulted in the listing of this species. Like most other imperiled scrub plants, habitat acquisition and implementation of proper land management techniques are needed to ensure the continued survival of the pigeon wings.

This account represents a revision of the existing recovery plan for the pigeon wings (FWS 1996).

Description

The pigeon wings (*Clitoria fragrans*) is a 15 to 100 cm tall, long-lived perennial herb with an erect habit. The thick horizontal root, which may grow to more than 2 m long, bears one to several purplish, glaucous, wiry, very straight stems. The somewhat leathery leaves consist of three leaflets. Leaflets of the upper leaves are obtuse at the tip and narrower than those of lower leaves (58 FR 25746).

Clitoria fragrans have chasmogamous (insect pollinating) and cleistogamous (self-pollinating) flowers. The chasmogamous flowers usually occur in pairs, each corolla consisting of one 3.5 to 4.5 cm-long (Fantz 1977) or 4.5 to 5 cm-long (Isely 1990) standard petal and a small white keel. The common name of this species refers to the petals of the chasmogamous flowers, which resemble wings (Fantz 1979). Pigeon wings plants are easily recognizable due to the inverted position of these pale purple flowers (Fantz 1979). The flowers are inverted so that the anthers and stigma touch the backs of visiting insects (the only other legume genus with inverted flowers is *Centrosema*, with two species in central Florida). The seed pod (legume) is 5 to 8 cm long and extends from the calyx (Fantz 1979). This species can be confused with *C.*

mariana but can be easily distinguished as *C. fragrans* has purplish, glaucous stems, non-twining habit, narrow leaflets, smaller flowers, and long-stipitate fruits (Fantz 1977). A detailed technical description is provided by Kral (1983).

Taxonomy

Clitoria fragrans was described and named from a Highlands County specimen in 1926 (Small 1926). The name *C. pinetorum* was recognized but never published (Fantz 1977). The North American *Clitoria* species were moved to the genus *Martiusia* by Small (1933), but were later transferred back to the genus *Clitoria* by Fantz (1977).

This herb's common name, pigeon wings, was derived because of its flowers' bird-like appearance (Fantz 1979). It is one of three species of the genus occurring in the southeastern United States. The others are the native butterfly pea *(C. mariana)* and a butterfly pea escaped from cultivation *(C. ternata)*.

Distribution

Clitoria fragrans is distributed along the Lake Wales Ridge primarily in Highlands, Orange, and Polk counties (Fantz 1977, Wunderlin *et al*. 1980, Christman 1988)(Figure 1). It was also found at one site in central Osceola County in 1964 and near Leesburg, Lake County in 1910 (Fantz 1977). It has not recently been reported from either historic locality.

Habitat

Some confusion exists with respect to the vegetative community inhabited by *C. fragrans.* Christman (1988) indicates that the species is found primarily within habitats intermediate with high pine and scrub. Christman and Judd (1990) reported the species from scrub, turkey oak barrens, and the edges of high pines. Others report *C. fragrans* from scrubby high pine, more typical of hickory-dominated scrub (hickory phase of high pineland)(E. Menges, Archbold Biological Station, personal communication 1997). This apparent disagreement indicates that more information is needed on the distribution of these plants. It also demonstrates the limits to developing and applying consistent terminology to describe a complex mosaic of vegetation.

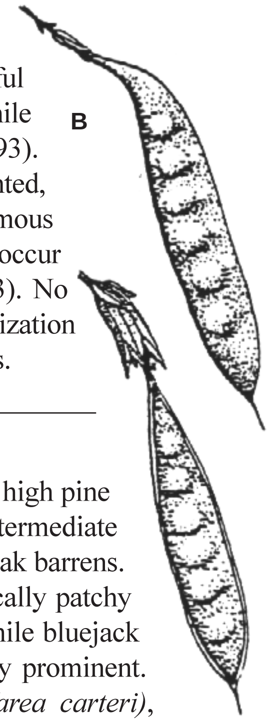
There is also disagreement about the plant's preference for white sand soils versus yellow sand soils. As mentioned above, the species has been found in turkey oak barrens and scrub hickory, both of which occur on yellow sand soils. However, Fantz (1979) regards the pigeon wings as a species of white sand soils. The species has also been seen in white sand scrub at Carter Creek, Highlands County, and has been noted in the Lake Wales Ridge SF on both white (Archbold) and yellow (Tavares) sands (FWS 1996, C. Weekley, DACS Division of Forestry, personal communication 1998).

Pigeon wings.
Original drawings by Lisa C. Magahee.

A. plant
B. fruit

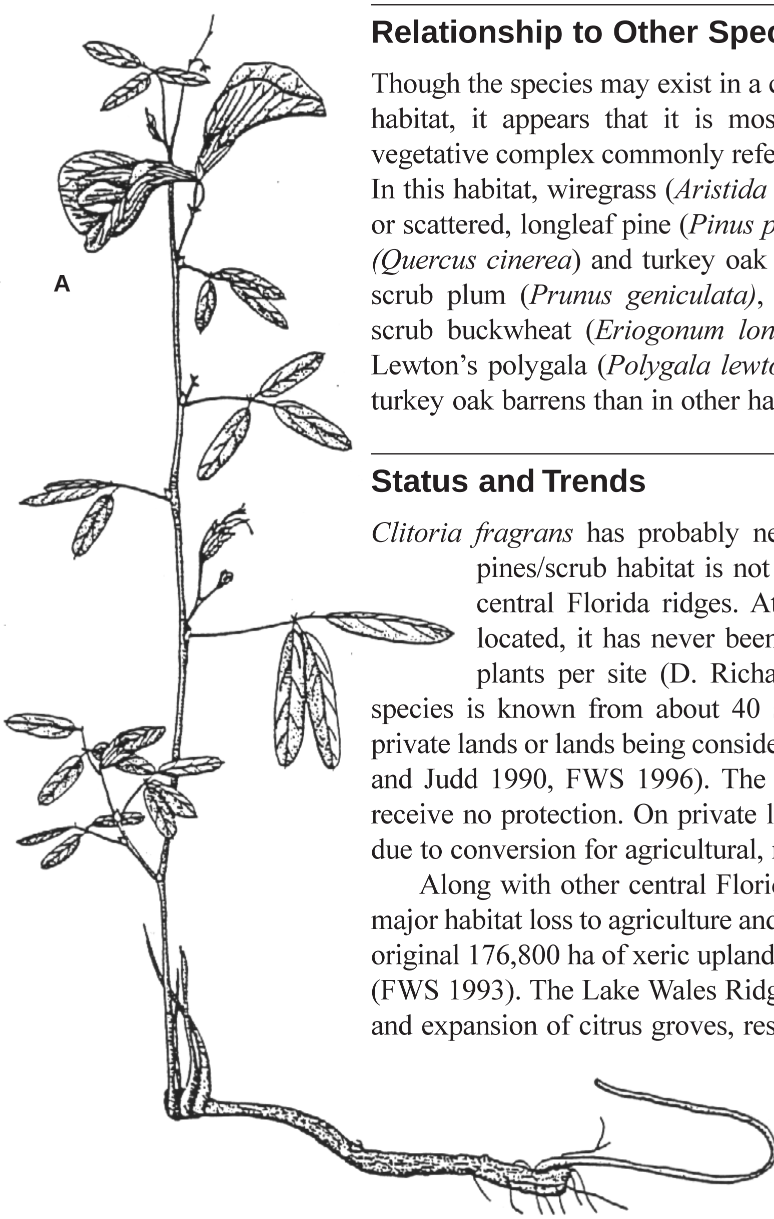
Reproduction

Clitoria fragrans has two kinds of flowers; the colorful chasmogamous flowers are pollinated by insects, while cleistogamous flowers are self-pollinating (FWS 1993). Cross-fertilization of cleistogamous flowers is prevented, since the flowers do not open (Fantz 1979). Chasmogamous flowers bloom from May to June. Cleistogamous flowers occur later in the summer through late September (FWS 1993). No information is available on the pollination vector, fertilization rate, seed production, or germination rates for this species.



Relationship to Other Species

Though the species may exist in a continuum of scrub to high pine habitat, it appears that it is most prevalent in an intermediate vegetative complex commonly referred to as the turkey oak barrens. In this habitat, wiregrass (*Aristida beyrichia*) may be locally patchy or scattered, longleaf pine (*Pinus palustris*) scattered, while bluejack *(Quercus cinerea*) and turkey oak (*Q. laevis*) are usually prominent. scrub plum (*Prunus geniculata)*, Carter's mustard (*Warea carteri)*, scrub buckwheat (*Eriogonum longifolium* var. *gnaphalifolium)*, and Lewton's polygala (*Polygala lewtonii)* also appear to be more common in the turkey oak barrens than in other habitats (Christman 1988).



Status and Trends

Clitoria fragrans has probably never been abundant since intermediate high pines/scrub habitat is not a major vegetative complex associated with central Florida ridges. At specific sites where *C. fragrans* has been located, it has never been found in large numbers; typically 20 to 30 plants per site (D. Richardson, personal communication 1995). The species is known from about 40 sites, 13 of which are protected public and private lands or lands being considered for acquisition and protection (Christman and Judd 1990, FWS 1996). The remainder of sites are on private lands and receive no protection. On private land, the species is threatened by habitat loss due to conversion for agricultural, residential and commercial uses.

Along with other central Florida scrub plants, *C. fragrans* has experienced major habitat loss to agriculture and residential development. Only 11,500 of the original 176,800 ha of xeric upland vegetation remains on the Lake Wales Ridge (FWS 1993). The Lake Wales Ridge continues to experience population growth and expansion of citrus groves, resulting in further destruction of scrub habitat. Other threats to *C. fragrans* include off-road vehicle use, trash dumping, and trampling (FWS 1993). *C. fragrans* is especially at risk because it is found in small, fragmented populations (Fantz 1979).

The total number of *C. fragrans* has been estimated to be less than 3,000 in Orange, Polk, and Highlands counties (Muller *et al.* 1989). Most populations are found on the Lake Wales Ridge in Highlands and Polk counties (Fantz 1977, Wunderlin *et al*. 1980, Christman 1988), where they are protected at Archbold Biological Station, Lake Wales Ridge SF and SP, Saddle Blanket Lakes, Lake Apthorpe, Tiger Creek, and at Bok Tower Gardens in the Ridge Pine Nature Preserve and in the surrounding natural buffer areas of the Gardens. The species can also be found at the Air Force's Avon Park Bombing Range, and at two areas undergoing active acquisition efforts (FWS 1993). The species may also exist in suitable, unsurveyed habitat within and adjacent to its known range.

Management

Florida scrub has historically experienced variable fire frequencies and patchy high-intensity fires (Myers 1990). Scrub plant communities are therefore fire-adapted, and recover relatively quickly (Abrahamson 1984). The fire ecology of the turkey oak barrens varies slightly from surrounding scrub and high pine. The irregular pattern of hills, valleys, and wetlands affects the frequency and magnitude of fires in this habitat. Periods of relatively frequent fires favor high pine species, while periods of infrequent fire favor scrub species. The result of this changing fire regime is a plant complex in which neither scrub nor high pine vegetation dominate.

Studies at Archbold Biological Station have documented positive post fire responses in flowering and vegetative growth of *C. fragrans* (Menges, Archbold Biological Station, personal communication 1997). Decreased flowering within one year after burning suggests fire suppression and canopy closure adversely affect this plant, resulting in reduced vegetative vigor and reproduction. However, the plant has been observed flowering in a location that had not been burned in 30 years, indicating that *C. fragrans* will persist for many years under suboptimal conditions. Even though plants may persist with infrequent fire, we believe that fire management is essential to the long-term survival of this species. *C. fragrans'* dependence on fire is particularly evident when considering the quick and profuse blooming in response to fire. Adequate management is still needed at many of the protected sites.

Several ongoing habitat acquisition efforts are intended to benefit *C. fragrans*, along with other threatened and endangered plant species in central Florida. Florida's Conservation and Recreation Lands program (CARL) and The Nature Conservancy are acquiring scrub land for preservation, and the FWS plans to add to Lake Wales Ridge NWR. Populations of *C. fragrans* will also benefit as the FWS undertakes protection of other federally listed plants and the endangered Florida scrub-jay (*Aphelocoma coerulescens*), an inhabitant of the scrub vegetation on Lake Wales Ridge. Critical habitat has not been designated for the pigeon wings, since designation could increase the risk of collection and/or extermination (FWS 1993).

The number and distribution of *C. fragrans* has been greatly reduced. It is clear that additional losses of habitat and individuals will occur as more than half of the known remaining sites are on private lands and are afforded no protection. Though protected sites represent a small fraction of the historic distribution of many endemic scrub plants, a number of *C. fragrans* sites are, or soon will be, protected by public and private purchase and conservation efforts. Although more than half of the remaining sites where this species occurs are still afforded no protection, current conservation efforts may be sufficient to ensure long-term survival of this plant. On those protected sites described above, land management efforts are targeting restoration and maintenance of scrub and high pine vegetative complexes. Management of other public scrub habitats will likely favor most endemic scrub plants, including *C. fragrans*. Management of scrub habitat on Avon Park AFR appears to be successful as many scrub endemics are responding well to their management activities. Monitoring of turkey oak barrens' response to fires regime and other management tools used in scrub and high pine habitats will help determine which techniques most effectively maintain the turkey oak barrens vegetative complex.

Abrahamson, W.G. 1984. Post-fire recovery of the Florida Lake Wales Ridge

Literature Cited

vegetation. American Journal of Botany 71:9-21.

Christman, S.P. 1988. Endemism and Florida's interior sand pine scrub. Final project report submitted to Florida Game and Fresh Water Fish Commission, Nongame Wildlife Program project GFC-84-101; Tallahassee, Florida.

Christman, S.P. and W.S. Judd. 1990. Notes on plants endemic to Florida scrub. Florida Scientist. 53(1)52-73.

Fantz, P.R. 1977. A monograph of the genus *Clitoria* (Leguminosae:Glycineae). Ph.D. dissertation, University of Florida; Gainesville, Florida.

Fantz, P.R. 1979. Pigeon-wings. Pages 77-79 *in* D.B. Ward, ed. Rare and endangered biota of Florida, volume V: Plants. University Presses of Florida; Gainesville, Florida.

Isely, D. 1990. Vascular flora of the southeastern United States, volume 3, part 2. Leguminosae (Fabaceae). University of North Carolina Press; Chapel Hill, North Carolina.

Kral, R. 1983. A report on some rare, threatened, or endangered forest-related vascular plants of the south, volume I, Isoetaceae through Euphorbiaceae, Technical publication R8-TP 2, U.S. Forest Service; Atlanta, Georgia.

Menges, E. 1997. Meeting discussion, 23 January, 1997.

Muller, J.W., E.D. Hardin, D.R. Jackson, S.E. Gatewood, and N. Caire. 1989. Summary report on the vascular plants, animals and plant communities endemic to Florida. Nongame wildlife program technical report number 7. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Myers, R.L. 1990. Scrub and high pine. Pages 150-193 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University Presses of Florida; Gainesville, Florida.

Small, J.K. 1926. A new butterfly-pea from Florida (*Clitoria fragrans*). Torreya 26:56-57.

Small, J.K. 1933. Manual of the Southeastern flora. University of North Carolina Press; Chapel Hill, North Carolina.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery plan for nineteen central Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Weekley, C. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. January 28, 1998.

Wunderlin, R.P., D. Richardson, and B. Hansen. 1980. Status report on *Clitoria fragrans*. Unpublished report, U. S. Fish and Wildlife Service; Jacksonville, Florida.

Recovery for the Pigeon Wings

Clitoria fragrans Small

Recovery Objective: **DELIST** the species once recovery criteria are met.

Recovery Criteria

Clitoria fragrans may be delisted when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations and sites needed to ensure 95 percent probability of persistence for 100 years; when these sites, within the historic range of *C. fragrans*, are adequately protected from habitat loss, degradation, and fragmentation; when these sites are managed to maintain the ecotone between xeric oak scrub and high pine that supports *C. fragrans*; and when monitoring programs demonstrate that populations of *C. fragrans* on these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species.

Species-level Recovery Actions

S1. Determine current distribution of *C. fragrans*. Some portions of *C. fragrans*'s range have been well surveyed, yet a total distribution has not been ascertained for this species. A thorough survey is needed to determine the distribution for this species.

S1.1. Conduct surveys for additional populations of *C. fragrans*.

S1.1.1. Continue surveys in Polk and Highlands counties. The Lake Wales Ridge has probably been adequately surveyed, though new sites for *C. fragrans* may still be found.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. Maintain distribution of known populations and suitable habitat in GIS database. Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. Acquire or otherwise protect privately owned habitat through acquisition, conservation easements, or agreements with landowners.

S2.2. Protect populations on public lands. Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. Use local or regional planning to protect habitat. Utilize available regional and county planning processes to encourage protection of suitable habitat, both unoccupied and occupied of *C. fragrans*.

S2.4. Continue *ex situ* conservation. *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *C. fragrans*.

S2.4.1. Conserve germ plasm. The seed for this species is not presently in long-term storage.

S2.4.2. Maintain *ex situ* collection. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *C. fragrans* as part of the National Collection.

S2.5. Enforce available protective measures. Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *C. fragrans* lives.

S2.5.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. Enforce take and trade prohibitions. This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. Conduct research on life history characteristics of *C. fragrans*. Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species, more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *C. fragrans*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring information will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S4. Monitor populations of *C. fragrans*.

S4.1. Develop monitoring protocol to assess population trends for *C. fragrans*.

S4.1.1. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival, and mortality. Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. Monitor the effects of various land management actions on *C. fragrans*. Assess any changes in demographic characteristics of *C. fragrans* in response to land management activities, such as prescribed fire, exotic plant control, *etc.*

S4.2. Develop a quantitative description of the population structure of *C. fragrans*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) should also be included.

S5. Provide public information about *C. fragrans*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. Care is needed, though, to avoid revealing specific locality information about where *C. fragrans* is found.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *C. fragrans* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there are eight protected sites for *C. fragrans* in Polk and Highlands counties.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *C. fragrans* populations by preventing damage from off-road vehicle use, and overcollection, and by providing proper management of habitat, including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *C. fragrans.*

H1.2.3. Control access to areas where listed plants are growing. Collection, trampling, and off-road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *C. fragrans* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc.*, on the habitats where *C. fragrans* occurs.

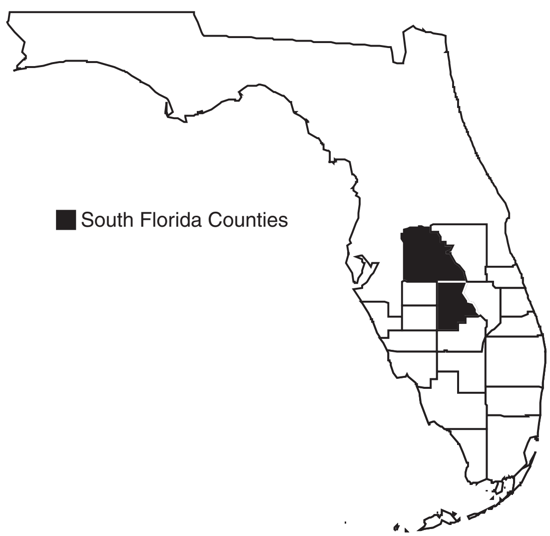
H5. Provide public information about scrub and its unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the SFWMD, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Short-leaved Rosemary

Conradina brevifolia Shinners

Federal Status:	**Endangered (July 12, 1993)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. Distribution of the short-leaved rosemary.



The short-leaved rosemary is one of five shrubby mints found in the central Florida scrub. It inhabits white sand scrub on the Lake Wales Ridge in Polk and Highlands counties. The short-leaved rosemary occurs in about 30 sites whose combined areas total less than 2,000 ha. This species is threatened with extinction because of its restricted range and habitat destruction from residential, commercial, and agricultural land conversions. It is currently protected or will be protected within three parcels of public land. Specific land management practices that benefit this species are not known, but management for other associated scrub endemics may ultimately be useful in protecting and managing the short-leaved rosemary.

This account represents a revision of the existing recovery plan for the short-leaved rosemary (FWS 1996).

Description

The short-leaved rosemary (*Conradina brevifolia*) is a short-lived, erect, woody, perennial shrub that reaches about 1 m in height (Kral 1983). It is very similar to the relatively widespread, and quite variable *C. canescens* of the Florida panhandle, Alabama, and Mississippi, and it is similar to the endangered *C. glabra* of the Apalachicola bluffs (Gray 1965, FWS 1994). As its name implies, *C. brevifolia's* alternate leaves are shorter than *C. canescens.* The larger leaves on well-developed flowering branches are 6.0 to 8.2 mm long, and mostly shorter than the internodes, whereas *C. canescens'* leaves are 7 to 20 mm long and are mostly longer than the internodes. *C. brevifolia* also tends to have more flowers per axil than *C. canescens*: one to six per axil versus one to three in *C. canescens*.

Taxonomy

The short-leaved rosemary is one of five shrubby mints in the interior central Florida scrub. The others are *Calamintha ashei*, *Dicerandra frutescens, D. christmanii*, and a

Dicerandra population whose taxonomic status is unresolved. *C. brevifolia* was described as a new species by Shinners (1962).

Taxonomic reviews of *Conradina* have upheld *C. brevifolia's* treatment as a distinct species (Gray 1965, Wunderlin *et al*. 1980, Kral 1983, Kral and McCartney 1991). However, Wunderlin (1982) and DeLaney and Wunderlin (1989) included *C. brevifolia* in *C. canescens*, without noting *C. brevifolia* as a synonym. Gray (1965) showed that *C. brevifolia*, like *C. glabra*, is morphologically not strongly differentiated from, and is less variable than, *C. canescens*.

Distribution

This species has a very restricted range in the middle of the Lake Wales Ridge. It occurs at only about 30 sites whose total area is less than 2,000 ha in the Sebring-Avon Park area of Highlands and Polk counties (Christman 1988, Christman and Judd 1990) (Figure 1).

Habitat

Conradina brevifolia inhabits white sand scrub with a scattered overstory of sand pine (*Pinus clausa*), interspersed with evergreen scrub oaks (*Quercus* spp.). *C. brevifolia* is usually found interspersed in clearings with other small shrubs and herbs (FWS 1992). Like all other xeric scrub communities, oak scrub is a fire-dependent vegetative complex that persists when burned at intervals of 10 to 20 years. In the slower-growing oak scrub of Florida's ridges, including Highlands and Polk counties, fire frequencies of 15 to 20 years are sufficient to maintain the vegetative diversity of the scrub habitats.

Reproduction

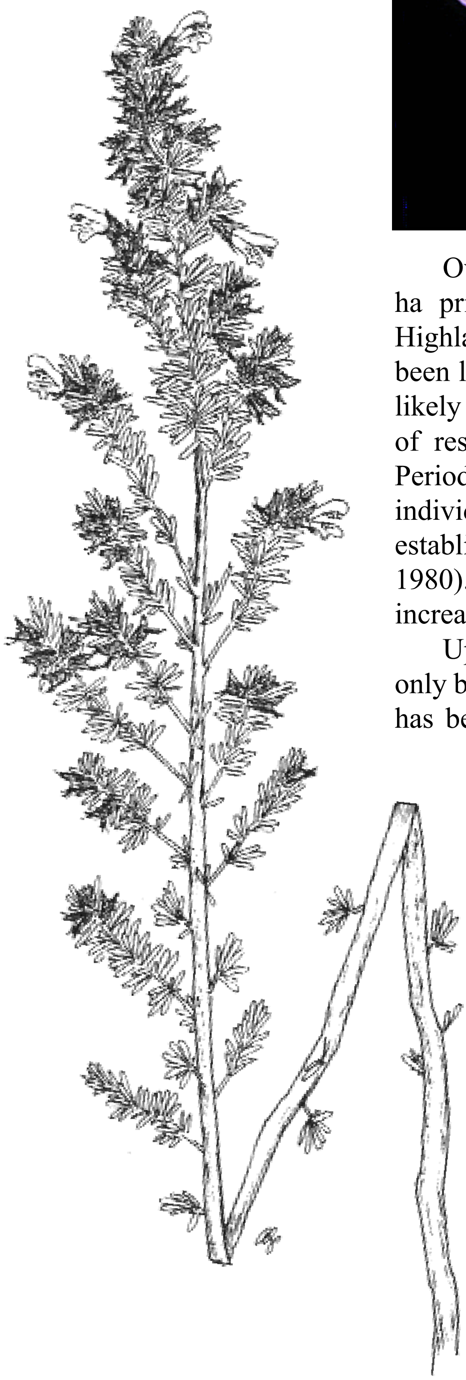
We have no species-specific data on the reproductive biology of *C. brevifolia.* In fire-dependent scrub habitat, most plants respond to fire by sprouting while a few recruit from seed that is stored in the sand (Johnson and Abrahamson 1990). Anecdotal information suggests that *C. brevifolia* does not persist when burned, clipped, or defoliated (FWS 1996). If this is true, sprouting and other forms of asexual reproduction are unlikely.

Relationship to Other Species

The ecology of *C. brevifolia* has not been studied and special or unique relationships with other species are not known.

Status and Trends

The distribution of *C. brevifolia* is more restricted than most other rare endemic scrub plants. This species was probably never common nor widely distributed since apparently suitable, but unoccupied habitat exists outside of its current range. However, since surveys in the 1980s, there have been substantial losses and fragmentation of scrub habitat in Highlands and Polk counties (FWS 1992, 1996).



Short-leaved rosemary. *Original drawing by Anna-Lisa King; original flower photograph by Steve Shirah.*

Overall, scrub habitat has declined in total area from an estimated 32,000 ha prior to human settlement to about 11,000 ha (Christman 1988). In Highlands County, it was estimated that about 74 percent of scrub habitat had been lost by 1981; by now the loss must be much greater. Similar losses have likely occurred in Polk County. Most habitat destruction has occurred because of residential and agricultural expansion in Highlands and Polk counties. Periodic mowing has apparently caused a decline in the total number of individuals in some locations; however, no permanent plots have been established to monitor the fate of individuals in mowed sites (Wunderlin *et al.* 1980). Where habitat has not been destroyed, it is often degraded because of increased competition due to fire suppression.

Upon completion of land acquisition efforts, *C. brevifolia* will probably only be protected at five of the 30 scrub sites where it is currently found. It also has been established at Bok Tower Gardens as part of the Center for Plant Conservation's National Collection of Endangered Species. Scrub sites at Avon Park Lakes, Carter Creek, and Saddle Blanket Lakes are critical for its conservation and additional acquisition in these areas is needed to secure *C. brevifolia*. Continued land acquisition is planned for all three sites, although residential development at Avon Park Lakes limits preserve options there (FWS 1996).

Management

No specific information is available on the ecological requirements of *C. brevifolia*. However, existing information on the natural fire regimes of various scrub communities suggest that the white sand, scrub oak-dominated vegetative complex within which *C. brevifolia* is commonly found, generally requires periodic, patchy, high-intensity fires. Fire cycles of 15 to 20 years reduce overstory competition and provide disturbed open sandy patches within which obligate seeding species may re-establish. We suspect that *C. brevifolia* does not persist after fire (FWS 1996), or other disturbance, but readily germinates post-fire from seeds stored in the sand (Menges 1992).

In order to effectively conserve *C. brevifolia*, therefore, management of protected lands must restore and maintain scrub communities. To achieve this, land managers must mimic the timing and intensity of natural fire regimes. If adequate fire management programs are developed for protected lands, *C. brevifolia* is likely to persist in the wild.

The restricted range and distribution of this species may also require conservation measures to protect against the possibility of catastrophic, stochastic, natural events that could eliminate it from the wild or greatly reduce its genetic diversity. These measures may include augmentation of existing populations, introduction into suitable unoccupied habitat, and germ plasm conservation.

Literature Cited

Abrahamson, W.G. 1984. Post-fire recovery of Florida Lake Wales Ridge vegetation. American Journal of Botany 71:9-21.

Christman, S.P. 1988. Endemism and Florida's interior sand pine scrub. Final report no. GFC-84-101, Florida Game and Fresh Water Fish Commission, Nongame Wildlife Program; Tallahassee, Florida.

Christman, S.P. and W.S. Judd. Notes on plants endemic to Florida scrub. Florida Scientist 53:52-73.

DeLaney, K.R., and R.P. Wunderlin. 1989. A new species of *Crotalaria* (Fabaceae) from the Florida Central Ridge. Sida 13:315-324.

Gray, T.C. 1965. A monograph of the genus *Conradina* A. Gray (Labiatae) from northeastern peninsular Florida. Sida 14:391-398.

Johnson, A.F. and W.G. Abrahamson. 1990. A note on the fire responses of species in rosemary scrubs on the southern Lake Wales Ridge. Florida Scientist 53:138-143.

Kral, R. 1983. A report on some rare, threatened, or endangered forest-related vascular plants of the South. USDA Forest Service, technical publication R8-TP 2; Atlanta, Georgia.

Kral, R., and R.B. McCartney. 1991. A new species of *Conradina* (Lamiaceae) from northeastern peninsular Florida. Sida 14:391-398.

McCormick, K.D., M.A. Deyrup, E.S. Menges, S.R. Wallace, J. Meinewald, and T. Eisner. 1993. Relevance of chemistry to conservation of isolated populations: The case of volatile leaf components of *Dicerandra* mints. Proceedings of the National Academy of Science USA 90:7701-7705.

Menges, E.S. 1992. Habitat preferences and responses to disturbance for *Dicerandra frutescens*, a Lake Wales Ridge (Florida) endemic plant. Bulletin of the Torrey Botanical Club 119(3):308-313.

Menges, E.S. 1995. Report on 1994 contract experimental research and monitoring of four species of endangered plants on the Lake Wales Ridge, Florida. Report to Florida Department of Agriculture, Division of Forestry, FDACS Contract 2136; Tallahassee, Florida.

Shinners, L.H. 1962. Synopsis of *Conradina* (Labiatae). Sida 1:84-88.

U.S. Fish and Wildlife Service. 1992. Endangered and threatened species of the southeast United States (The Red Book). Prepared by Ecological Services, Division of Endangered Species, Southeast Region, Government Printing Office; Washington, D.C.

U.S. Fish and Wildlife Service (FWS). 1994. Recovery plan for Apalachicola rosemary (*Conradina glabra*); U.S. Fish and Wildlife Service; Atlanta, Georgia.

U.S. Fish and Wildlife Service (FWS). 1996. Recovery Plan for nineteen central Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Wunderlin, R.P., D. Richardson, and B. Hansen. 1980. Status report on *Conradina brevifolia.* U.S. Fish and Wildlife Service; Jacksonville, Florida.

Wunderlin, R. 1982. A guide to the vascular plants of central Florida. University Presses of Florida; Gainesville, Florida.

Recovery for the Short-leaved Rosemary

Conradina brevifolia Shinners

Recovery Objective: STABILIZE, then reclassify to threatened.

Recovery Criteria

The short-leaved rosemary may be considered stabilized when existing populations, within its historic range, are adequately protected from further habitat loss, degradation, and fire suppression. These sites must also be managed to maintain sand pine scrub. Land acquisition is critical for this species. The most important sites for acquisition are the Carter Creek scrub tract and Avon Park Lakes site.

Reclassification to threatened of this species will be considered when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations required to ensure 20 to 90 percent probability of persistence for 100 years; when these populations, within the historic range of *C. brevifolia,* are adequately protected from further habitat loss, degradation, and fire suppression; when these sites are managed to maintain sand pine scrub; and when monitoring demonstrates that these sites support sufficient population sizes, are distributed throughout the historic range, and are sexually or vegetatively reproducing at sufficient rates to maintain the population.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *C. brevifolia.* Some portions of *C. brevifolia*'s range have been well surveyed yet a total distribution has not been ascertained for this species. A thorough survey is needed to determine the distribution for this species.

S1.1. Conduct surveys for additional populations of *C. brevifolia.*

S1.1.1. Continue surveys in Polk and Highlands counties. The Lake Wales Ridge has probably been adequately surveyed, though new sites for *C. brevifolia* may still be found.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. Maintain distribution of known populations and suitable habitat in GIS database. Map existing populations and assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection.

S2.1. Acquire or protect privately owned habitat through acquisition, conservation easements, or agreements with landowners. Acquisition of Saddle Blanket Lakes, Carter Creek, and Avon Park Lakes is crucial to the survival of this species.

S2.2. Protect populations on public lands. Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. Use local or regional planning to protect habitat. Utilize available regional and county planning processes to encourage protection of suitable habitat, both unoccupied and occupied of *C. brevifolia*.

S2.4. Continue *ex situ* conservation. *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *C. brevifolia*.

S2.4.1. Conserve germ plasm. The seed for this species is not presently in long-term storage.

S2.4.2. Maintain *ex situ* collection. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *C. brevifolia* as part of the National Collection.

S2.5. Enforce available protective measures. Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *C. brevifolia* is found.

S2.5.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. Enforce take and trade prohibitions. This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. Conduct research on life history characteristics of *C. brevifolia*. Little is known of the basic biology and ecology of this species. To effectively recover this species more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *C. brevifolia*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring information will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S4. Monitor populations of *C. brevifolia*.

S4.1. Develop monitoring protocol to assess population trends for *C. brevifolia*.

S4.1.1. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival, and mortality. Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. Monitor the effects of various land management actions on *C. brevifolia*. Assess any changes in demographic characteristics of *C. brevifolia* in response to land management activities, such as prescribed fire, exotic plant control, *etc.*

S4.2. Develop a quantitative description of the population structure of *C. brevifolia*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data are also needed about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors).

S5. Provide public information about *C. brevifolia*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit, since the recovery of *C. brevifolia* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. Of the 30 sites known to support *C. brevifolia* in Polk and Highlands counties, only five are protected.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of protecting habitat that supports *C. brevifolia* should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *C. brevifolia* populations by preventing habitat damage from off-road vehicle use and overcollection, and by providing proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. Appropriate seasonality and a variable interval in fire return are important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. Scrub vegetation is naturally made up of islands of suitable and unsuitable habitat. To replicate this landscape pattern, sites should be burned to create a mosaic of successional stages when possible.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other habitats in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *C. brevifolia*.

H1.2.3. Control access to areas where listed plants are growing. Collection, trampling, and off-road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer areas remaining, they may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species may be reintroduced if natural colonization is no longer possible.

H3. Conduct habitat-level research projects. Study the response of *C. brevifolia* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. **Monitor habitat/ecological processes.** Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc.*, on the habitats where *C. brevifolia* occurs.

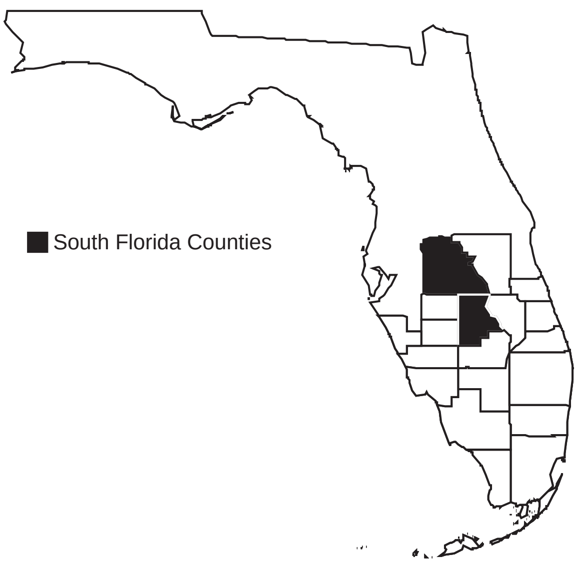
H5. **Provide public information about scrub and its unique biota**. Educational programs, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing programs by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the SFWMD, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating information about these unique communities.

Avon Park Harebells

Crotalaria avonensis (K.R. DeLaney and Wunderlin)

Federal Status:	**Endangered (April 27, 1993)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of Avon Park harebells.



The principal cause of decline of the scrub community of central Florida's Lake Wales Ridge is conversion of high pineland and scrub for agricultural purposes (principally citrus), and for commercial, residential, and recreational purposes. *Crotalaria avonensis* is one of the many scrub species that have suffered loss of habitat. As a result, it was federally listed as an endangered plant in 1993.

This account represents a revision of the existing recovery plan for the Avon Park harebells (FWS 1996).

Description

Avon Park harebells (*Crotalaria avonensis*) is a spreading, perennial herb with one to three moderately hairy, flowering stems that may grow 2 to 10 cm above the surface. It has a large taproot, up to 14 mm thick and 40 cm long. The leaves of this plant are 8 to 19 mm long, broadly elliptic or round, somewhat succulent, and coated with white or yellowish-white hairs. The stems terminate in flowering racemes. Flowering is from March until June. The flower, shaped like a typical pea flower, has a yellow corolla 8 to 9 mm long. The seed pods are inflated and 14 to 25 mm long. These pods are tan to grey or maroon, and can be nearly as long as the upright stems that hold them in place. The pods contain up to 18 seeds, chestnut to maroon in color and 3.4 to 3.8 mm long by 2.4 to 2.6 mm wide. The plant generally appears to resemble clusters of fuzzy grayish leaves hugging the ground and sometimes appears bushy (DeLaney and Wunderlin 1989).

Taxonomy

C. avonensis is a member of the pea family (Fabaceae/Leguminosae). This small herb with large seed pods was not named until 1989, evidently because very few specimens had ever been collected and they had not been examined by taxonomists. This species is most closely related to *C. rotundifolia*, a variable species that ranges from Virginia to Panama (DeLaney and Wunderlin 1989). *Crotalaria* is a very large, mostly tropical genus that includes a number of robust annual weeds, all with inflated "rattlebox" seed pods. It has been suggested that this endemic is a relic of the Miocene on the southern Lake Wales Ridge (DeLaney and Wunderlin 1989).

Distribution

Avon Park harebells is one of the most narrowly distributed of the Lake Wales Ridge endemics, having only been identified at three sites in Polk and Highlands counties (DeLaney and Wunderlin 1989, The Nature Conservancy 1991) (Figure 1). Specifically, its distribution includes the Avon Park Lakes acquisition area and the Saddleblanket Lakes State Preserve in Polk County, and the Carter Creek acquisition area in Highlands County.

Habitat

This species inhabits scrub communities found on the Lake Wales Ridge where it typically grows in full sun, on bare white sand, or in association with clumps of *Cladonia* lichens. However, it may also occur in the partial shade of other plants (DeLaney and Wunderlin 1989). It may also grow along trails, open edges, or previously disturbed roadbeds. The soils associated with this species have been classified as Archbold and Satellite sands (The Nature Conservancy 1991). Like other small scrub endemics, it appears to depend on bare patches of sand to become established.

Reproduction

Flowering begins in mid-March and continues profusely until June. After flowering, this deciduous plant enters a vegetative phase, forming clusters of stems that give a clumped or rosette appearance. They are then dormant from late fall or early winter until March (DeLaney and Wunderlin 1989). Demographic information on pollinators, seed dispersers, and seed viability is lacking for this species.

Relationship to Other Species

Avon Park harebells are found in association with clumps of *Cladonia* lichens (DeLaney and Wunderlin 1989). It seems immune to allelopathic effects from shrubs, and it invades disturbed areas (K. DeLaney, personal communication 1995). Other plants *C. avonensis* may be found in association with include *Chionanthus pygmaea*, *Bonamia grandiflora*, *Calamintha ashei*, *Conradina canescens*, *Liatris ohlingerae*, *Paronychia chartacea*, *Hypericum cumulicola*, *Polygonella basiramia*, and *P. myriophylla* (DeLaney *et al*. 1990).

In addition to these plant associates, galls have been observed on the stem tip of this species (The Nature Conservancy 1991), however, the causative organism has not been identified.

Avon Park harebells. *Original photograph by George Jenkins.*

Status and Trends

The principal cause of decline of central Florida's upland vegetation is conversion of high pineland and scrub for agricultural purposes (principally citrus groves), and for commercial, residential, and recreational purposes. Peroni and Abrahamson (1985) used aerial photography to determine that in Highlands County, 64.2 percent of the xeric vegetation (scrub, scrubby flatwoods, and southern ridge sandhills) present before settlement had been destroyed by 1981. An additional 10.3 percent of the xeric vegetation was moderately disturbed, primarily by road construction for residential subdivisions. The total remaining xeric vegetation was approximately 9,713 ha. Similar conditions are present in Polk County. Christman's (1988) estimate of scrub habitat loss for the Lake Wales, Lake Henry and Winter Haven Ridges indicated that approximately 11,129 ha out of the original 31,000 ha of scrub vegetation remain in this area. This number has, undoubtedly continued to decrease in the last 10 years, and should be viewed as an optimistic estimate of remaining scrub habitat on these ridges.

It has been stated that a population of *C. avonensis* should have 100 or more plants in appropriate habitat (The Nature Conservancy 1991). One population measured had a density of 0.016 plants/m^2, and densities as high as

20 plants/m^2 have been recorded. At the protected Saddleblanket Lakes site, the *C. avonensis* population was estimated by Doria Gordon (The Nature Conservancy, personal communication 1995) at 200 plants. Avon Park Lakes, a platted subdivision, is developing fast enough to make land acquisition difficult and was excluded from the Lake Wales Ridge NWR acquisition program for this reason. In addition, the area is invaded by cogon grass (E. Menges, Archbold Biological Station, personal communication 1995). Difficulties in land acquisition also hamper protection efforts for the Carter Creek site.

Avon Park harebells are threatened by residential and agricultural development. Road-side soil stabilization through the placement of shell or sod may preclude the establishment of *C. avonensis.* Illegal trash dumping in scrub habitat may also eliminate open areas that could be colonized by this species. Off-road vehicle traffic has already damaged the Avon Park Lakes population, and will continue to be a problem until the sites are protected.

Management

Avon Park harebells are maintained at Bok Tower Gardens in the national endangered plant collection. It is known to occur at only three sites where protection is feasible. All three sites are targeted for land acquisition, and one, Saddle Blanket Lakes, is substantially protected already. Protected sites need to be free from exotic plant species invasion and soil disturbance.

This plant has been successfully propagated in *ex situ* collections and should be a good candidate for population reestablishment. The population at Saddleblanket Lakes is currently being monitored with permanent plots; however, more information on seed viability and recruitment is needed.

Monitoring of the status of this species is essential. So little is known on the ecology of *C. avonensis* that formulating appropriate management plans may be difficult. The fact that it will invade slightly disturbed areas may be advantageous for its continued survival.

Literature Cited

Christman, S. 1988. Endemism and Florida's interior sand pine scrub. Final project report, project no. GFC-84-101. Submitted to Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

DeLaney, K.R. 1995. FWS Multi-Species Recovery Team meeting December 6-8.

DeLaney, K.R., and R.P. Wunderlin. 1989. A new species of *Crotalaria* (Fabaceae) from the Florida Central Ridge. Sida 13:315-324.

DeLaney, K.R., and R.P. Wunderlin, and B. Hansen. 1990. Status report on *Crotalaria avonensis*. Report to the U.S. Fish and Wildlife Service. Unpublished report.

Gordon, D. 1995. FWS Multi-Species Recovery Team meeting December 6-8.

Menges, E. 1995. FWS Multi-Species Recovery Team meeting December 6-8.

The Nature Conservancy. 1991. Element stewardship abstract for *Crotalaria avonensis,* tortoise bells. The Nature Conservancy. Arlington, Virginia.

Peroni, P.A., and W.G. Abrahamson. 1985. A rapid method for determining losses of native vegetation. Natural Areas Journal 5:20-24.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery plan for nineteen central Florida Scrub and High Pineland Plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Recovery for the Avon Park Harebells

Crotalaria avonensis (K.R. DeLaney and Wunderlin)

Recovery Objective: **PREVENT EXTINCTION**, then stabilize.

Recovery Criteria

The Avon Park harebells will, most likely, never reach a level at which reclassification could be possible. The objective of this recovery plan is to increase existing populations and prevent extinction. This species may be considered stabilized when existing populations, within the historic range, are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression. These sites must also be managed to support *C. avonensis*.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be developed if new information identifies ways of re-establishing populations of this species to expand its distribution within its historic range.

Species-level Recovery Actions

S1. **Determine current distribution of *C. avonensis.*** This species' known distribution is isolated to Polk and Highlands counties. Additional surveys of scrub habitat with appropriate soils should be conducted in these two counties. A geographic information systems database should be developed to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review and in land acquisition activities.

S2. **Protect and enhance existing populations.** Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or residential development. The remaining habitat is fragmented into small parcels and in many cases, isolated.

S2.1. **Protect populations on public lands.** Develop land management plans that incorporate prescribed burning, invasive/exotic vegetation control, and controlled off-road vehicle access.

S2.2. **Continue *ex situ* conservation.** Collections held *ex situ* will be instrumental for preserving the genetic diversity, evaluating the ecological requirements, and preventing the loss of *C. avonensis*.

S2.3. **Conserve germ plasm.**

S2.4. **Enforce available protective legislation.** State, Federal, tribal and local regulations should be used to protect this species from overcollection and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *C. avonensis* is found.

S2.4.1. **Initiate section 7 consultation when applicable.** Section 7 of the Endangered Species Act applies to Federal activities that may affect listed species.

S2.4.2. **Encourage implementation of management plans.** Federal agencies are obligated under section 7(a)(1) of the ESA to use their authorities to further the purposes of the Act. For example, an agency could develop a conservation program which incorporated prescribed burning to improve habitat for the benefit of listed species.

S2.4.3. **Continue to enforce take and trade prohibitions.** This species is protected by take provisions of the Endangered Species Act (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. **Conduct research on life history characteristics.** Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species, more specific biological information is needed.

S3.1. **Continue research to determine species demographics.** Additional information is needed on the number of populations this species has in the wild, and factors which influence its survival such as recruitment, dispersal, growth, and mortality. Data on pollinators, herbivory, disease and injury are also lacking.

S3.2. **Develop population viability and risk assessment.** The demographic information collected from research should be used to develop models to evaluate spatial distribution and population size necessary to ensure persistence of the species.

S3.3. **Conduct research to assess management requirements of *C. avonensis*.** Evaluate management practices (*e.g.*, prescribed burning, mowing, exotic plant control) for their effects upon this species. Provide the results to land managers.

S4. **Develop standardized monitoring.** Standardized monitoring needs to be developed for this and other listed scrub species to determine the effect of management actions.

S4.1. **Collect existing and historical data, and place in a central location.** Contact former and present researchers for historical data, gather information from herbaria and museums, and compile the data for placement in a geographic information system database. The South Florida Field Office could maintain the database. This location would allow all researchers access to both historic and current data, and provide the FWS with a means to monitor the success of recovery tasks.

S5. Provide public information about *C. avonensis*. It is important that governmental agencies, conservation organizations, and private land owners be appropriately informed about this species.

S6. Establish reclassification criteria. Once the population is stabilized, research and monitoring results may provide data necessary to develop reclassification criteria.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. To date, there is only one protected site for *C. avonensis* in South Florida.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. Little xeric scrub habitat remains for this species; any method of securing land to protect populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *C. avonensis* populations by preventing competition from exotic or invasive species, off-road vehicles, over-collection. Provide proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. The frequency of fire return and seasonality are important to mimic the natural fire regime. The scrub landscape is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned to create a mosaic when possible to allow for variation.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in areas supporting populations of *C. avonensis* compared to other areas in South Florida. Without control however, exotic or invasive plants may become a threat to the survival and recovery of this species.

H1.2.3. Evaluate the effects of off-road vehicles on sensitive lands and limit access where damage to the habitat is documented.

H1.2.4. Restore areas to suitable habitat. Native habitats that have been disturbed and have the appropriate soils may be prime candidate sites for restoration.

H1.2.5. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc*., on the habitats where *C. avonensis* occurs.

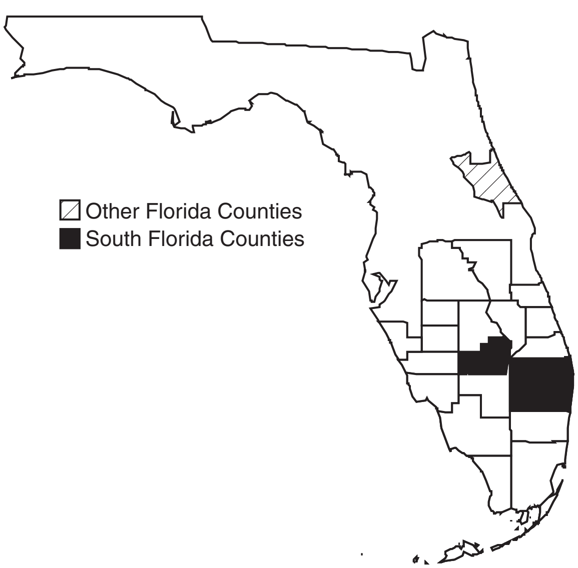
H2. Provide public information about scrub and its unique biota. Educational programs, especially those conducted by Archbold Biological Station, have been successful. Without these efforts, the Lake Wales Ridge National Wildlife Refuge would not have been created. The State's system of biological preserves depends on a broad base of public understanding and support for its funding and future success.

Okeechobee Gourd

Cucurbita okeechobeensis ssp. *okeechobeensis* Small

Federal Status:	**Endangered (July 12, 1993)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Original (May 18, 1999)**
Geographic Coverage:	**South Florida**

Figure 1. County distribution of the Okeechobee gourd.



The Okeechobee gourd is a vine that was locally common in the extensive pond apple (*Annona glabra*) forest that once grew south of Lake Okeechobee (Small 1922). As early as 1930, at least 95 percent of the pond apple forests had been destroyed (Small 1930), and pond apple now persists as scattered trees or small stands around Lake Okeechobee and in the Everglades. The conversion of these swamps and marshes for agriculture and water-level regulation in Lake Okeechobee have been the principal causes of the reduction in range and number of Okeechobee gourd plants. The Okeechobee gourd is now restricted in the wild to two small disjunct populations— one along the St. Johns River which separates Volusia, Seminole, and Lake counties in north Florida, and a second around the shoreline of Lake Okeechobee in South Florida.

Currently, the survival of the Okeechobee gourd in South Florida is threatened by the water-regulation practices in Lake Okeechobee and the continued expansion of exotic vegetation in the lake. Careful use of herbicides to control exotic woody vegetation (primarily *Melaleuca)* and dense growths of aquatic vegetation can be compatible with recovery of the Okeechobee gourd.

This account represents the recovery plan for the Okeechobee gourd.

Description

The Okeechobee gourd is an annual or perennial, fibrous-rooted, high-climbing vine with tendrils, belonging to the gourd family (Cucurbitaceae). The Okeechobee gourd possesses heart- to kidney-shaped leaf blades, with 5 to 7 angular, shallow lobes, and irregularly serrated margins (Walters and Decker-Walters 1993). Young leaves are covered with soft hairs. The cream-colored flowers are bell-shaped, with the corolla 6 to 7 cm long. They can be distinguished from flowers of *C. martinezii* (Martinez gourd) by the presence of dense pubescence on the hypanthium of the male flower and on the ovary of the female flower. The light green gourd is globular or slightly oblong, with 10 indistinct stripes, and hard shelled with bitter flesh. The seeds are gray-green and flat (Small 1930, Tatje 1980, Walters and Decker-Walters 1991). The stems produce adventitious roots at the nodes and will separate from the parent plant if they contact soil or water (Minno and Minno 1995).

Taxonomy

Small (1922, 1930) originally described the gourds he found in the pond apple forest surrounding Lake Okeechobee as *Pepo okeechobeensis*. Bailey (1930) transferred the Okeechobee gourd to the genus *Cucurbita*, which includes pumpkins and squashes. Bailey (1943) subsequently described two new gourd species, *C. martinezii* and *C. lundelliana*. These two gourds were proven to be closely related to the Okeechobee gourd.

Closely related gourds with cream-colored corollas (all others in the genus *Cucurbita* are bright yellow) are found in Florida and in Mexico, near the Gulf Coast. The Florida plants were described as the Okeechobee gourd (Bailey 1930) and the Mexican plants were designated (Bailey 1943) as the Martinez gourd (*C. martinezii*). However, Robinson and Puchalski (1980) showed through isozyme analysis that there was only a single allelic difference between the two varieties. The (ESA) does not allow Federal listing of disjunct populations of widespread plant species. Since the Mexican gourds are moderately abundant, and considering the findings of Robinson, the FWS originally opposed listing of the Okeechobee gourd. A later study by Walters and Decker-Walters (1991), also using isozyme analysis, showed a difference of just one allele. However, they calculated an estimated time since divergence of about 450,000 years between the Martinez and Okeechobee gourds, and concluded that they should be considered distinct at the subspecies level. Walters and Decker-Walters (1993) rearranged the nomenclature, designating the Florida gourds as *Cucurbita okeechobeensis* (Small) Bailey ssp. *okeechobeensis,* and assigning the Mexican gourds to the subspecies *C. okeechobeensis* ssp. *martinezii* (Bailey) Andres and Nabhan ex T. Walters and Decker Walters. The FWS concurred with this finding, and because the ESA allows protection of distinct subspecies, the Okeechobee gourd was subsequently listed as endangered.

Distribution

The Okeechobee gourd was historically found on the southern shore of Lake Okeechobee, in Palm Beach County, and formerly in the Everglades. The relative abundance of the Okeechobee gourd in the Everglades region south of the original pond apple forest along the southern rim of Lake Okeechobee is not known. In 1965, it was seen north of Homestead in an agricultural area of Dade County (Florida Natural Areas Inventory data, 1992). A population on a disturbed roadside north of Andytown, Broward County, was discovered in 1978 and was destroyed by road construction the following year (Tatje 1980).

In recent surveys, the species was found to be restricted to nine sites along

Okeechobee gourd.
Original drawing by Jean C. Putnam Hancock; original flower photograph by Steve Shirah; fruit photograph courtesy of U.S. Fish and Wildlife Service.

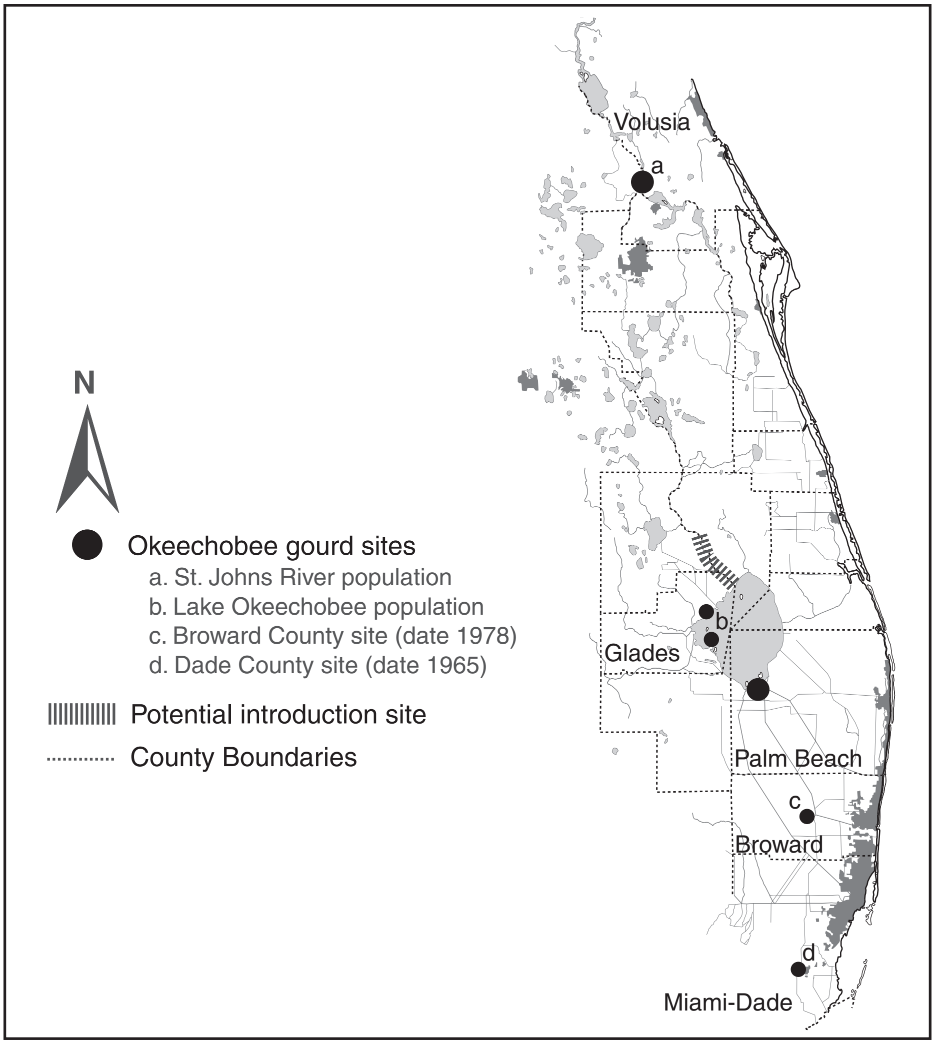
the middle St. Johns River in Volusia County (Minno and Minno 1995, 1998) and and around Lake Okeechobee in Glades and Palm Beach counties (Figure 1). It was present at 11 sites along the southeastern shore of Lake Okeechobee, including Torry Island, Ritta Island, Kreamer Island, Bay Bottom Dynamite Hole Island, South Shore Dynamite Hole Island, and the southern shore of the Lake Okeechobee Rim Canal (Walters *et al*. 1992; Walters and Decker-Walters 1993) (Figure 2)

The documented population of Okeechobee gourd around the southeastern shore of Lake Okeechobee is strongly associated with Torry muck, a soil formed in the extensive pond apple forests that once surrounded Lake Okeechobee. However, successful growth and reproduction of the gourd under cultivation suggests that the species can grow in a wider range of soils.

Habitat

Nabhan (1988) noted that the gourd seemed to need the natural trellises of pond apple branches. However, the gourd readily climbs any plant that will provide a trellis; in both Lake Okeechobee and the St. Johns River, the Okeechobee gourd grows on elderberry (*Sambucus canadensis*) and buttonbush (*Cephalanthus occidentalis*). Around Lake Okeechobee, the gourd is frequently associated with alligator nests. These disturbed sites provide areas where competition is reduced and elevated areas that promote the growth of

Figure 2.
Site-specific distribution of the Okeechobee gourd.



elderberry, button bush, and other erect bushes and shrubs.

Walters and Decker-Walters (1991) conclude that "...for the gourd to maintain viable healthy populations, fluctuations in lake level are necessary. High lake levels facilitate dispersal and inundate and destroy aggressive weeds in local habitats. As lake levels decrease, the cleared open habitats allow the quickly germinating Okeechobee gourd seeds to sprout and begin climbing before they have to compete with other pioneer species." Similiary, artificially disturbed sites can provide suitable habitat in some circumstances. Gourds have been observed growing in mowed powerline and road right-of-ways (M. Minno, Eco-Cognizant, Inc., personal communication (1998).

Reproduction

The flowers open at dawn and although specific pollinators have not been identified, based on closely related gourds, a variety of insects are likely to be available, including bees, flies, and squash beetles. Preliminary information indicates that pollination may be a problem for this species, especially in small colonies. Typically, male flowers greatly outnumber female flowers and where pollinators are rare, decreased fruit set may be observed (M. Minno, Eco-Cognizant, Inc., personal communication 1998). In at least one collection of *C. okeechobeensis,* flowers must be pollinated by hand to ensure fruit set (T. Race, Bok Tower Gardens, personal communication, 1998).

The seeds germinate in early spring during the dry season. Seedlings do not tolerate water-soaked soil for extended time periods, which would account for Nabhan's (1989) discovery of a stand of Okeechobee gourds apparently in decline, inundated in 20 to 30 cm of water. By the rainy season, the vines will have climbed shrubs, avoiding complete inundation as water levels rise. The vines and fruit become most visible by early to mid-summer.

Although the exact mechanism for seed dispersal of the Okeechobee gourd is unknown, Walters *et al*. (1992) suggest that Okeechobee gourds disperse by floating in water bodies (in canals and along the shore of islands in Lake Okeechobee); however, no information is available regarding the distances seeds may disperse. Walters et al. (1992) also indicate that marsh rabbits are the main terrestrial disperser of gourd seeds, but others suggest that rabbits are only a predator of these seeds and are unlikely to be significant seed dispersers (M. Minno, Eco-Cognizant, Inc., personal communication 1998).

Relationship to Other Species

Around Lake Okeechobee, the gourd relies on pond apple trees to support its vines above rising water levels during the wet season. Other trees and shrubs, such as willow (*Salix caroliniana*) and cypress (*Taxodium distichum*), may also provide suitable support for the vines. Along the St. Johns River, Okeechobee gourds are most typically found growing on elderberry and common reed (*Phragmites* spp.)

The Okeechobee gourd also seems to readily germinate on alligator (*Alligator mississippiensis*) nests in Lake Okeechobee, which provide suitably elevated soil berms in full sun, with no competition from other plants. Although alligators do not typically construct nests in woody vegetation, they do clear herbaceous vegetation, sometimes close to shrubs and trees. After gourds germinate on the cleared ground around the nest, they begin to grow prostrate. If trees or shrubs are present nearby, the gourd plants will eventually climb. Alligators, though, do not seem to be important to survival of the gourd in the St. Johns River (M. Minno, St. Johns River Water Management District, personal communication 1996).

Walters *et al*. (1992) observed a rabbit gnawing on a green gourd and saw gnawed and broken gourds in their nests, which suggests that marsh rabbits feed on and may disperse gourd seeds. Because many insect species have evolved with specific cucurbits, the Okeechobee gourd could be a keystone species for some, as yet unidentified, pollinator. Both the Floridian and Mexican subspecies of *C. okeechobeensis* are highly resistant to many diseases which threaten economically valuable plants. The Martinex gourd is currently used as a source of disease resistance for summer squash, pumpkins, and gourds. However the Okechobee gourd has been known to be attacked by powdery mildew fungus, melon worms, and pickle worms (M. Minno, Eco-Cognizant, Inc., personal communication, 1998),but the extent to which these diseases affect the gourd population is not known.

Water management practices in Lake Okeechobee affecting the

Okeechobee gourd are also likely to affect the wood stork and the snail kite. However, the hydrologic requirements for the three species are not mutually exclusive. All three species are adapted to withstand periods of drought and high water, but prolonged periods of three or more successive years at either extreme might be adverse to their survival. The snail kite temporarily benefits from periods of high water, but prolonged periods would drown out woody vegetation needed by kites as nesting substrate. Extended periods of high water for several continuous years could possibly jeopardize the Okeechobee gourd, because the seeds would not germinate and young plants cannot tolerate deep water. On the other hand, the gourd might temporarily benefit from drought conditions, because low water provides more suitable habitat within the Herbert Hoover Dike surrounding Lake Okeechobee. However, extended periods of low water could favor dense stands of woody vegetation (including *Melaleuca*), which would not be favorable to the gourd or the overall productivity of Lake Okeechobee. More research is needed on fluctuations in abundance of the gourd in response to water conditions, particularly extended periods of high water, to determine the level of risk to the survival of the species in the long term.

Status and Trends

The Okeechobee gourd persisted around Indian villages with the Seminole pumpkin, *C. moschata* (Small 1930), which is edible. The Okeechobee gourd's bitterness precluded its use for food, but it may have been used as a ball, rattle, or ceremonial cup.

Small observed and/or collected the Okeechobee gourd in 1913 and 1917 and found it to be locally common in the remnant pond apple forests surrounding Lake Okeechobee (Small 1922). At least 95 percent of this habitat had already been destroyed when he named the gourd *Pepo okeechobeensis* (Small 1930).

After 1930, the Okeechobee gourd was observed infrequently. In 1941, it was found on Observation Island in Lake Okeechobee, Glades County (Florida Natural Areas Inventory data, 1992). Robinson (1987) was unable to relocate the Okeechobee gourd there in 1984 or 1987. In 1981, the Okeechobee gourd was found in some lake, levee, and canal bank areas at Kreamer and Torry Islands (Florida Natural Areas Inventory data, 1992). Nabhan's 1988 search only turned up three gourds (the fruits of the Okeechobee gourd), and no live plants. Seeds from those gourds were planted at Bok Tower Gardens, Florida, where the plant currently thrives under cultivation.

A new population of the Okeechobee gourd was found along the shore of the middle St. Johns River in September 1993. Gourds had not been noted in this area for more than 200 years (Bartram 1774). Surveys conducted from 1995 to 1997 documented 12 locations along the St. Johns River, but only three of these localities contained Okeechobee gourds during a 1998 survey. (M. Minno, Eco-Cognizant, Inc., personal communication 1998).

Because the Okeechobee gourd flourishes when suitable soils are exposed during low water levels, the best time to survey for the species is during moderate or severe drought. The most recent surveys were conducted during drought conditions in 1990 and 1991. The species was found at a total of 11 sites along the southeastern shore of Lake Okeechobee, including Torry Island, Ritta Island, Kreamer Island, Bay Bottom Dynamite Hole Island, South Shore Dynamite Hole Island, and the southern shore of the Lake Okeechobee Rim Canal (Walters *et al*. 1992, Walters and Decker-Walters 1993). Water levels have been high in recent years (1994-1996), and no organized search has been conducted recently for the species around Lake Okeechobee.

The GFC reported finding the Okeechobee gourd in 1985 on a spoil island just west of the outlet of Harney Pond Canal along the northwestern shore of Lake Okeechobee in Glades County (Don Fox, GFC, personal communication 1996), suggesting that the species may be more widespread around the shores of the lake. More systematic and thorough searching needs to be conducted throughout Lake Okeechobee and the surrounding creeks.

Searches for the Okeechobee gourd in the past have been irregularly timed and of limited geographic scope. The FWS recommends that a complete survey be conducted along shorelines (including any islands) of Lake Okeechobee at least once a year. If surveys are limited to once a year, the best time to survey is from late December through mid-February when the trees and shrubs are leafless and the fruit more visible. If resources are available to conduct semi-annual surveys, surveys should be done in May and June in the early morning (before 10 am), when the large flowers are likely to be open. Yearly surveys would provide information necessary to begin to identify population fluctuations and long-term trends, information which is unavailable for any previous period.

Gourds are ephemeral by nature; they appear at a site for one or many years and then disappear. They tend to grow well under good conditions (appropriate hydrology and reduced competition) and subside when conditions become unfavorable. Therefore, searches should not be limited to previously documented sites. Because of the rambling growth habit of the gourd, and because plants can root at the nodes, it is difficult to count numbers of individual plants. Counting the number of fruits on the vines in the fall may provide a good index of the reproductive health of the population, rather than attempting to count individual plants.

The plant’s decline is largely attributable to two factors: (1) conversion of swamp forests to agriculture and (2) water level management in Lake Okeechobee. Agricultural conversion was the principal form of habitat destruction for the gourd prior to 1940. Today, water management practices appear to be the greatest threat. Permanent inundation of suitable soils is detrimental to the species. Water regulation practices can greatly influence the timing and duration of flooding and drying cycles across remnant areas of suitable elevation and soils around Lake Okeechobee.

Because the Okeechobee gourd has been found growing along the edges of canals, and because herbicides are routinely applied around Lake Okeechobee to keep aquatic weeds from choking the waterways, aquatic vegetation management practices should be modified to ensure compatibility with recovery of the species.

Another potential threat to this plant is the proliferation of exotic plant species around the edges of Lake Okeechobee, particularly *Melaleuca*. Although scattered *Melaleuca* trees may provide suitable support for climbing gourd plants, *Melaleuca* stands generally become a dense monoculture. Densely shaded areas in the center of *Melaleuca* stands are not suitable for the Okeechobee gourd. Control of aquatic weeds can involve spraying from airboats or airplanes, but *Melaleuca* control can be accomplished by cutting and squirting herbicide into individual tree trunks. The FWS believes *Melaleuca* control is a necessary management practice to prevent degradation of littoral zone habitat quality for a variety of animals and plants in Lake Okeechobee, including the Okeechobee gourd; the controlled use of herbicide applied directly to *Melaleuca* trees is not likely to have adverse effect on the Okeechobee gourd.

The extensive pond apple forest that once surrounded the southern shore of Lake Okeechobee most likely supported a stable core population of the gourd that allowed long-term survival of the species, despite year-to-year changes in peripheral sites that became temporarily available or unavailable in response to natural water fluctuations. Because no stable core population remains within the dike surrounding the lake, the species is more vulnerable to the threats identified above.

Management

Aside from regulation of collecting and interstate trade, management for this endangered plant is non-existent. The FWS recommended a program of habitat modification and enhancement. Should such measures prove feasible, we recommend that control or extirpation of exotic pest plants such as *Melaleuca* and Brazilian pepper in specific areas where the Okeechobee gourd is known to grow be balanced with planting of pond apple or other appropriate native woody vegetation to provide potential vine-supporting vegetation. Proposed changes to the regulation schedule of Lake Okeechobee will be evaluated for potential effects on the species, but this will be only one of several factors used to evaluate water regulation. A variety of factors related to human values (water storage, flood control, navigation) and ecological values (waterfowl, fisheries, littoral zone vegetation, water quality, snail kite recovery, and others) can potentially conflict. A balance must be found among these competing interests that will promote recovery of the Okeechobee gourd. Spraying of herbicides to control growth of aquatic vegetation should be avoided or strictly controlled in areas where habitat is being managed for recovery.

Improved coordination among agencies (principally the SWFMD, COE, DEP, FWS, and GFC) should avoid unscheduled or unannounced aquatic weed control in areas likely to support the Okeechobee gourd. Experimentation is needed to test how sensitive the Okeechobee gourd is to the chemicals currently being used. Depending on the results of that experimentation, aerial spraying may need to be prohibited in areas where the species grows. For boat-based spraying, an outreach program is needed to educate spraying crews to recognize the Okeechobee gourd and avoid spraying the plants. If spraying is unavoidable, the least vulnerable period for the Okeechobee gourd may be November and December, after plants have fully developed fruit and before seedlings emerge.

Removal of exotic woody vegetation, such as Brazilian pepper (*Schinus* *terebinthifolius*), Australian pine (*Casuarina equisetifolia*), and *Melaleuca quinquenervia* along the shoreline of Lake Okeechobee should be accompanied by planting of native trees and shrubs, particularly pond apple. The primary technique for control of woody exotic vegetation should be application of herbicide to individual trees wherever practical, while aerial spraying should be used with great caution only on large *Melaleuca* heads adjacent to the Lake Okeechobee rim canal.

Recovery of the Okeechobee gourd may require special emphasis on protection and management of Ritta Island. This is the only site in Lake Okeechobee with what appeared to be more mature plants. Plants at other sites around the lake appeared to be in poor health and transitory. Lacking the large pond apple forest that likely served as a stable reserve bank of plants, Ritta Island is now the likeliest among the sites identified in 1991 to be persistent. However, we lack information on how well the plants have survived several recent years of high water levels. Dense growth of *Colocasia* appears to be blocking free dispersal of fruits at Ritta Island. Rather than attempt to remove or control *Colocasia*, it may be more effective to intervene by dispersing the seed according to a management plan.

The relationship of fire and the Okeechobee gourd is also not fully understood. Fire could be a threat in that it could destroy plants, yet it could also be a management tool because gourds sprout in areas cleared by disturbance. More frequent and more thorough surveys for the plant may reveal a pattern of response to fire or mechanical disturbances.

A recovery team meeting for the Okeechobee gourd was held in April 1996. In addition to the above-mentioned recovery actions, the group recommended introduction of plants to sites within and outside of Lake Okeechobee. Within the lake, Observation Island and Little Rocky Island should first be more thoroughly searched to see if the Okeechobee gourd is present. If not, these islands are good candidates for introduction. Public lands should be identified along the Kissimmee River that have suitable environmental conditions for introduction of the species. Because the species now occurs in two widely separated populations (Lake Okeechobee and St. Johns River), establishment of a third population between the two existing populations is considered a desirable safeguard against extinction, particularly with respect to catastrophes, such as hurricanes.

Other potential recovery actions would involve physical alteration of the environment, either removal of levees or mounding of organic material to provide substrate at appropriate elevations. It is unclear at this time whether degrading the levees at Torry and Ritta islands would promote recovery of the Okeechobee gourd. Improved water flow through these areas may promote dispersal of fruits. Mounding of organic soil on Torry and/or Ritta, islands could be part of a restoration plan for those islands and could provide a safeguard against prolonged periods of high water. Roads are present on both islands, making access of earth-moving equipment more practical. Additional contaminant sampling may be necessary on both islands to ensure that residue from previous application of agricultural chemicals does not preclude moving these sediments. Another possibility is mounding of organic berms that have built up in an area southwest of Buckhead Ridge. However, the latter project would require water levels in the lake be held down around 4 m and may present logistical problems in terms of access and operation of machinery, which would tend to get stuck.

Isozyme analysis of Okeechobee gourds from southeastern Lake Okeechobee indicates no distinguishable differences among the specimens. No material has been analyzed from the St. Johns River. This could be done relatively easily and should be a high priority. Pending results of this study, a genetic management plan must be prepared by the FWS prior to considering crossing of Okeechobee and St. Johns plants. It appears that there is very little risk in crossing plants from these two areas, and there may be advantages in terms of generating heterozygosity.

Literature Cited

Andres, T.C. and G.P. Nabhan. 1988. Taxonomic rank and rarity of *Cucurbita okeechobeensis*. Food and Agriculture Organization Plant Genetic Resources Newsletter 75/75:21-22.

Bailey, L.H. 1930. Three discussions on Cucurbitaceae. Gentes Herbarium 2:175-186.

Bailey, L.H. 1943. Species of *Cucurbita*. Gentes Herbarium 6:267-322.

Bartram, W. 1791. Travels through North & South Carolina, Georgia, East & West Florida, the Cherokee country, the extensive territories of the Muscogulges, or Creek Confederacy, and the country of the Choctaws. Republication edition of the 1928 Macy-Masius Publishers edition, M. VanDoren (ed.) 1955. Travels of William Bartram. Dover Publications, Inc.; New York, New York.

Minno, M.C. and M. Minno. 1995. Status and habitat requirements of the endangered Okeechobee gourd along the middle St. Johns River, Florida. Submitted to U.S. Fish and Wildlife Service; Jacksonville, Florida.

Minno, M.C. and M. Minno. 1998. Phenology, pollination, and distribution of the Okeechobee Gourd (*Cucurbita okeechobeensis*) along the St. Johns River, Florida, 1997. Submitted to U.S. Fish and Wildlife Service, Jacksonville, Florida.

Nabhan, G.P. 1989. Lost gourds and spent soils on the shores of Okeechobee. *in* Enduring seeds. North Point Press; San Francisco, California.

Robinson, R.W. and J.T. Puchalski. 1980. Synonymy of *Cucurbita martinezii* and *C. okeechobeensis*. Cucurbit Genetics Cooperative Report 3:45-46.

Small, J.K. 1922. Wild pumpkins. Journal New York Botanical Garden 23:19-23

Small, J.K. 1930. The Okeechobee gourd. Journal New York Botanical Garden 31:10-14.

Tatje, B.E. 1980. Status report on *C. okeechobeensis*. U.S. Fish and Wildlife Service; Jacksonville, Florida.

Walters, T.W. and D.S. Decker-Walters. 1991. The elusive, endangered and endemic Okeechobee gourd: the systematics of *C. okeechobeensis* (Cucurbitaceae). Final report submitted to Center for Plant Conservation; St. Louis, Missouri, and U.S. Fish and Wildlife Service; Jacksonville, Florida.

Walters, T.W. and D.S. Decker-Walters. 1993. Systematics of the endangered Okeechobee gourd, *C. okeechobeensis* (Cucurbitaceae). Systematic Botany 18(2):175-187.

Walters, T.W., D.S. Decker-Walters, and S. Katz. 1992. Seeking the elusive Okeechobee gourd. Fairchild Tropical Garden Bulletin 47(1)23-30.

Recovery for the Okeechobee Gourd

Cucurbita okeechobeensis ssp. *okeechobeensis* Small

Recovery Objective: RECLASSIFY to threatened.

Recovery Criteria

The Okeechobee gourd has an extremely limited distribution; it is vulnerable to the highly managed hydrologic conditions in Lake Okeechobee. A significant portion of the Kissimmee River-Lake Okeechobee-Everglades watershed that once supported the gourd has been irreversibly lost, and information on the gourd's tolerance to specific environmental stressors is lacking. Consequently, the FWS can only define general conditions that could allow reclassification from endangered to threatened. This objective will be achieved when: the Okeechobee gourd is protected at all known sites within Lake Okeechobee; when plants on Kreamer, Torry and Ritta islands and the southern Rim Canal of Lake Okeechobee produce fruit at each of these locations at least every other year (their absence for a period of two or more consecutive years will violate this requirement); when the distribution of fruiting plants is expanded within Lake Okeechobee either by the discovery of additional sites or by translocation; when one or two sites are established outside of the southeastern quadrant of Lake Okeechobee (outside of Palm Beach County); when a stable, self-sustaining population of the Okeechobee gourd is established within the South Florida Ecosystem outside of Lake Okeechobee; when measures of vitality are developed and monitored at each of the sites described above; and when based on the results of research on the viability of seeds following prolonged submergence and the survival of plants under rising water stages, the water regulation schedule for Lake Okeechobee is found not to jeopardize the continued existence of the Okeechobee gourd.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. It may be possible to delist the Okeechobee gourd if there is sufficient, restorable habitat that can be recolonized by additional populations; however, the feasibility of such a restoration and recolonization is still uncertain. This recovery objective will be reassessed annually based on new research, management, and monitoring information. These criteria will be refined when new information identifies ways of re-establishing populations of this species and expanding its current distribution. This recovery narrative covers recovery actions only within the South Florida Ecosystem; recovery actions for the Okeechobee gourd along the St. Johns River must be added for a complete recovery plan.

Species-level Recovery Actions

S1. Maintain information on the distribution and status of the Okeechobee gourd.

S1.1. Conduct regularly scheduled surveys. Past surveys for the Okeechobee gourd have been sporadic and not comprehensive. More thorough searching of Lake Okeechobee is needed at least once per year, preferably 3 times (spring, summer, fall) a year. Airboats are the most efficient vehicles for conducting surveys.

S1.2. **Individuals should be encouraged to provide information on sightings of the Okeechobee gourd.** Due to the size of Lake Okeechobee, the difficult access to interior portions of its littoral zone, and the potentially wide dispersal of floating gourds that start germination, it is impossible for professional biologists to search all potential habitat in the lake. Private citizens involved in a number of activities on the lake can provide useful information to help locate plants.

S2. Protect and enhance existing populations.

S2.1. **Ensure that spraying for control of aquatic vegetation does not harm or kill Okeechobee gourd plants.** The regularly scheduled surveys provide information on locations of the Okeechobee gourd; this information (using maps and GPS coordinates) must be conveyed to spray crews to reduce the likelihood of damage to the gourd. Spray crews must also be trained to recognize the gourd and the need to avoid impacts on the species.

S2.2. **Assess the effect of *Melaleuca* and Brazilian pepper control efforts (both cut-and- squirt and aerial spraying methods); use techniques to avoid direct impact on Okeechobee gourd plants.** Although control of *Melaleuca* and Brazilian pepper is needed for ecosystem restoration, the climbing stems of the Okeechobee gourd now use both species as support. Train crews to identify the Okeechobee gourd. Where exotic trees or shrubs are supporting living Okeechobee gourd plants, instruct the crew to avoid killing the Okeechobee gourd plants and to inject herbicide in the exotic species without cutting it down.

S2.3. **Use provisions of section 7 of the ESA to protect the Okeechobee gourd.** Water management of the COE's C&SF project will affect survival and recovery of the Okeechobee gourd, particularly the water regulation schedule for Lake Okeechobee. Field monitoring and experimental research are needed to determine the gourd's tolerance of water levels to effectively evaluate alternative water regulation schedules and provide effective conservation recommendations.

S2.4. **Augment natural populations of the Okeechobee gourd.**

S2.4.1. **Establish a protocol for translocation.** Source plants must be cultivated and recorded at a nursery or botanical garden.

S2.4.2. **Locate potential translocation sites.** First, more thorough surveys of the present range of the species are needed within Lake Okeechobee. Later, potential sites for translocation within the lake need to be assessed. Some of these are Little Rocky Island (Hendry County), Observation Island (Glades County) and other sites in Okeechobee County. Other potential translocation sites should be selected north of Lake Okeechobee, with emphasis on the islands in Lake Istokpoga and public lands along the Kissimmee River.

S2.3.3. **Translocate plants to the selected sites.**

S3. Initiate research on the life history and genetics of the Okeechobee gourd.

S3.1. **Test experimentally the viability of Okeechobee gourd seeds kept submerged for long periods (1 to 3 years).** The tolerance of Okeechobee gourd seeds to extended periods of submergence in the waters of Lake Okeechobee is a critical parameter needed to assess the potential risk to the species from extended periods of high water under various lake regulation schedules.

S3.2. **Characterize the range of soil conditions where the Okeechobee gourd currently grows and provide detailed mapping of soil types in southeastern Lake Okeechobee.** Although distribution of the Okeechobee gourd in Lake Okeechobee appears to be associated with the presence of muck soils formed historically in the pond apple forests that once bordered the lake, the soil profile appears to be modified in some areas where the gourd grows. Dredging of flood control canals (and lining them with revetment), construction of levees, and construction of farm roads and drainage ditches have evidently altered the soil at many of the Okeechobee gourd sites. Presence of some native organic soil appears to be necessary, but the range of soil profiles should be determined to characterize occupied habitat and assess unoccupied, but potentially suitable, habitat.

S3.3. **Through field surveys, determine dates of germination under natural conditions.** Because the specific locations for germination may vary from year to year, it may be difficult to identify areas to search for germinating plants, but some areas of consistently suitable habitat may be identifiable to obtain this information. Areas may need to be revisited for several years to account for interannual variation in response to water levels and temperature patterns. Timing of water management decisions relative to germination and growth of young Okeechobee gourd plants is important to survival and recovery of the species.

S3.4. **Test experimentally the effect of seasonally rising water level on the survival of young plants**. Determine rates of rising water level and/or depths that may reduce survival of young plants. Identify at what stage their growth rate and ability to climb adjacent vegetation make them less vulnerable to rising water level.

S3.5. **After information is available from the research studies described above and the annual field surveys, conduct population viability and risk assessment studies particularly with respect to water regulation schedule alternatives for Lake Okeechobee.**

S3.6. **Investigate the role of animals in dispersing seeds of the Okeechobee gourd.**

S3.7. **Document the potential ecological relationship between the American alligator and the Okeechobee gourd.** The mounds of soil around alligator nests may serve as favorable germination sites for the gourd. This relationship should be investigated, determining whether indeed gourds preferentially germinate around nests and how frequently these seedlings produce at least one mature plant at a nest.

S3.8. **Investigate the genetic distance between the two known populations of the Okeechobee gourd.** Isozyme analysis has indicated a single population of the gourd in southeastern Lake Okeechobee. Additional analysis should be performed on specimens from the St. Johns River. Researchers should make a recommendation to the FWS regarding the desirability of cross-breeding gourds from the two populations to provide additional variability within the populations. If a third population is established geographically between the two existing populations, a decision must be made on the genetic source of the specimens.

S4. **Monitor existing populations of the Okeechobee gourd.**

S4.1. **Determine the most effective approach to monitor the condition of the Okeechobee gourd.** Because the Okeechobee gourd generally grows in a tangle of vines and sprawling over other vegetation, it is difficult to distinguish individual plants to estimate a total population size. The sprawling growth habit also makes the plant vulnerable to inadvertent damage by people conducting the monitoring, so the method should minimize intrusion and disruption. A combination of condition indices may be needed, such as area covered, average leaf size, and number of fruit at each site.

S4.2. **After determining the most effective methods and indices, onduct monitoring on an annual basis**. In addition to monitoring of condition indices at each site, the overall distribution of sites should also be recorded. Selected individual vines should be marked to determine if they are annual or persist into the following growing season. Water stage should be recorded for each day of monitoring, noting any extremes of drought or high water. Freezes should also be noted, as they will influence the condition of the population.

S5. Increase public awareness about the Okeechobee gourd. Public awareness can be addressed through a variety of strategies, including, but not limited to, classroom programs, newspaper and magazine articles, public information displays at boat ramps in Lake Okeechobee, and outreach to fishing and airboating clubs.

Habitat-level Recovery Actions

H1. Prevent degradation of existing Okeechobee gourd habitat.

H1.1. **Determine water regulation practices promoting recovery of the Okeechobee gourd, assess the implications on an ecosystem-wide scale, and make appropriate recommendations to water managers.** The preference and tolerance of the species to specific water regimes must first be researched and monitored as described above. This information should be evaluated in the context of the overall ecosystem health of the lake before making water management decisions.

H1.2. **Control or remove exotic vegetation in wetlands**. The main species of vegetation needing control are *Melaleuca quinquenervia* and *Hydrilla verticillata.* Although crews conducting control measures must be instructed to avoid impacts on the Okeechobee gourd, adjustment of the methods, timing, and pace of control measures to accommodate the gourd are required, rather than prohibition of the control program over large areas. Since populations of the Okeechobee gourd will shift from one specific location to another from year to year, areas not treated during one year could likely be treated in the following year. This added caution will require flexibility in planning control of exotic vegetation in the general range of the Okeechobee gourd.

H1.3. **Plant native trees or shrubs to replace exotics.** Removal of exotic trees and shrubs in areas where the Okeechobee gourd occurs should be compensated by planting of native trees and shrubs, such as willow and pond apple, to provide potential supporting vegetation.

H1.4. **Use controlled burns to open up areas of overly dense herbaceous and/or shrubby vegetation in lake littoral zones and marshes.** Such actions are beneficial for a variety of fish and wildlife, not just the Okeechobee gourd, which is a pioneer species in disturbed areas. Because Lake Okeechobee is too large for practical application of scheduled extreme drawdowns, burning must take place at times of naturally occurring low water levels. If the range of the species is extended to other lakes, riverine swamps, or marshes, managed extreme drawdowns may be an effective management tool in conjunction with burning.

H1.5. **Prevent cultural eutrophication of lakes and marshes.** Addition of nitrogen and phosphorus from agricultural and residential areas is accelerating eutrophication of Florida's lakes and marshes, particularly Lake Okeechobee. Long-term degradation of habitat caused by eutrophication leads to buildup of organic muck, overly dense herbaceous and shrubby vegetation, and oxygen depletion. Moderate eutrophication may not harm the Okeechobee gourd, but in the long term, dense growth of vegetation will impede dispersal of seeds, germination, and growth of the Okeechobee gourd. Reduction of nutrient inputs at the source needs to be addressed by best management practices, including rates of application and stormwater retention on site. Construction and maintenance of wastewater treatment plants must be improved to control discharge of nutrients in lakes and streams.

H2. **Restore areas to suitable habitat.**

H2.1. **Restoration of Kreamer, Torry, and Ritta islands within Lake Okeechobee was included by the Governor's Commission for a Sustainable South Florida among "40 Preferred Options" in their conceptual plan for the C&SF Restudy.** The FWS is unaware of any existing design criteria for restoration of these islands. Any proposal to restore these islands must consider the present habitat conditions for the Okeechobee gourd, fish, and wildlife, relative to proposed future conditions, before claiming any net benefits. Levels of contaminant residues in the soil from historic agricultural activities must be determined prior to any plan for earth movement.

H2.2. **Restoration of the Kissimmee River (as presently proposed, or with inclusion of the Paradise Run segment) will affect any attempt to translocate the Okeechobee gourd to the Kissimmee floodplain.** Selection of potential translocation sites must account for anticipated conditions following restoration, and monitoring of the Okeechobee gourd would be added to the monitoring program established for the restoration project.

H3. **Research the acute and long-term tolerance of the Okeechobee gourd and other wetland plants to herbicides commonly used to control nuisance species of aquatic vegetation.** The principal herbicides used in control of *Hydrilla* are SONAR (fluridone) and AQUATHOL K (dipotassium endothall). Rodeo (glyphosate) is occasionally used to control dense growths of emergent vegetation, such as cattails. The acute toxicity of each of these chemicals to the Okeechobee gourd must be determined; since fluridone is used in greater quantity and repeatedly at the same sites, its long-term toxicity to a variety of plants and animals should also be determined.

H4. **Monitor habitat/ecological processes**. The SFWMD, GFC, and other agencies have well-established research and monitoring activities in Lake Okeechobee. These existing efforts need to be modified or expanded to conform with the adaptive assessment strategy that will be required for the C&SF Restudy. Prior research and monitoring has included a broad range of parameters, including vegetation of the littoral zone, fish, benthic invertebrates, wading birds, phytoplankton, and water chemistry. Continued monitoring of wetland vegetation in the littoral zone of Lake Okeechobee is particularly relevant to recovery of the Okeechobee gourd. This should include assessment of the influence of dominant stressors, such as water regulation and fire, on the emergent plant communities of the littoral zone.

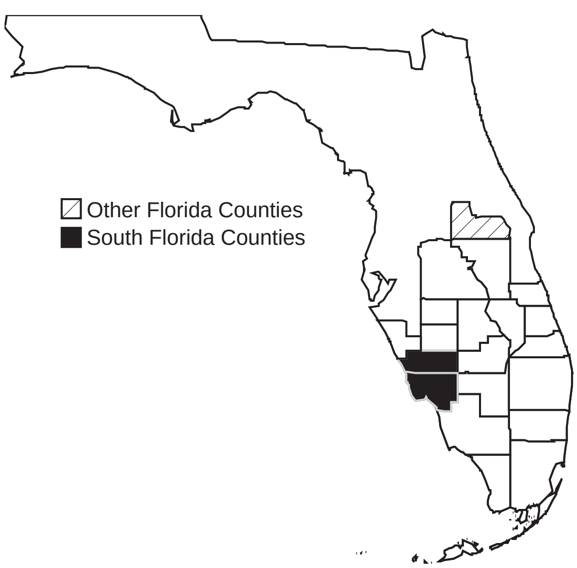
H5. **Increase public awareness of ecological relationships, environmental stressors, and restoration activities in the South Florida Ecosystem.** Among the themes of significance to the Okeechobee gourd are the ecological and economic importance of natural resources in the littoral zone of Lake Okeechobee and awareness of the environmental issues associated with protection of the littoral zone. These issues involve a balance of potentially competing interests, including water supply, flood control, recreation, biodiversity, and productivity of the ecosystem. Information on the Okeechobee gourd's status, threats, and its ecological relationship with other species should be integrated in public education on restoration activities. Public outreach can include newsletters, newspapers, magazines, the worldwide web, and classroom materials.

Beautiful Pawpaw

Deeringothamnus pulchellus Small

Federal Status:	**Endangered (Sept. 26, 1986)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision: May 18, 1999**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of the beautiful pawpaw.



The beautiful pawpaw (*Deeringothamnus pulchellus*) is a low shrub of the Annonaceae family that occurs in two disjunct locations in central and southwest Florida. It is found in xeric, mesic, and hydric pine flatwoods in western Charlotte and Lee counties and eastern Orange County. The beautiful pawpaw is threatened with extinction because of habitat loss due to agricultural, residential, and commercial conversion of land. The exclusion of fire is also responsible for habitat degradation throughout much of the species' range. Habitat conservation and management are conservation measures that will ensure survival of this species.

This account represents a revision of the existing recovery plan for the beautiful pawpaw (FWS 1988).

Description

The beautiful pawpaw is a low-growing, diminutive shrub rarely exceeding 0.5 m in height. In mowed areas the plant grows more prostrate with decumbent woody stems, whereas in fire-maintained habitat it grows more erect with arching stems. In both growth forms, the stems may be annual or perennial. The stems arise from a stout taproot that averages 32.5 cm long and is about 2.5 cm wide at its widest point (Passarella and Associates, Inc. 1996). The leaves are alternate, leathery, deciduous, and 4.0-7.0 cm long with slightly revolute (curving under) margins. The leaf shape is oblong to oblong-ovate or spatulate, with a rounded or notched end. The base of the leaf is rounded or tapering to a 2.0-4.0 mm long petiole. Young leaves have sparse, short, red hairs on both sides. Maturing leaves become dark green to glossy green above and paler green below.

The flowers of *D. pulchellus* occur singly in leaf axils and have between six and 10 creamy-white petals that are about 2.0-3.0 cm long. The fruits are fleshy, smooth and yellow-green when ripe and are 4.0-7.0 cm long. The seeds are dark brown and from 1.0-1.5 cm long.

Taxonomy

The beautiful pawpaw was described and named by Small (1926) as *Deeringothamnus pulchellus.* Zimmermann (1944) later renamed the plant *Asimina pulchella*, but this name was not accepted by the botanical community. Rehder and Dayton (1944) combined *Deeringothamnus* and *Asimina* and then correctly named the beautiful pawpaw *Asimina pulchella*. Subsequently, Walker (1971) indicated that pollen of *D. pulchellus* and *D. rugelii* were distinct and warranted generic status. *Deeringothamnus* is currently considered a distinct genus.

Distribution

Deeringothamnus pulchellus occurs in the vicinity of Charlotte Harbor and the Caloosahatchee River from Punta Gorda to Fort Myers in southwestern Florida (Wunderlin and Richardson 1981). It is also found in eastern Orange County, in the suburbs of Orlando (Hilsenbeck 1992). Overall, 11 sites are known from Lee County, seven from Charlotte County, and three from Orange County (Beever 1990, E. Norman, Stetson University, personal communication 1998) (Figure 1).

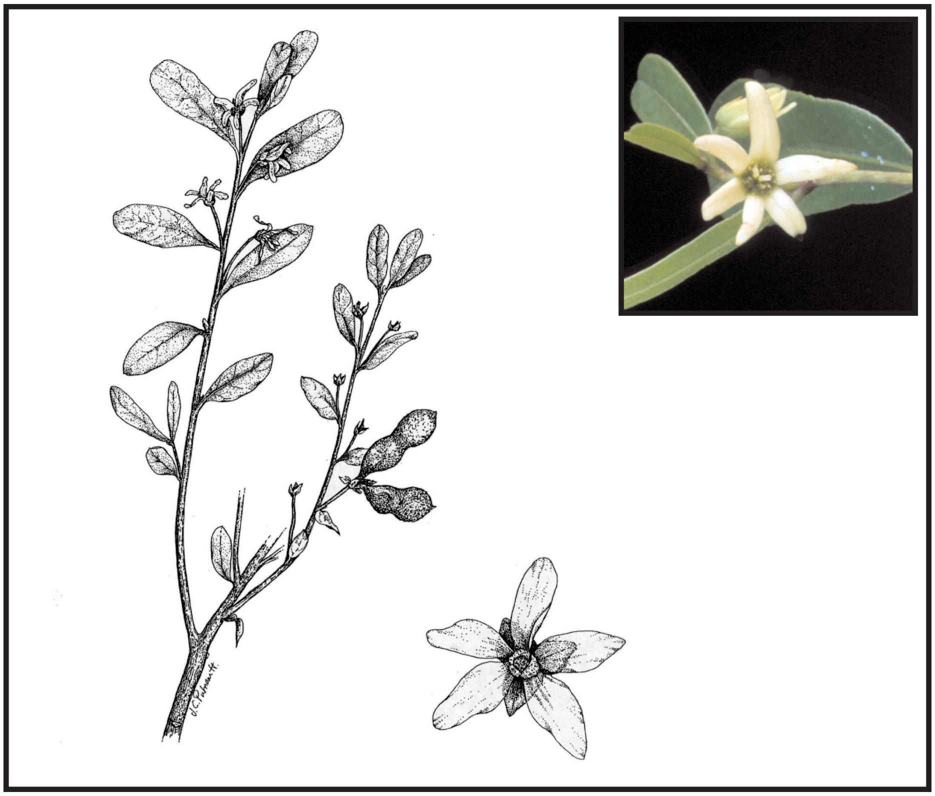
In Lee County, the pawpaw exists on Pine Island, where it occurs in pristine and modified flatwoods, on road edges, and on mowed lots. In Charlotte County it is found in an area broadly known as the Charlotte Harbor flatwoods and includes sites along State Road 765 and the GFC's Cecil M. Webb Wildlife Management Area.

Recently, 200 individual pawpaws were relocated from private land on Pine Island where habitat destruction was anticipated due to conversion for agricultural purposes. The plants were relocated to suitable, but unoccupied habitat in Lee County's St. James River Preserve on Pine Island and the Charlotte Harbor Environmental Center (CHEC) in Charlotte County (Passarella 1996). If these relocations prove successful, neither site will result in an extension of the historical range of the species; however, the CHEC location will represent a new site within the species' range.

Habitat

The beautiful pawpaw is native to longleaf pine (*Pinus palustris*) and slash pine (*P. elliotii*) flatwoods consisting of *Aristida* spp. low shrubs including evergreen blueberries (*Vaccinium myrsinites*), saw palmetto (*Serenoa repens*), wax myrtle (*Myrica cerifera*), flag pawpaw (*Asimina reticulata*) and dwarf oak (*Quercus minima*), *Lyonia fruticosa*, and *Befaria racemosa*. Soils in these habitats are poorly drained, although slight elevations provide better drainage than surrounding soils that are wetter. The pine flatwoods are adapted to frequent ground fires that seldom kill or harm mature pine trees, but are usually hot enough to thin or clear understory vegetation. *Deringothamnus pulchellus* depends on such fires to limit competition with larger grasses and shrubs. It takes advantage of fire-created openings by flowering and setting fruit the first growing season after a fire.

Beautiful pawpaw.
Original drawing by Jean C. Putnam Hancock; original flower photograph by Steve Shirah.



Reproduction

The reproductive biology of *D. pulchellus* is not thoroughly understood but the plant is thought to reproduce entirely by seed. D. Martin (FWS, personal communication 1996) indicated that available information suggests this species has poor fertilization, seed-setting, and germination rates. However, because *D. pulchellus* is probably long-lived, it does not need to be reproductively successful each year.

On Pine Island, plants begin flowering by mid-March and are at the peak of flowering the last week of April. On the mainland, flowering dates are probably one to two weeks later. The pollinators of this species have not been identified. Fruit is likely produced and dispersed during the summer. Gopher tortoises (*Gopherus polyphemus*) may be an important seed disperser. Although not investigated in detail, ingestion of the seeds by gopher tortoises or other herbivores may be important for seed germination. However, seeds have been germinated without this type of treatment (E. Norman, Stetson University, personal communication 1998).

Relationship to Other Species

The pollination vector for this species is not known. However, if a single species pollinator system is present, it could be extremely important to the continued survival of this species, particularly since encroaching agricultural and urban land uses often rely on broad-spectrum insecticides to control nuisance pests. Adverse effects from chemical drift or long-term persistence could reduce or eliminate pollinators.

Seeds of this species are probably dispersed with the assistance of animal vectors since *D. pulchellus* is low growing and there are no seed structures that would aid aerial dispersal. Herbivores, though not common in the pine flatwoods, are probably responsible for seed dispersal. Whitetail deer (*Odocoileus virginianus*) likely eat *D. pulchellus*, but whitetail tend to browse more than they graze, suggesting that a low-growing plant such as the beautiful pawpaw may not be utilized extensively. The eastern cottontail rabbit (*Sylvilagus floridanus*) and gopher tortoise probably consume pawpaw opportunistically since forbs and small shrubs are seasonally important components of the diet of these two species. It is not known whether *D. pulchellus* depends on any of these herbivores, or others, for dispersal and germination.

Status and Trends

Beever (1992) estimated that about 9,550 individuals may have been present in southwestern Florida in the early 1990s. This estimate probably represents only a small portion of the historic numbers. *Deeringoyhamnus pulchellus* numbers and distribution have undoubtedly decreased since agricultural and residential projects have degraded or destroyed pawpaw habitat in southwestern and central Florida. On the mainland of Charlotte County, extensive land clearing associated with land speculation and development of Cape Coral probably resulted in substantial losses of habitat and individual plants. Currently, pawpaws along State Road 765 in Charlotte County are particularly susceptible to residential development. On Pine Island, increasing threats from land clearing for horticulture, tropical fruit production, grazing, and residential housing have destroyed habitat and individual plants. Residential housing demands and associated infrastructure also threaten plants in eastern Orange County.

The suppression of fire has also resulted in the degradation of habitat throughout the beautiful pawpaw's range. As mentioned above, this species does not persist where it must compete for light with tall grasses and larger shrubs. Because fires are typically excluded from urban and agricultural settings, much of the remaining habitat for *D. pulchellus* is overgrown.

A small number of plants persist in areas where continued human alterations have created and maintained a suitable environment. On Pine Island and the mainland of Charlotte County, mowing of undeveloped agricultural, residential, and commercial property, and maintenance of road right-of-ways effectively limit competition with other vegetation. Unfortunately, protection of plants in these areas is tenuous and depends entirely on the location and rate of habitat alteration associated with agricultural and residential uses of the landscape.

Very few *D. pulchellus* are protected on public lands. To date, only five sites for pawpaw occur on public lands. Two of these sites, St. James Creek Preserve and CHEC, were recipient sites of pawpaw relocations in 1996. The State's (CARL) program currently protects one *D. pulchellus* site, and two other sites are on the Cecil M. Webb WMA. Some pawpaw may exist on county road right-of-ways but these have not been inventoried. One site on private land is protected because of its use as a pawpaw mitigation area. Existing and proposed land management techniques on these public and private lands will probably be sufficient to ensure localized persistence of the species. Additional monitoring is needed to verify the species' status on public lands. The vast majority of plants and habitat occur on private lands and are under increasing threat from agricultural and urban land conversion.

Management

The survival and recovery of *D. pulchellus* requires that additional habitat be protected and properly managed. Habitat acquisition may include fee title purchase, establishment of conservation easements, transfer of development rights, *etc*. Land management techniques include burning, mowing, and possibly selective grazing.

Control of competing vegetation is essential to the survival of *D. pulchellus*. Periodic fire or mowing can reduce competition and allow beautiful pawpaw to persist indefinitely. Low-intensity fires at one-to three-year intervals, or mowing at similar intervals have been used with success on several public lands. Prescribed fire is used on Lee County's St. James Creek Preserve on Pine Island and at the CHEC in Charlotte County. Pawpaw also persists on Cecil M. Webb WMA where periodic winter burns in combination with grazing are used to manage wildlife habitat. At the Greater Pine Island Water Association's pawpaw preserve, periodic mowing has replaced burning as the preferred management technique. Preliminary surveys of the site after mowing indicate that pawpaws persist on the preserve. However, concerns exist that mowing may not sufficiently recycle nutrients and could result in long-term adverse affects. Monitoring of burned and mowed sites is needed to assess which technique is most beneficial to pawpaw reproduction and survival.

Under the CARL program about 1,440 ha of pine flatwoods have been acquired under the Charlotte Harbor Flatwoods project (DEP 1995). At least one *D. pulchellus* site is known from these CARL lands (J. Beever, GFC, personal communication 1996). Additional sites are known to exist on about 6,040 ha that are still being considered for acquisition, protection, and management under the CARL program. Areas outside South Florida, in Orange County, should also be assessed for possible acquisition.

If managed properly, all existing public land and lands proposed for public acquisition that contained *D. pulchellus* would probably be sufficient to ensure the persistence of the species. However, management for this species may conflict with other public land uses. For example, *D. pulchellus* occurs on the GFC's Cecil M. Webb WMA under a frequent, low-intensity, winter fire prescription (Martin 1984). Recent changes from a winter to growing-season burning regime have been proposed, but such changes could result in damage to the above-ground vegetation during the flowering period (Beever 1990). Seed destruction over a number of consecutive years could adversely affect recruitment of sufficient seed stock to ensure survival of pawpaws in this area. The use of fire on other public lands that contain *D. pulchellus* appears to be compatible with the needs of this species. However, long-term monitoring of individual pawpaws must be initiated to ensure that existing and proposed land management actions benefit this endangered species.

Though the species may persist for some time on small tracts of publicly held land, many of the remaining individual pawpaws exist on private lands, and as a result are susceptible to habitat degradation and loss associated with land alterations or mismanagement. Protection of additional habitat through fee title acquisition, conservation easements, transfer of development rights, or other mechanisms that ensure perpetual protection are needed to ensure persistence of the species in the wild.

In addition to protection afforded through acquisition of habitat, Lee County protects the pawpaw through a listed species ordinance which requires that adverse effects to state and federally listed species be mitigated (Municipal Code Corporation 1994, Lee County 1996). Currently, one preserve site has been established for mitigation purposes. Unfortunately, the protective ordinances are not applicable to agricultural lands or lands being rezoned for agricultural purposes. Since most of the current threats to *D. pulchellus* in Lee County are from agricultural activities, the conservation of pawpaws cannot be achieved by county ordinances.

In Charlotte County, the Southwest Florida Regional Planning Council and Florida Department of Community Affairs provided on-site preserves for the beautiful pawpaw on a Development of Regional Impact (DRI) for a large subdivision. Unfortunately, *D. pulchellus* occurring in areas where smaller-scale projects and single family homes are constructed have not been protected by the DRI process. In addition, Charlotte County has no ordinances to protect federally or state listed plants at the county level (D. Beter, Charlotte County Division of Community Development, personal communication 1996).

Most known *D. pulchellus* do not occur on protected public lands and are afforded only limited protection by local conservation measures. These measures are insufficient to protect *D. pulchellus* on private land. Additional protection is needed and will most likely have to be accomplished by local municipalities or county governments.

In the absence of sufficient local, state, or federal regulatory protection, we consider the relocation of *D. pulchellus* to be a potentially valuable management tool. To date three pawpaw relocations have been undertaken. None of these efforts have been monitored long enough to determine the success rate of transplanting this species. Initial inspections, up to two years post-transplant, indicate good vegetative regrowth and flowering (K. Passarella, Passarella and Associates, Inc. personal communication 1996, G. Wass de Czege, Southern Biomes, personal communication 1996) and a 40 to 60 percent survival rate (FWS, unpublished data). Transplantation of *D. rugelii* in Volusia County has been successful; however, comparison of mortality, flowering, and seed production may not be possible since these data are not readily available for pawpaw in undisturbed sites. If monitoring indicates that plant relocation is biologically viable, we believe this technique could be used where destruction of plants and permanent alteration of habitat is inevitable. Even if relocation success is not high, this technique may still be preferred to the destruction of plants and habitat. Relocation of pawpaw may be limited by the relatively high cost associated with contracting consultants experienced in relocating this species.

Literature Cited

Beever, J.W. Telephone conversation. 26 November 1996.

Beter, D. Telephone conversation. 25 November 1996.

Department of Environmental Protection. 1995. Conservation and Recreation Lands annual report, 1995. Annual report to Board of Trustees of the Internal Improvement Trust Fund; Tallahassee, Florida.

Hilsenbeck, R.A. 1992. Status survey for *Deeringothamnus pulchellus* (beautiful pawpaw) conducted by the Florida Natural Areas Inventory.

Lee County. 1996. The 1994 Lee Plan, 1996 codification, Department of Community Development, Division of Planning, Fort Myers, Florida.

Martin, D. 1984. Field notes, U.S. Fish and Wildlife Service, Vero Beach, Florida.

Martin, D. 1996. Telephone conversation. 26 November 1996.

Municipal Code Corporation. 1994. Land development code, Lee County, Florida. Lee County Board of County Commissioners; Fort Myers, Florida.

Norman, E. 1998. Comments on draft species account. January 29.

Passarella, K. 1996. Telephone conversation. 12 December 1996.

Passarella and Associates, Inc. 1996. Beautiful pawpaw transplanting and time-zero monitoring report. Final Report to the U. S. Fish and Wildlife Service; Vero Beach, Florida.

Rehder, A. and W. Dayton. 1944. A new combination in *Asimina*. Journal of the Arnold Arboretum.

Small J.K. 1926. *Deerignothamnus pulchellus*. Addisonia 11:33-34.

U.S. Fish and Widlife Service [FWS]. 1988. Recovery plan for three Florida pawpaws. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Walker, J.W. 1971. Pollen morphology, phytogeography, and phylogeny of the Annonaceae. Contributions to the Gray Herbarium 202:1-132.

Wass de Czege, G. 1996. Telephone conversation. 6 December 1996.

Wunderlin, R.P. and D. Richardson. 1981. Status report of *Deeringothamnus pulchellus*. Contract No. 14-16-0004-78-106, U.S. Fish and Wildlife Service; Atlanta, Georgia.

Zimmerman, G.A. 1941. Hybrids of the American pawpaw. Journal of Heredity 32:82-91.

Recovery for the Beautiful Pawpaw

Deeringothamnus pulchellus Small

Recovery Objective: RECLASSIFY to threatened, then delist.

Recovery Criteria

Deeringothamnus pulchellus may be reclassified from endangered to threatened when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations and sites needed to ensure 20 to 90 percent probability of persistence for 100 years; when these sites, within the historic range of *D. pulchellus*, are adequately protected from further habitat loss, degradation, and fragmentation; when these sites are managed to maintain pine flatwoods to support *D. pulchellus*; and when monitoring programs demonstrate that these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *D. pulchellus*.

S1.1. Conduct surveys for *D. pulchellus*.

S1.1.1. Continue surveys in Lee and Charlotte counties. Though the range of this species has been thoroughly surveyed, current survey work is needed. An accurate survey of all suitable habitat would maximize the possibilities for protection, by enabling agency personnel to work with individual landowners as projects are proposed.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. Maintain distribution of known populations and suitable habitat in GIS database. Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database.

S2. Protect and enhance existing populations. Much of the native pine flatwood community in Florida has been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. Acquire or otherwise protect habitat through acquisition, conservation easements, or agreements with landowners.

S2.2. Protect populations on public lands. Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. Use local or regional planning to protect habitat. Utilize available regional and county planning processes to encourage protection of suitable unoccupied and habitat occupied habitat of *D. pulchellus*. Protecting this species on private property in Lee County is possible due to county ordinances that require conservation of listed plants.

S2.4. Enforce available protective measures. Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *D. pulchellus* lives.

S2.4.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.4.2. Enforce take and trade prohibitions. This species is protected by take provisions of the Endangered Species Act (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S2.5. Develop an *ex situ* collection. *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *D. pulchellus*. Since longterm seed storage seems impossible for this species, cultivated populations are very important. Although *D. pulchellus* is not easily grown from cuttings, young plants should be kept for study and reintroduction material.

S2.6. Augment natural populations of *D. pulchellus.*

S2.6.1. Establish a protocol for reintroduction. Records for source plants, techniques for establishing new populations, and protocols for monitoring are needed.

S2.6.2. Locate potential (re)introduction sites. Survey habitat within the historic range of *D. pulchellus* and identify protected lands, both public and private, that will be suitable habitat.

S2.6.3. (Re)introduce plants to protected sites. Use plants under cultivation to (re)establish plants in suitable habitat.

S3. Conduct research on life history characteristics of *D. pulchellus*. To effectively recover this species more specific biological information is needed.

S3.1. **Conduct research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality**. Observations of the relation of flowering to fire, pollination, seed production, and seedling biology will help to guide reintroduction efforts.

S3.2. **Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.**

S3.3. **Conduct research to assess management requirements of *D. pulchellus*.** Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring information will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S3.4. **Assess feasibility of relocating *D. pulchellus*.** Removing plants threatened with destruction may be the only conservation strategy available in some situations. Information on transplant techniques and plant survival are needed to assess whether transplanting should be pursued.

S4. **Monitor existing populations of *D. pulchellus*.**

S4.1. **Develop monitoring protocol to assess population trends for *D. pulchellus*.**

S4.1.1. **Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival, and mortality.** Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. **Monitor the effects of various land management actions on *D. pulchellus*.** Assess any changes in demographic characteristics of *D. pulchellus* in response to land management activities, such as prescribed fire, exotic plant control.-.

S4.2. **Develop a quantitative description of the population structure of *D. pulchellus***. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) may prove helpful in future management.

S4.3 **Monitor reintroduced plants.** Monitoring of reintroduced plants will be essential for assessing the status of new plants and their contribution to the population as a whole. Compare adult survival, seed production, germination rates, seed survival, seedling survival, and growth rates between transplanted plants and natural plants. Where monitoring indicates that the introduction has been unsuccessful, reevaluate protocol and methodology.

S5. **Provide public information about *D. pulchellus*.** It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *D. pulchellus* and other rare species requires a self-sustaining, secure, number of natural populations.

S6. Establish delisting criteria. Once reclassification is achieved, research and monitoring results may provide data necessary to develop delisting criteria.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Urbanization, fire suppression, and agricultural land uses have decreased the available habitat.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little undisturbed pine flatwoods habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *D. pulchellus* populations by preventing damage from off-road vehicle use and overcollection, and by providing proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the pine flatwood community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. Pine flatwoods are naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation. *D. pulchellus* appears to benefit from burning at the short intervals of a natural pine flatwood community.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida high pine as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *D. pulchellus*.

H1.2.3. Control access to areas where listed plants are growing. Trampling and off-road vehicles can severely threaten individual populations. Fencing may be needed for some sites, and clearing around individual *D. pulchellus* plants has been suggested.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.2. **Enhance sites with native plant species.** Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. **Continue habitat-level research projects.** Study the response of *D. pulchellus* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. **Monitor habitat/ecological processes.** Monitor the effects of land management actions, such as prescribed fire, mechanical disturbance, *etc*., on the habitats where *D. pulchellus* occurs.

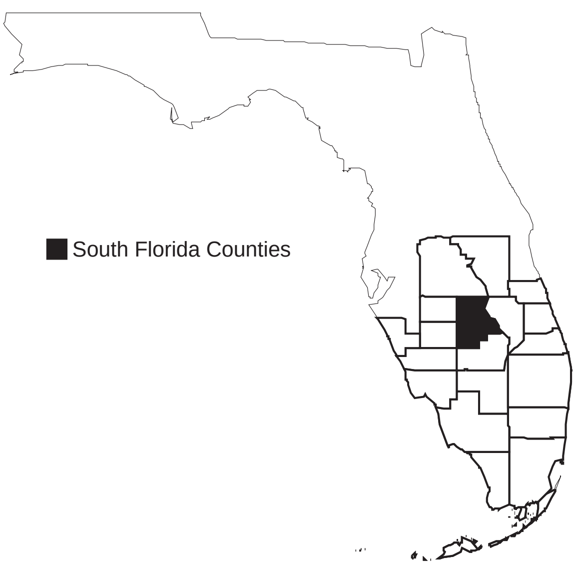
H5. **Provide public information about pine flatwood vegetative communities and their unique biota**. Educational efforts, especially those conducted by private conservation organizations, have been successful in providing important information about pine flatwood plant communities to the public. The State's system of biological preserves depends for its funding and future success on a broad base of public understanding and support. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, the Florida Park Service, the Florida Native Plant Society and local garden clubs will play crucial roles in increasing public appreciation of pine flatwood plant communities and *D. pulchellus*.

Garrett's Mint

Dicerandra christmanii Huck and Judd

Federal Status:	**Endangered (Sept. 21, 1989)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of Garrett's mint.



Garrett's mint is a small, fragrant suffrutescent shrub that inhabits the scrub of central peninsular Florida. Due to *Dicerandra christmanii's* strong resemblance to the scrub mint (*Dicerandra frutescens*) it was originally classified as scrub mint. It can be differentiated from the scrub mint by its scent, leaf size, and color of its flowers. Loss of habitat to residential and agricultural development (particularly for citrus groves), as well as fire suppression in tracts of remaining habitat, are the principal threats to this species.

This account represents a revision of the existing recovery plan for the Garrett's mint (FWS 1987).

Description

Dicerandra christmanii is a small, fragrant shrub that reaches 50 cm in height (Huck *et al.* 1989). Both its floriferous and vegetative shoots are stiff and ascend from a ramose (many branched, branching), woody base. Its taproot is branched with extensive, spreading, fibrous roots.

The leaves of Garrett's mint are sessile and have rounded apices, cuneate bases, entire margins and glandular-pitted upper and lower surfaces (Huck *et al.* 1989). Leaves found on the determinate, flowering shoots are narrowly ovate to narrowly oblong. Those that subtend the cymes are 2 to 8 mm long and 0.5 to 1.8 mm wide, while those that do not subtend the cymes are approximately 5 to 11 mm long, and 1 to 2.5 mm wide. The leaves of overwintering, vegetative shoots are similarly shaped, but larger.

The inflorescence is a verticillaster (Huck *et al.* 1989), with each cyme containing 1 to 3 flowers. The calyx is 6.5 to 10 mm long, approximately 2 mm wide (at midpoint), and bordered with an indistinct white band. The corolla is funnel shaped and abruptly bent to about 90 degrees. Its tube is 7 to 10 mm long, and its limb (from geniculum to distal edge of upper lobe) is 5 to 10 mm long. The corolla buds yellow, but at maturity, it is a pale cream (eventually fading to white). It has vivid purple-red markings that are often trellise-patterned on the upper lobe, but irregularly spotted on the lower lobe. The upper lobe is a recurving, cleft standard, and the lower lobe is tripartite (three parted) with a recurving middle petal.

The flowers have four, paired stamens, which are exerted slightly beyond the lower corolla lip (Huck *et al.* 1989). The filaments are white, the anther sacs are brilliant yellow, and the connective is widened and may be covered with a few small, reddish and yellow glands at the basal end. The pollen is white and sticky. The pistil is white and has a slender, hirtellous style. The fruit is a schizocarp of four ovoid, brown, smooth nutlets.

Dicerandra christmanii is very similar in appearance to another *Diceranda* species, *D. frutescens.* The two species are separated using the following characteristics. One, *D. frutescens* has a minty aroma, whereas *D. christmanii* smells of menthol (Huck *et al.* 1989). Two, the leaves of *D. frutescens* are longer than those of *D. christmanii* (Huck *et al.* 1989). Three, the anthers of *D. frutescens* are deep purple to white in color, while the anthers of *D. christmanii* are a brilliant yellow (Huck *et al.* 1989). Four, the corolla of *D. frutescens* fades from a cream color to a white within 1 to 3.5 hours of anthesis, while the corolla of *D. christmanii* retains its cream color throughout most of the first day of anthesis (Huck *et al.* 1989). Five, the anther connectives of *D. frutescens* have more, and larger, glands than those of *D. christmanii* (Huck *et al.* 1989).

Taxonomy

Specimens of *D. christmanii* were first collected by Garrett in 1948 east of Sebring and originally identified as *D. frutescens* by Ward (1979), Wunderlin (1984), and Huck (1987). *D. christmanii* was named as a distinct species in 1989 (Huck *et al.* 1989).

Distribution

Dicerandra christmanii has an extremely small range. It is known from five populations, all in Highlands County (Huck *et al.* 1989). These populations are located between Lake Jackson and Lake Istokpoga (FNAI 1996), 10.5 km north of the range of *Dicerandra frutescens* (Huck *et al.* 1989) (Figure 1). Interestingly, a slight break in the ridge occurs between the ranges of the two species at Josephine Creek (Huck *et al.* 1989).

Habitat

Dicerandra christmanii is found within openings in sclerophyllous oak scrub (Huck *et al.* 1989). As a "gap" species, it prefers open areas and does not grow vigorously when in shaded conditions. The species occurs on well-to excessively drained yellow sands of Astatula and Tavares soil types and is found where the seasonal high water table is at least 1 to 2 m deep.

Reproduction

Dicerandra christmanii flowers from July to November, primarily in September and October (Huck *et al.* 1989). Like other *Dicerandra* species, it has spurred

Garrett's mint flower.
Original photograph by Steve Shirah.

anthers which must be triggered by insects for the pollen to be released and dispersed (FWS 1987). This pollination process occurs mainly through bee-flies (*Exoprosopa fasciata*), and few other insects visit the plant (Huck *et al.* 1989).

The seeds do not have mechanisms for wind dispersal and generally fall close to the plant (R. Huck, personal communication, 1996). Some *Dicerandra* species have been shown to use water as a dispersal agent, sometimes having their seeds carried by streams (Huck 1987). However, the limited distributions of *D. christmanii, D. frutescens,* and *D. immaculata* indicate that this mechanism is not effective in South Florida. Given this limited dispersal, colonization of a newly disturbed area by *D. christmanii* depends on whether or not it is present in the seedbank. The lifespan of seeds in the seedbank is unknown.

Relationship to Other Species

Garrett's mint is frequently visted by its pollinators, bee-flies, but seldom by other insects. Like other *Dicerandra* species, it contains essential oils which protect it from feeding animals (McCormick *et al.* 1993). Interestingly, the chemical composition of the essential oils in *D. christmanii* is much different than that of *D. frutescens*, *D. immaculata* and *D. cornutisma* (McCormick *et al.* 1993). This explains the distinct difference in odor between Garrett's mint and the other *Dicerandra* species.

Though the interaction has not been observed, Garrett's mint may be susceptible to feeding Pyralid moths. These are the only insects known to feed on scrub mint (Eisner *et al.* 1990), so they may be consumers of Garrett's mint as well.

Status and Trends

Dicerandra christmanii was listed as endangered on September 21, 1989 (54 FR 38947). It had originally been classified as *D. frutescens* and was protected under that earlier listing. Loss of habitat to residential and commercial development, compounded by an extremely small distribution, threatens this species.

The principal site for *D. christmanii* is Flamingo Villas, an unbuilt subdivision adjacent to Sebring Airport. At present, it is the only protected site for the species, and the remaining lots in the area are the highest priority for acquisition for the Lake Wales Ridge National Wildlife Refuge. As of November 1995, the FWS had arrived at contracts on 698 of the 1,028 interior lots and 14 of the 30 lots facing State Road 623.

Although habitat loss is the primary threat to Garrett's mint, there are other factors that endanger its survival. The suppression of fire has limited the number of clearings available for the growth of gap species like *D. christmanii*. Also, dumping of trash and off-road vehicular traffic has resulted in erosion of habitat and trampling of individuals. This is of particular concern at Flamingo Villas, where management of the property is urgently needed to combat the rapidly increasing off-road vehicle use, trash dumping, and exotic plant invasion (FWS 1996).

Management

No research has been conducted on the response of *D. christmanii* to management practices. However, research on this subject has been completed for *D. frutescens*, and *D. christmanii* is likely to respond in a similar manner (E. Menges, Archbold Biological Station, personal communication 1997). This research can, therefore, serve as a guideline for management of *D. christmanii*.

Periodic fire appears to benefit *D. frutescens*, as colonies found in areas burned within the last 10 years exhibit the most vigorous growth (Menges 1992). Though growth appears most vigorous during this period, it has not been demonstrated to be the optimum frequency of disturbance. In fact, scrub mint may not be sensitive to burning frequency, as it is found in areas that were last burned as recently as 3 and as long as 65 years ago.

Based on the response of scrub mint, Garrett's mint should require a burning or alternative disturbance regime to maintain the quality of its habitat. In addition, fencing of sites is needed to protect the habitat from trash dumping and erosion due to off-road vehicle use. *D. christmanii* is vulnerable to trampling and vehicular traffic and is adversely affected by such impacts.

Archbold Biological Station has integrated research into the conservation biology of *D. christmanii* with monitoring efforts (FWS 1996). The breeding system, pollinators, demographic patterns, and genetic variability (through enzyme electrophoresis) are being investigated (FWS 1996). In addition to this research, experimentation with small-scale fire management is needed.

Literature Cited

Eisner, T., D. McCormick, M. Sakaino, M. Eisner, S.R. Smedley, D.J. Aneshansley, M. Deyrup, R.L. Myers, and J. Meinwald. 1990. Chemical defense of a rare mint plant. Chemoecology 1 (1990):30-37.

Florida Natural Areas Inventory. 1996. Element occurrence data for *Dicerandra christmanii*; Tallahassee, Florida.

Huck, R.B. 1987. Systematics and evolution of *Dicerandra* (Labiatea). Phanerogamarum Monographiae Tomas XIX. J. Cramer, Berlin.

Huck, R.B., W.S. Judd, W.M. Whitten, J.D. Skean Jr., R.P. Wunderlin, K.R. Delaney. 1989. A new *Dicerandra* (Labiatae) from the Lake Wales Ridge of Florida, with a cladistic analysis and discussion of endemism. Systematic Botany 14(2):197-213.

Huck, R.B. 1996. Telephone communication. 10 October 1996.

McCormick, K.D., M. Deyrup, E.S. Menges, S.R. Wallace, J. Meinwald, and T. Eisner. 1993. Relevance of chemistry to conservation of isolated populations: The case of volatile leaf components of *Dicerandra* mints. Proceedings of the National Academy of Science, volume 90; 7701-7705.

Menges, E.S. 1992. Habitat preferences and response to disturbance for *Dicerandra frutescens*, a Lake Wales Ridge (Florida) endemic plant. Bulletin of the Torrey Botanical Club 119(3):308-313.

Menges, E. 1997. Letter. 5 February 1997.

U.S. Fish and Wildlife Service. 1987. Recovery plan for three Florida mints. U.S. Fish and Wildlife Service; Atlanta, Georgia.

U.S. Fish and Wildlife Service. 1996. Recovery plan for nineteen central Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Ward, D.B., ed. 1979. Rare and endangered biota of Florida, volume 5, Plants. University Presses of Florida; Gainesville, Florida.

Wunderlin, R.P. 1984. Status report on *Dicerandra frutescens* Shinners. Unpublished report prepared for U.S. Fish and Wildlife Service; Jacksonville, Florida.

Recovery for the Garrett's Mint

Dicerandra christmanii Huck and Judd

Recovery Objective: STABILIZE, then reclassify to threatened

Recovery Criteria

Dicerandra christmanii may be considered stabilized when existing populations, within the historic range of *D. christmanii*, are adequately protected from further habitat loss, degradation, and fire suppression. These sites must also be managed to maintain xeric oak scrub to support *D. christmanii.*

Once the existing populations are stabilized, *D. christmanii* may be considered for reclassification to threatened status. Reclassification will be considered when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations required to ensure 20 to 90 percent probability of persistence for 100 years; when these populations, within the historic range of *D. christmanii* are adequately protected from further habitat loss, degradation, and fire suppression; when these sites are managed to maintain the seral stage of xeric oak scrub that supports *D. christmanii*; and when monitoring programs demonstrate that these sites support sufficient population sizes, are distributed throughout the historic range, and are sexually or vegetatively reproducing at sufficient rates to maintain the population.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Delisting criteria may be defined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *D. christmanii.*

S1.1. Conduct surveys for additional populations of *D. christmanii*.

S1.1.1. Continue surveys in Highlands County. Though the range of this species has been thoroughly surveyed, it should be periodically re-surveyed to learn the status of the species on private lands.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. Maintain distribution of known populations and suitable habitat in GIS database. Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. **Protect and enhance existing populations.** Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. **Acquire or otherwise protect privately owned habitat through acquisition, conservation easements, or agreements with landowners**.

S2.2. **Protect populations on public lands.** Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. **Use local or regional planning to protect habitat.** Utilize available regional and county planning processes to encourage protection of suitable, unoccupied, and occupied habitat of *D. christmanii*.

S2.4. **Continue *ex situ* conservation.** *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *D. christmanii*.

S2.4.1. **Conserve germ plasm.** The seed for this species is not presently in long-term storage.

S2.4.2. **Maintain *ex situ* collection**. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *D. christmanii* as part of the National Collection.

S2.5. **Enforce available protective measures.** Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *D. christmanii* lives.

S2.5.1. **Initiate section 7 consultation when applicable.** Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. **Enforce take and trade prohibitions.** This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from state lands.

S2.6. **Augment natural populations of *D. christmanii.*** *A*ugmentation of populations on protected land is appropriate because there is little prospect for protecting additional sites.

S2.6.1. **Establish a protocol for reintroduction.** Records for source plants, techniques for establishing new populations, and protocols for monitoring are needed.

S2.6.2. **Locate potential (re)introduction sites.** Survey habitat within the historic range of *D. christmanii* and identify protected lands, both public and private, that would be suitable habitat.

S2.6.3. **(Re)introduce plants to protected sites.** Use plants under cultivation to (re)establish plants in suitable habitat.

S3. Continue research on life history characteristics of *D. christmanii*. Although recent work on *D. christmanii* can be used to infer answers to some life history questions, much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, pollinators, dispersal, growth, survival, and mortality.

S3.2. Assess genetic variability in the *Dicerandra*. Work on this topic is underway. *Dicerandra* species are taxonomically difficult to distinguish without genetic work.

S3.3. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.4. Conduct research to assess management requirements of *D. christmanii*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring information on the localities of *D. christmanii* will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S4. Monitor existing populations of *D. christmanii*.

S4.1. Develop monitoring protocol to assess population trends for *D. christmanii*.

S4.1.1. **Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival, and mortality.** Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. **Monitor the effects of various land management actions on *D. christmanii*.** Assess any changes in demographic characteristics of *D. christmanii* in response to land management activities, such as prescribed fire, exotic plant control, *etc.* At present, the burn frequency for this species is unknown. Though *D. christmanii* grows more vigorously in areas burned within the last 10 years, it can be found in areas that were last burned from 3 to 65 years ago. More information is needed on the role of fire for this species.

S4.2. Develop a quantitative description of the population structure of *D. christmanii*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) may prove valuable in future management actions.

S4.3. Monitor re-introduced plants. Monitoring of reintroduced plants will be essential for assessing the status of new plants and their contribution to the population as a whole. Compare adult survival, seed production, germination rates, seed survival, seedling survival, and growth rates between transplanted plants and natural plants. Where monitoring indicates that the introduction has been unsuccessful, reevaluate protocol and methodology.

S5. Provide public information about *D. christmanii*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. However, caution should be taken to avoid revealing specific locality information of *D. christmanii*.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *D. christmanii* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there is one protected site for *D. christmanii*.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *D. christmanii* populations by preventing habitat damage from off-road vehicle use and over collection by providing proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. *D. christmanii* is experiencing competition from tall grasses. Without control, exotic/invasive plants may become a threat to the survival and recovery of *D. christmanii*.

H1.2.3. Control access to areas where listed plants are growing. Trampling, trash dumping, and off-road vehicles can severely threaten individual populations. Presently, the one protected site for this species is threatened by trash dumping and off-road vehicle use. This property may require fencing or other protection to eliminate this threat.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *D. christmanii* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc.,* on the habitats where *D. christmanii* occurs.

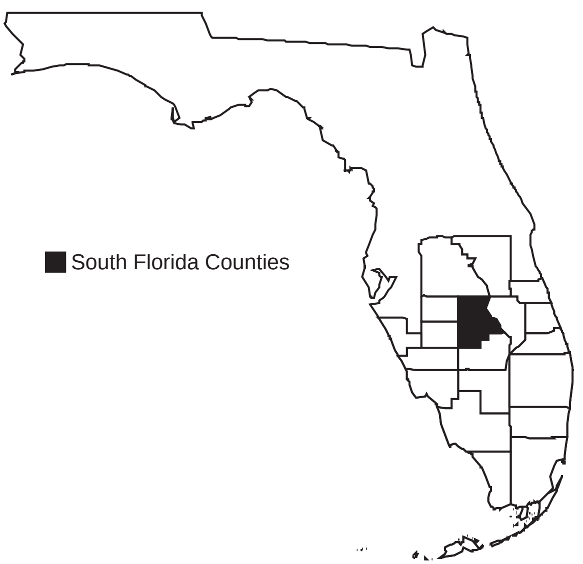
H5. Provide public information about scrub and its unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the SFWMD, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Scrub Mint

Dicerandra frutescens Shinners

Federal Status:	**Endangered (Nov. 1, 1985)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of scrub mint.



The scrub mint is a small, fragrant shrub that inhabits the scrub of central peninsular Florida. It bears a strong resemblance to another *Dicerandra* species, Garrett's mint, but can be differentiated by its scent, the color of its flowers, and the size of its leaves. Loss of habitat due to residential and agricultural development (particularly for citrus groves), as well as fire suppression in tracts of remaining habitat, are the principle threats to this plant.

This account represents a revision of the existing recovery plan for the scrub mint (FWS 1987).

Description

The scrub mint is a dense or straggly, low-growing shrub (Kral, 1983). It reaches 50 cm in height and grows from a deep, stout, spreading-branching taproot. Its branches are mostly spreading, and sometimes are prostrate. Its shoots have two forms, one which is strictly leafy and overwintering, and another which is flowering and dies back after fruiting.

The leaves vary in shape. They can be narrowly oblong-elliptic, linear-elliptic, or linear-oblanceolate (Kral 1983). The upper surface of the leaves is dark green, with the midrib slightly impressed. The lower surface is slightly paler, with the midrib slightly raised. They are 1.5 to 2.5 cm long, 2 to 3 mm wide, subsessile, flattish but somewhat fleshy, narrowly or broadly rounded at the apical end, have entire margins, and are not revolute.

Scrub mint has an inflorescence that is elongated and interrupted, and, at least half of the flowering shoot is floriferous (Kral 1983). The calyx, at anthesis, is approximately 9 to 10 mm long, nearly erect, proximally and medially green, and distally tinged with red, with a broad white zone around the orifice. The corolla is 1.9 to 2.0 cm long, with an erect tube that is approximately 7 mm long. The external surface of the throat and limb is white or yellowish white. The upper lip is marked internally with a trellis pattern of lines and dots of deep purple, while the lower lip is maculate with larger, concentric spots from lobe bases to base of the lip.

The flower has two pairs of stamens, with one pair slightly longer than the other (Kral 1983). The filaments are white, and the anthers are purple. Styles are almost white and bent forward or curved downward (usually above the anthers).

Dicerandra frutescens is very similar in appearance to another *Dicerandra* species, *D. christmanii.* These two mints are separated using the following characteristics. One, *D. frutescens* has a minty aroma, whereas *D. christmanii* smells of menthol (Huck *et al.* 1989). Two, the leaves of *D. frutescens* are longer than those of *D. christmanii* (Huck *et al.* 1989). Three, the anthers of *D. frutescens* are deep purple to white in color, while the anthers of *D. christmanii* are a brilliant yellow (Huck *et al.* 1989). Four, the corolla of *D. frutescens* fades from a cream color to white within 1 to 3.5 hours of anthesis, while the corolla of *D. christmanii*, however, retains its cream color throughout most of the first day of anthesis (Huck *et al.* 1989). Five, the anther connectives of *D. frutescens* have more, and larger, glands than those of *D. christmanii* (Huck *et al.* 1989).

Taxonomy

Dicerandra frutescens was named by Lloyd Shinners (1962); his circumscription of the species was modified by Huck (1981), who reassigned specimens from Sumter and Marion counties to a new species, *Dicerandra cornutissima*. Kral (1982), working independently of Huck, came to the same conclusion.

Distribution

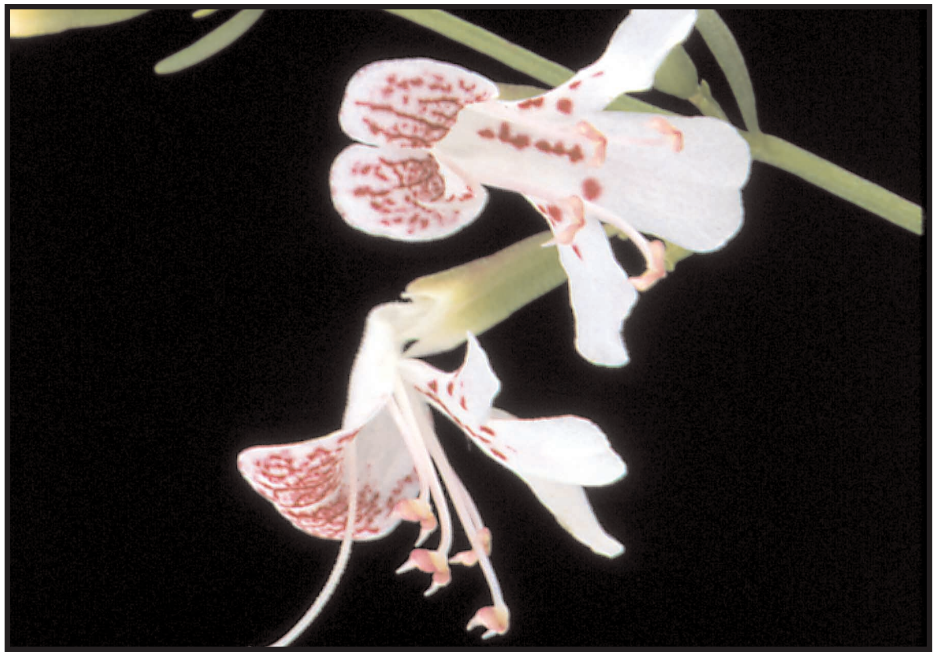
The known range of the scrub mint is quite small. It occurs on the southern portion of the Lake Wales Ridge in Highlands County, and is found from just north of Lake June in Winter, south to the Archbold Biological Station (FNAI 1996, Menges 1992).(Figure 1). The range of Garrett's mint lies only 10 km to the north (Huck *et al.* 1989). The two ranges are separated by a slight break in the ridge at Josephine Creek (Huck *et al.* 1989).

Habitat

Dicerandra frutescens is mostly restricted to excessively drained, yellow sandy soils of the Astatula and Paola soil types (Menges 1992). However, it has been found on a moderately well-drained, yellow sand of the Orsino type (Menges 1992). In these soil types, scrub mint occurs adjacent to or within disturbed areas in sand pine scrub, oak scrub and sandhill habitats (FWS 1987, Menges 1992). It occupies sites with shallow litter layers that have an incomplete, or non-existent, tree and shrub canopy (Menges 1992).

Reproduction

Dicerandra frutescens has perfect flowers (Kral 1983) and reproduces sexually, with outcrossing (Huck 1981). It is not capable of spreading clonally (Menges 1992), but has been shown to root easily from cuttings of vegetative growth (FWS 1987). Growth containing flowers or flower buds will also root, but will often flower then die (FWS 1987).



Scrub mint flower.
Original photograph by Steve Shirah.

Scrub mint needs insects for pollination. Its flowers have spurred anthers, which require triggering by insects to release and disperse pollen (FWS 1987). Though visited by a variety of insects (Huck *et al.* 1989), the scrub mint is pollinated mainly by bee-flies (Menges 1992). Its flowering occurs from August through winter, and fruit production occurs from September through winter (Wunderlin 1984).

The scrub mint's seed dissemination mechanisms are unknown, though they possibly include passive dispersal (E. Menges, Archbold Biological Station, personal communication 1997). It is possible that the seeds are not dispersed far from the parent plant, since seed dispersal in the related Lakela's mint (*Dicerandra immaculata*) is known to be very limited. Observations of an introduced population of Lakela's mint at Hobe Sound NWR indicate that the seedlings occur a maximum distance of 2 m from parent plants (Race 1994). Scrub mint's seeds survive in the seed bank for at least 2 years (E. Menges, Archbold Biological Station, personal communication 1997), and if dispersal in scrub mint is similarly limited, then persistence in the seed bank may be an important strategy that this species uses for colonizing newly disturbed areas.

Relationship to Other Species

Dicerandra frutescens is a gap-utilizing species; it inhabits open areas in the vegetation (FWS 1996). Thus, it does not tolerate shading by other plants.

Scrub mint is not often damaged by herbivores (Menges 1992). It contains essential oils which protect it from feeding animals (McCormick *et al.* 1993). The cut leaves of the plant have been shown to repel ants, and the extracted aromatic chemicals have been shown to repel both ants and cockroaches (Eisner *et al.* 1990). Only caterpillars of Pyralid moths are known to feed on this species (Eisner *et al.* 1990)

Status and Trends

Scrub mint was given endangered status on November 1, 1985 because of its extremely restricted range and the threat of commercial and residential development of its habitat (50 FR 45618). At present, the species is known from only 12 sites in Highlands County, and its scrub habitat continues to be developed or converted to agricultural uses.

Based on estimates from Archbold Biological Station, the total population of *D. frutescens* numbers approximately 12,000 individuals (E. Menges, Archbold Biological Station, personal communication 1997). However, a very large population of an unidentified mint (possibly *D. frutescens*, possibly a different subspecies) exists outside the accepted range of the scrub mint. This population is estimated to contain approximately 44,500 individuals (E. Menges, Archbold Biological Station, personal communication 1997). If it is determined to be *D. frutescens*, then the species is closer to its recovery goal than originally believed, and searches for the mint outside of its accepted range may be warranted. However, if this population is determined to be a new subspecies of the scrub mint, it may be a candidate for listing as an endangered or threatened species.

Dicerandra frutescens occurs mostly on unprotected, private land. Protected sites for the species exist only at Archbold Biological Station (FWS 1996). Though it also occurs on the right-of-way of U.S. Highway 27, the possibility of road widening and changes in land use adjoining the road limit the protective value of the right-of-way (FWS 1996).

Fire suppression may pose an additional threat to the species. *Dicerandra frutescens* inhabits the clearings created by fires and other disturbances. Thus, tracts of land that are protected from fire may be limited in their ability to support scrub mint.

Dicerandra frutescens, and the other *Dicerandra* species, have small ranges and very few protected sites. Among plants of the Lake Wales Ridge, they are second only to scrub lupine (*Lupinus aridorum*) in priority for land acquisition (FWS 1996). Fortunately, the potential for easements exists in Highlands County, as several private lots containing *D. frutescens* are for sale.

Management

Dicerandra frutescens requires clearings in which to grow and seems to benefit from periodic fires. Colonies found in areas burned within the last 10 years exhibit the most vigorous growth (Menges 1992). However, though growth appears most vigorous during this period, it has not been demonstrated to be the optimum frequency of disturbance. In fact, the species may not be sensitive to burning frequency, since it is found in areas that were last burned as recently as 3 and as late as 65 years ago (Menges 1992).

Although colonies of *D. frutescens* respond favorably to periodic fires, the individuals die after being burned, defoliated, or cut at their bases (Menges 1992). Recruitment after a disturbance occurs via the seed bank (Menges 1992). Thus, scrub mint is vulnerable to trampling, and access to protected sites should be restricted.

At this time, *D. frutescens* is in cultivation under the auspices of the Center for Plant Conservation as part of the permanent rare plant collection at Bok Tower Gardens, Lake Wales, Florida. Research on its breeding system, pollinators, demographic patterns, and genetic variability is being conducted by Archbold Biological Station in conjunction with monitoring efforts (FWS 1996).

Literature Cited

Eisner, T., D. McCormick, M. Sakaino, M. Eisner, S.R. Smedley, D.J. Aneshansley, M. Deyrup, R.L. Myers, and J. Meinwald. 1990. Chemical defense of a rare mint plant. Chemoecology 1 (1990):30-37.

Florida Natural Areas Inventory. 1996. Element occurence data for: *Dicerandra frutescens*; Tallahassee, Florida.

Huck, R.B. 1981. *Dicerandra cornutissima*, a new woody labiate from Florida. Phytologia 47:313-315.

Huck, R.B., W.S. Judd, W.M. Whitten, J.D. Skean Jr., R.P. Wunderlin, K.R. Delaney. 1989. A new *Dicerandra* (Labiatae) from the Lake Wales Ridge of Florida, with a cladistic analysis and discussion of endemism. Systematic Botany 14(2):197-213.

Kral, R. 1982. Some notes on *Dicerandra* (Lamiaceae). Sida 9(3): 238-262.

Kral, R. 1983. A report on some rare, threatened, or endangered forest-related vascular plants of the South. USDA Forest Service Technical Publication. R8-TP2; Atlanta, Georgia.

McCormick, K.D., M. Deyrup, E.S. Menges, S.R. Wallace, J. Meinwald, and T. Eisner. 1993. Relevance of chemistry to conservation of isolated populations: The case of volatile leaf components of *Dicerandra* mints. Proceedings of the National Academy of Science, volume 90, pp. 7701-7705.

Menges, E. S. 1992. Habitat preferences and response to disturbance for *Dicerandra frutescens*, a Lake Wales Ridge (Florida) endemic plant. Bulletin of the Torrey Botanical Club 119(3): 308-313.

Menges, E. 1997. Letter. 5 February 1997.

Race, T. 1994. Establishment of a new population of *Dicerandra immaculata* at the Hobe Sound National Wildlife Refuge in Florida. Unpublished report prepared for the U.S. Fish and Wildlife Service; Jacksonville, Florida. On file at U.S. Fish and Wildlife Service; Vero Beach, Florida.

Shinners, L.H. 1962. Synopsis of *Dicerandra* (Labiatae). Sida 1(2):89-91.

U.S. Fish and Wildlife Service. 1987. Recovery plan for three Florida mints. U.S. Fish and Wildlife Service; Atlanta, Georgia.

U.S. Fish and Wildlife Service. 1996. Recovery plan for nineteen Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Wunderlin, R.P. 1984. Status report on *Dicerandra frutescens* Shinners. Unpublished report prepared for U.S. Fish and Wildlife Service; Jacksonville, Florida.

Recovery for the Scrub Mint

Dicerandra frutescens Shinners

Recovery Objective: STABILIZE, then reclassify to threatened

Recovery Criteria

Dicerandra frutescens may be considered stabilized when existing populations, within the historic range of *D. frutescens*, are adequately protected from further habitat loss degradation and fire suppression. These sites must also be managed to maintain xeric oak scrub to support *D. frutescens.*

Once the existing populations are stabilized, *D. frutescens* may be considered for reclassification to threatened status. Reclassification will be considered when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations required to ensure 20 to 90 percent probability of persistence for 100 years; when these populations, within the historic range of *D. frutescens,* are adequately protected from further habitat loss, degradation, and fire suppression; when these sites are managed to maintain the seral stage of xeric oak scrub that supports *D. frutescens*; and when monitoring programs demonstrate that these sites support populations of sufficient sizes, are distributed throughout the historic range, and are sexually or vegetatively reproducing at sufficient rates to maintain the population.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Delisting criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *D. frutescens.*

S1.1. Conduct surveys of *D. frutescens*.

S1.1.1. Continue surveys in Highlands County. Though the Lake Wales Ridge has been thoroughly surveyed, it should be periodically resurveyed to learn the status of the species on private lands.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. Maintain distribution of known populations and suitable habitat in GIS database. Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database.

Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S1.3. Determine identity of *Dicerandra* population outside accepted scrub mint range.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. Acquire or otherwise protect privately owned habitat through acquisition, conservation easements, or agreements with landowners. *D. frutescens* has been found on the right-of-way of Highway 27. Here working with the DOT on management needs, such as altering mowing schedules until after flowering and seed set, should be explored.

S2.2. Protect populations on public lands. Develop management guidelines that allow for a fire regime that fosters a mosaic of successional stages.

S2.3. Use local or regional planning to protect habitat. Utilize available regional and county planning processes to encourage protection of suitable, unoccupied, and occupied habitat of *D. frutescens*.

S2.4. Continue *ex situ* conservation. *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *D. frutescens*.

S2.4.1. Conserve germ plasm. The seed for this species is not presently in long-term storage.

S2.4.2. Maintain *ex situ* collection. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *D. frutescens* as part of the National Collection.

S2.5. Enforce available protective measures. Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *D. frutescens* lives.

S2.5.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. Enforce take and trade prohibitions. This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S2.6. Augment natural populations of *D. frutescens.* Augmentation of populations on protected land is appropriate because there is little prospect for protecting additional sites.

S2.6.1. **Establish a protocol for reintroduction.** Records for source plants, techniques for establishing new populations, and protocols for monitoring are needed.

S2.6.2. **Locate potential (re)introduction sites.** Survey habitat within the historic range of *D. frutescens* and identify protected lands, both public and private, that will be suitable habitat.

S2.6.3. **Reintroduce plants to protected sites.** Use plants under cultivation to re-establish plants in suitable habitat.

S3. **Continue research on life history characteristics of *D. frutescens*.** Although recent work on *D. frutescens* can be used to infer answers to some life history questions, much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species more specific biological information is needed.

S3.1. **Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, pollinators, dispersal, growth, survival, and mortality.**

S3.2. **Assess genetic variability for the genus *Dicerandra*.** Work on this topic is underway. *Dicerandra* species are taxonomically difficult to distinguish without genetic work.

S3.3. **Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.**

S3.4. **Conduct research to assess management requirements of *D. frutescens*.** Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring at *D. frutescens* sites, will provide information about factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should well provide to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S4. **Monitor existing and reintroduced populations of *D. frutescens*.**

S4.1. **Develop monitoring protocol to assess population trends for *D. frutescens*.**

S4.1.1. **Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival and mortality.** Also monitor for pollinators, herbivory, disease and injury.

S4.1.2. **Monitor the effects of various land management actions on *D. frutescens*.** Assess any changes in demographic characteristics of *D. frutescens* in response to land management activities, such as prescribed fire, exotic plant control, etc. At present, the burn frequency for this species is unknown. Though *D. frutescens* grows more vigorously in areas burned within the last 10 years, it can be found in areas that were last burned from 3 to 65 years.ago More information is needed on the role of fire for this species.

S4.2. **Develop a quantitative description of the population structure** of ***D. frutescens***. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) may prove valuable in future management actions.

S4.3. **Monitor reintroduced plants.** Monitoring of reintroduced plants will be essential for assessing the status of new plants and their contribution to the population as a whole. Compare adult survival, seed production, germination rates, seed survival, seedling survival, and growth rates between transplanted plants and natural plants. Where monitoring indicates that the introduction has been unsuccessful, reevaluate protocol and methodology.

S5. **Provide public information about *D. frutescens*.** It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. However, caution should be taken to avoid revealing specific locality information of *D. frutescens*.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *D. frutescens* and other rare species require a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. **Prevent degradation of existing habitat.** Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there are two protected sites for *D. frutescens*.

H1.1. **Secure habitat through acquisition, landowner agreements, and conservation easements.** With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. **Manage and enhance habitat.** Manage habitat to maintain *D. frutescens* populations by preventing habitat damage from off-road vehicle use and over collection, and by providing proper management of habitat including prescribed fire.

H1.2.1. **Conduct prescribed burns.** Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches are necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation.

H1.2.2. **Control and eliminate exotic and invasive plants and animals.** Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *D. frutescens*.

H1.2.3. Control access to areas where listed plants are growing. Trampling, trash dumping, and off-road vehicles can severely threaten individual populations. Research has shown that *D. frutescens* recovers from disturbance only by reseeding. As such, this species is very sensitive to trampling and other types of frequent disturbance.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *D. frutescens* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc*., on the habitats where *D. frutescens* occurs.

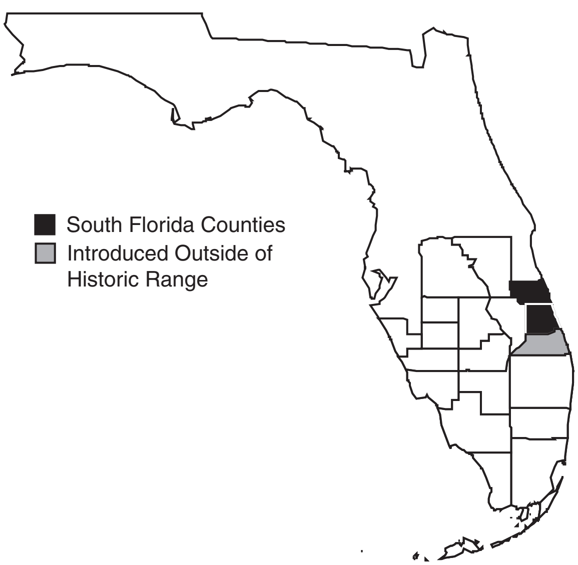
H5. Provide public information about scrub and its unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the SFWMD, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Lakela's Mint

Dicerandra immaculata Lakela

Federal Status:	**Endangered (May 15, 1985)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of Lakela's mint.



Lakela's mint is a small, fragrant shrub that can be differentiated from other *Dicerandra* by its spotless, lavender-rose colored flower. This mint inhabits a very limited area on the Atlantic coastal ridge in South Florida. This species faces a high risk of extinction because so much of its habitat has been destroyed and its populations have become so fragmented. No protected sites exist within its historic range, and the sites at which it occurs are likely to have degraded habitat.

This account represents a revision of the existing recovery plan for the Lakela's mint (FWS 1987).

Description

Dicerandra immaculata is a small, fragrant shrub that reaches 50 cm in height (Kral 1982). Its growth is bushy when in open sun but becomes lax when in shade. It forms small mats or domes of ascending to spreading or sprawling branches. The primary branches arise from a stout, deep, woody-branched taproot, and its numerous innovations arise from spreading or sprawling older growth.

The main leaves are spreading (horizontal) or ascending (pointing upward), while those in the inflorescence (flower cluster) are sometimes reflexed (pointing downward) (Kral 1982). All leaves are linear, oblong-linear, linear-elliptic, linear-lanceolate or linear-oblanceolate in shape. They are 2 to 3 cm long, 2 to 4 mm wide, smooth, flattened, subsessile, narrowly rounded at the apical end, often slightly emarginate, and entire, though larger leaves can be minutely serrulate at the apical end.

The inflorescence is usually 15 to 25 cm long (Kral 1982). Its flowering cymes overlap and each has one, three, or five flowers. The calyx body is 7 to 8 mm long and is usually purplish, becoming white or roseate toward the orifice. The corolla is 1.9 to 2.0 cm long, immaculate (not spotted), and is a bright lavender-rose. The upper corolla lip is broadly ovate to obovate, approximately 7 mm long, apically upswept, and broadly rounded-emarginate. The lower lip is broadly obovate, trilobate, 9 to 10 mm long, and downswept. The lateral lobes are spreading, oblong, broadly rounded, or oblique-truncate and the medial lobe is emarginate. The anthers are exserted, and the style is projecting.

The color of the corolla, lavender-rose to purplish, and its lack of spots separates *D. immaculata* from other species of the *Dicerandra* genus (FWS 1985).

Taxonomy

This species was named by Lakela in 1963 (Lakela 1963). There has been no other taxonomic treatment of the species.

Distribution

The range of *D. immaculata* is extremely small. It is known from a single population that occurs at six isolated sites in an area one-half mile wide by three miles long in southern Indian River and northern St. Lucie counties (Figure 1). The sites are in the vicinity of four small knobs, of greater than 45 ft elevation, along the coastal dune complex between Fort Pierce and Vero Beach (Robinson 1981). These knob formations are typical of this dune system and the next system to the north, however, they are not typical of the next dune system to the south. *Dicerandra immaculata* also occurs on Hobe Sound NWR in Martin County, where it was introduced in 1991 and 1992.

Habitat

Dicerandra immaculata is found in light shade or clearings in scrub along the Atlantic coastal ridge (FWS 1987). It occupies sites with varying degrees of litter, from partly covered to bare sand. These bare sands are probably created through a combination of wind action and fires.

Dicerandra immaculata has been observed growing on both white and yellow sands of the following soil series: Astatula sands, Paola sands, and St. Lucie sands (FWS 1985). These soils are deep, nearly level to sloping, occur on high, dune-like ridges, and are acidic.

Reproduction

Dicerandra immaculata only reproduces through seeding and needs insects for pollination. Its flowers have spurred anthers, which require triggering by insect vectors to release and disperse pollen (FWS 1987). The insect species responsible for the pollination of this mint are unknown.

Seed dispersal of Lakela's mint is very limited. Introduced colonies at the Hobe Sound NWR have dispersed no more than 2 m from parent plants (Race 1994). In addition, Austin *et. al.* (1980) indicated that areas of disturbed sandy soils within the vicinity of Lakela's mint colonies provided no evidence of recolonization.

Leafing occurs from February to August. Anthesis occurs primarily from September to November and sporadically throughout the year. Fruiting occurs primarily from October to December and sporadically throughout the year (Austin *et al.* 1980).

Lakela's mint.
Original photograph courtesy of U.S. Fish and Wildlife Service; flower photograph by Steve Shirah.

Relationship to Other Species

Dicerandra immaculata is a "gap" species. It abounds in open sunlight, but becomes straggly and weak as woody plants and saw palmetto invade open areas (Kral 1982).

Like other *Dicerandra* species, Lakela's mint is protected from insect herbivory by its essential oils (McCormick *et al.* 1993). The cut leaves of one of its relatives, *D. frutescens*, have been shown to repel ants, and only Pyralid moths are known to feed on it (Eisner *et al*. 1990). Whether Lakela's mint is protected to this degree has not been verified.

Though resistant to insect feeding, *D. immaculata* populations have been adversely affected by mildew. Mildew grows on the nectary glands and can cause destruction of the fruits, destroying the viability of seeds before dispersal (Austin *et al.* 1980).

Status and Trends

Dicerandra immaculata was federally listed as endangered because of its extremely small range and the rate at which its habitat was being destroyed (50 FR 20214). Although the opening of Interstate 95 has eased the rate of habitat loss and conversion along U.S. Highway 1 since the plant's listing, Lakela's mint habitat is still vulnerable.

The only protected site for *D. immaculata* exists at Hobe Sound NWR in Martin County. The population at Hobe Sound is doing well. The plants were introduced at two sites, the first in 1991, the second in 1992 (Race 1994). As of 1994, at least one-third of the original plants still survived at the first site, and at least one-half of the plants survived at the second site. Both sites contained new seedlings, which suggests successful reproduction (Race 1994).

In the fall of 1997, the plants were flowering in the second site, and newer plants were well established. The second site is receiving more protection now from visitor disturbance than before, and should continue to flourish. The first site is also still reproductively active.

St. Lucie County is working to purchase a parcel of land in the northern part of the county for preservation purposes (Coward 1995). This parcel is being considered for propagation of Lakela's mint, and could possibly provide the first protected site within the known historicrange. St. Lucie County is also considering another site for purchase that would protect the largest remaining population of *D. immaculata*.

Management

Dicerandra immaculata needs a protected site within its historic range. If a site is acquired, augmentation of the population may be helpful. Two successful introductions of *D. immaculata* have been conducted at Hobe Sound NWR, and information from this project may prove useful for future transplants.

The introductions at Hobe Sound occurred at two different sites on the refuge and were conducted at different times of the year. These two introductions had varying degrees of success, and based on these introductions, Bok Tower Gardens gives the following recommendations for transplanting *D. immaculata*. First, the transplanting site cannot be irrigated, because irrigation promotes the growth of species that will compete with Lakela's mint (Race 1994). Second, the planting should be done in early spring while temperatures are cool (Race 1994).

Lakela's mint occupies open areas in scrub, so prescribed burning or equivalent management is necessary to maintain the quality of its habitat. However, the way this species responds to disturbance and the frequency of disturbance needed are not known. The response of its central Florida relative, the scrub mint (*Dicerandra frutescens*), may serve as a reference point from which to begin Lakela's mint management.

Scrub mint individuals die after being burned, defoliated or cut at their base (Menges 1992). However, the species seems to benefit from periodic fires. Colonies found in areas burned within the last 10 years exhibit the most vigorous growth (Menges 1992). The frequency at which burns, or equivalent disturbances, need to be conducted to maintain the scrub mint is unknown. It is found in areas that were last burned as recently as 3 and as late as 65 years ago (Menges 1992).

Literature Cited

Austin D.E., C.E. Nauman, and B.E. Tatje. 1980. Final report: endangered and threatened plant species survey in southern Florida and the National Key Deer and Great White Heron National Wildlife Refuges, Monroe County, Florida. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Coward, D. 1995. Letter from R.L. Weigt Environmental Consultants, Inc. to Bok Tower Gardens, Lake Wales, Florida. July 11, 1995. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office, Vero Beach, Florida.

Eisner, T., D. McCormick, M. Sakaino, M. Eisner, S.R. Smedley, D.J. Aneshansley, M. Deyrup, R.L. Myers, and J. Meinwald. 1990. Chemical defense of a rare mint plant. Chemoecology 1 (1990):30-37.

Kral, R. 1982. Some notes on Dicerandra (Lamiaceae). Sida 9(3): 238-262.

Lakela, O. 1963. *Dicerandra immaculata* Lakela, sp. nov. (Labiatiae). Sida 1(3):184-185.

McCormick, K.D., M. Deyrup, E.S. Menges, S.R. Wallace, J. Meinwald, and T. Eisner. 1993. Relevance of chemistry to conservation of isolated populations: The case of volatile leaf components of *Dicerandra* mints. Pages 7701-7705 *in* Proceedings of the National Academy of Science, Volume 90.

Menges, E. S. 1992. Habitat preferences and response to disturbance for *Dicerandra frutescens*, a Lake Wales Ridge (Florida) endemic plant. Bulletin of the Torrey Botanical Club 119(3): 308-313.

Robinson, A.F. 1981. Status review of *Dicerandra immaculata* (Lakela's mint). Unpublished report prepared for U.S. Fish and Wildlife Service; Jacksonville, Florida.

Race, T. 1994. Establishment of a new population of *Dicerandra immaculata* at the Hobe Sound National Wildlife Refuge in Florida. Unpublished report prepared for the U.S. Fish and Wildlife Service; Jacksonville, Florida. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office, Vero Beach, Florida.

U.S. Fish and Wildlife Service [FWS]. 1987. Recovery plan for three Florida mints. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Recovery for the Lakela's Mint

Dicerandra immaculata Lakela

Recovery Objective: PREVENT extinction, then stabilize.

Recovery Criteria

Dicerandra immaculata may never reach a level at which reclassification could be possible. The objective of this recovery plan is to increase existing populations and prevent extinction. *D. immaculata* may be considered stabilized when existing populations, within the historic range, are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression. These sites must also be managed to maintain openings in the coastal scrub to support *Dicerandra immaculata.*

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *D. immaculata.* A comprehensive survey of *D. immaculata*'s range was completed in fall 1996. Taxonomic questions still exist with a newly located population at the Martin County border that make a definitive distribution difficult.

- **S1.1. Conduct surveys for *D. immaculata*.** Though the range of this species has been thoroughly surveyed, it should be periodically re-surveyed to learn the status of the species on private lands.

- **S1.2. Maintain distribution of known populations and suitable habitat in GIS database.** Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review and in land acquisition activities.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Atlantic coastal ridge has been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

- **S2.1. Protect habitat through acquisition, conservation easements or agreements with landowners.** This species has no populations on public property within its historic range. A population exists at Hobe Sound NWR, but it is outside of the historic range for this species.

S2.2. Protect populations on public lands. Possible county acquisitions may give protected native sites for this species. If these are obtained, management guidelines would need to be developed to replicate natural coastal scrub disturbance. This may be difficult since most of the possible sites are small and may make management difficult.

S2.3. Use local or regional planning to protect habitat. Utilize available regional and county planning processes to encourage protection of suitable habitat, both unoccupied and occupied of *D. immaculata*.

S2.4. Continue *ex situ* conservation. *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *D. immaculata*. *Dicerandra immaculata* is easily grown from cuttings and can be kept as young plants for study and for reintroduction material.

S2.4.1. Conserve germ plasm. The seed for this species is not presently in long-term storage.

S2.4.2. Maintain *ex situ* collection. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *D. immaculata* as part of the National Collection.

S2.5. Enforce available protective measures. Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *D. immaculata* lives.

S2.5.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. Enforce take and trade prohibitions. This species is protected by take provisions of the Endangered Species Act (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S2.6. Augment natural populations of *D. immaculata.*

S2.6.1. Establish a protocol for reintroduction. Records for source plants, techniques for establishing new populations, and protocols for monitoring are needed.

S2.6.2. Locate potential (re)introduction sites. Survey habitat within the historic range of *D. immaculata* and identify protected lands, both public and private, that will be suitable habitat.

S2.6.3. (Re)introduce plants to protected sites. Use plants under cultivation to (re)establish plants in suitable habitat.

S3. Conduct research on life history characteristics of *D. immaculata*. To effectively recover this species, more specific biological information is needed.

S3.1. **Conduct research to determine demographic information,** such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality. Observations of the relation of flowering to fire, pollination, seed production, and seedling biology will help to guide reintroduction and management efforts.

S3.2. **Once demographic data are known, conduct population viability and risk assessment** analyses to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. **Conduct research to assess management requirements of *D. immaculata*.** Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring information will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S4. Monitor existing populations of *D. immaculata*.

S4.1. Develop monitoring protocol to assess population trends for *D. immaculata*.

S4.1.1. **Monitor to detect changes in demographic characteristics,** such as reproduction, recruitment, growth, dispersal, survival and mortality. Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. **Monitor the effects of various land management actions on *D. immaculata*.** Assess any changes in demographic characteristics of *D. immaculata* in response to land management activities, such as prescribed fire, exotic plant control, and off-road vehicle use.

S4.2. **Develop a quantitative description of the population structure of *D. immaculata*.** This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) may prove useful in future management.

S4.3. **Monitor re-introduced plants.** Monitoring of reintroduced plants will be essential for assessing the status of new plants and their contribution to the population as a whole. Compare adult survival, seed production, germination rates, seed survival, seedling survival, and growth rates between transplanted plants and natural plants. Where monitoring indicates that the introduction has been unsuccessful, re-evaluate protocol and methodology.

S5. **Provide public information about *D. immaculata*.** It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. However, caution should be taken to avoid revealing specific locality information of *D. immaculata*.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *D. immaculata* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there are no protected sites for this species in its historic range.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little Atlantic coastal scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *D. immaculata* populations by preventing habitat damage from off-road vehicle use and over collection, and by providing proper management of habitat, including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation. *Dicerandra immaculata* appears to benefit from burning at irregular intervals of a decade or more.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *D. immaculata*.

H1.2.3. Control access to areas where *D. immaculata* plants are growing. Trampling and off-road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *D. immaculata* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, mechanical disturbance, *etc*., on the habitats where *D. immaculata* occurs.

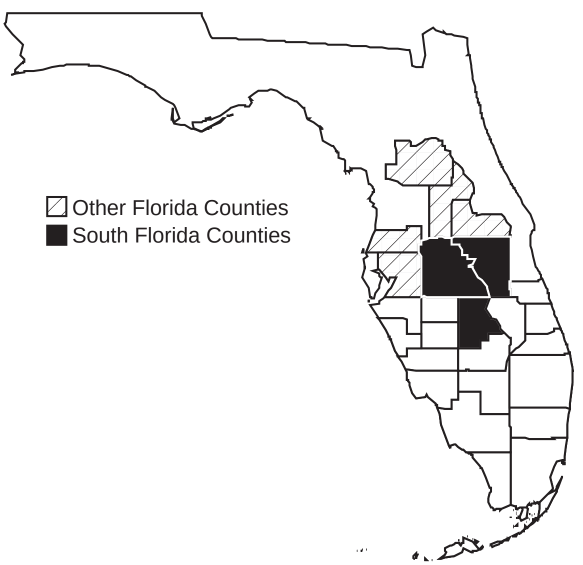
H5. Provide public information about xeric vegetative communities and its unique biota. Educational efforts, especially those conducted by private conservation organizations, have been successful in providing important information about xeric plant communities to the public. The State's system of biological preserves depends for its funding and future success on a broad base of public understanding and support. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, the Florida Park Service, the Florida Native Plant Society and local garden clubs will play crucial roles in increasing public appreciation of xeric plant communities and *D. immaculata*.

Scrub Buckwheat

Eriogonum longifolium Nutt. var. *gnaphalifolium* Gandog.

Federal Status:	**Threatened (April 27,1993)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contributiion: May 1999**
Geographic Coverage:	**South Florida**

Figure 1. County distribution of scrub buckwheat.



Eriogonum longifolium var. *gnaphalifolium* was federally listed in 1993 due to rapid loss of suitable habitat. Only about 15 percent of the original upland habitat remains; the remainder has been converted to citrus groves, pasture, and residential areas.

This account represents South Florida's contribution to the existing recovery plan for the scrub buckwheat (FWS 1996).

Description

Eriogonum longifolium var. *gnaphalifolium* is a perennial herb. It has a taproot and one to three above-ground stems up to 1 m tall, but upwards of 10 stems have been observed in vigorous specimens, especially post-fire. It has a basal rosette of leaves that are 15 to 20 cm long, narrow, and white-woolly on the underside. The stem leaves are smaller than the rosette leaves. The stem terminates in a corymb, with each branch of the corymb ending in a cup-shaped involucre that holds a cluster of 15 to 20 small flowers, with each flower hanging on its stalk down below the involucre. The involucre is silvery, silky-pubescent, and the flowers are green with pink anthers (Rickett 1967).

Taxonomy

The genus *Eriogonum* includes about 150 species, most of them in western North America. Florida has only two species, both native to high pineland. *Eriogonum tomentosum* is common throughout the northern part of the state, as far south as Highlands County. The second species, scrub buckwheat, was named *Eriogonum floridanum* by J.K. Small (1903). Subsequent publications on Florida's flora consistently adopted Small's treatment of *E. floridanum* as a full species (Small 1933, Kral 1983, Ward 1979, Wunderlin 1982), but James Reveal (1968), an expert on the genus, treats the Florida plants as a variety of *Eriogonum longifolium*, a widespread species of the Great Plains that is represented east of the Mississippi by var. *harperi* in northern Alabama, Tennessee, and Kentucky (Kral 1983), and by var. *gnaphalifolium* in Florida.

Distribution

Eriogonum longifolium occurs in Marion, Pasco, Hillsborough, Lake, and Orange counties in central Florida, and in Osceola, Highlands, and Polk counties in South Florida (Figure 1). Suitable habitat exists in Sumter County, but it is not known whether this plant occurs there. In Polk and Highlands counties, it is found on the Lake Wales Ridge as far south as Archbold Biological Station, south of Lake Placid. Most of the recent records for the species are from Polk and Highlands counties, partly because intensive biological surveys of scrub vegetation have been conducted in those counties (Christman 1988c). *Eriogonum longifolium* var. *gnaphalifolium* historically occurred in the Tampa area, assuming that a specimen cited by Gandoger (1906) as the type of "*E. longifolium var. floridana*" belongs to this variety.

Habitat

Eriogonum longifolium var. *gnaphalifolium* occurs in high pine and in turkey oak barrens habitats from Marion County to Highlands County (Christman 1988). The northern range limits for *E. longifolium* var. *gnaphalifolium* are in Ocala National Forest and in areas of mixed scrub and high pine south of Ocala in Marion County. Suitable habitat and possibly the plant extend south into northern Sumter County. *Eriogonum longifolium* var. *gnaphalifolium* historically occurred near Eustis in Lake County (where it was collected around the turn of the century), and it still occurs near Clermont in remnants of high pine with *Polygala lewtonii* and several other endangered plant species.

Reproduction

Although little information on the reproduction of this species is available, plants in the Ocala NF have been observed with immature flower stalks between April and mid-July and bloom from May to mid-October. Seedlings have been observed in a variety of substrates within a few feet of the parent plant (J. Clutts, USFS, personal communication 1998). Seedlings germinate in summer in open sand (R. Yahr, Archbold Biological Station, personal communication 1998).

Three species of Hymenoptera (wasps) have been observed visiting the flowers of this plant although additional information on pollination is not available (J. Clutts, USFS, personal communication 1998).

Relationship to Other Species

Relationships between plant species and their constituents may take many forms. Scrub buckwheat is foraged upon by herbivorous vertebrate species. In addition to this relationship is the relationship of this plant to the community surrounding it.

Several other endangered or threatened scrub plants occur in turkey oak scrub, notably *Chionanthus pygmaeus*, *Clitoria fragrans*, *Warea carteri*, and *Polygala lewtonii* (Christman 1992).

Scrub buckwheat flower.
Original photograph by Steve Shirah.

The low-intensity fires typical of high pineland are relatively easy to prescribe and conduct. The high pineland "islands" in Ocala NF show that appropriate fire management is feasible. The Ocala "islands," apart from being important for *Eriogonum longifolium* var. *gnaphalifolium* and *Polygala lewtonii*, are occupied by endangered red-cockaded woodpeckers (*Picoides borealis*). The USFS Service plans to manage the longleaf pines so that there are enough trees old enough for woodpecker nest cavities. Woodpecker-oriented management will almost certainly benefit the entire high pineland flora, but it is important to obtain site-specific analyses of the effects of logging and other management activities, at least to determine if such management affects the ground flora.

In Ocala NF, *E. longifolium* var. *gnaphalifolium* occupies 71 areas extending through the westerly part of the forest from Fore Lake south along county Road 314 to the area between Big Bass and Nicotoon Lakes along State Road 42 at the forest's southern boundary, an area of about 37 km from north to south and 10 km east to west (FWS 1996).

A USFS survey (Brandt 1992) and subsequent surveys in 1994 and 1995 located 976 *E. longifolium* var. *gnaphalifolium* plants in longleaf pine with wiregrass and turkey oak, 20 plants in areas where slash pine had been planted in high pineland, and 400 plants in sand pine scrub. The *E. longifolium* var. *gnaphalifolium* plants were well within stands, flowering in filtered light situations, not just along roadsides. Forest Service biologists conclude that the plant persists without regard to site preparation practices. The longleaf pine sites had some combination of mowing, single chopping, herbicide application, releasing by chain saw, prescription burning, and machine planting. Sand pine scrub was either not site-prepared or site-prepared by either single-chopping or burning, and seeded by either broadcast seeding, or row seeding. The apparent tolerance of *E. longifolium* var. *gnaphalifolium* for these various practices may be due to its woody taproot.

Status and Trends

The principal cause of decline of central Florida's upland plants is conversion of high pineland and scrub for agricultural purposes (principally citrus groves), and for commercial, residential, and recreational purposes. Peroni and Abrahamson (1985) used aerial photography to determine that in Highlands County, 64.2 percent of the xeric vegetation (scrub, scrubby flatwoods, and southern ridge sandhills [high pineland]) present before settlement was destroyed by 1981. An additional 10.3 percent of the xeric vegetation was moderately disturbed, primarily by building roads to create housing subdivisions. This left about 9,700 ha. The situation appeared similar in Polk County. Christman (1988) prepared an estimate of habitat loss by examining a 10 percent random sample of all land sections containing scrub on the Lake Wales, Lake Henry, and Winter Haven ridges. Present-day scrub was mapped using aerial photography taken November 1984 to January 1987, supplemented by more recent site visit data, where available. His results showed that the original area of scrub was 31,000 ha and the present area of scrub is 11,100 ha. In addition to habitat loss, this species is threatened by invasive species such as cogon grass and centipede grass. Preventive measures against invasive species, such as cogon grass, are needed on preserves such as Avon Park, Carter Creek, and Avon Park Lakes. Recreational motorized off-road vehicles (all-terrain vehicles and motorcycles) in publicly owned high pinelands also have the potential to severely impact *E. longifolium* var. *gnaphalifolium* (FWS 1996).

Management

On the Lake Wales Ridge in South Florida, *E. longifolium* var. *gnaphalifolium* is protected at Lake Arbuckle State Preserve, the Arbuckle and Lake Walk-in-the-Water tracts of Lake Wales Ridge SF, Catfish Creek State Preserve, the Lake Apthorpe preserve, The Nature Conservancy preserve at Tiger Creek, and Archbold Biological Station. A population is also protected on the Pine Ridge nature preserve at Bok Tower Gardens. More sites will be protected as State or Federal land acquisition proceeds.

The CARL program includes the Lake Wales Ridge Ecosystem Project, which in turn includes a subset of parcels commonly known as the Warea Archipelago sites. These sites target remnant high pine habitats in the northern Lake Wales Ridge. *Eriogonum longifolium* var. *gnaphalifolium* occurs on all six sites: Sugarloaf Mountain, Ferndale Ridge, Castle Hill, Flat Lake, Schofield Sandhill, and Lake Davenport. The 49 ha Flat Lake property in Lake County is now under contract for acquisition by The Nature Conservancy. The Nature Conservancy is still attempting to negotiate a sale for the Lake Davenport property in Osceola County (R. Hilsenbeck, The Nature Conservancy, Tallahassee, personal communication 1997). Purchase of all six properties should be a high priority for recovery of the species.

Post-fire response of *E. longifolium* results in many plants in bloom the year post-fire; this species steadily declines as open space declines (E. Menges, Archbold Biological Station, personal communication 1998). The only study of *E. longifolium* var. *gnaphalifolium*'s recovery from a site-preparation burn is from a recently-clearcut site in the Ocala NF (Carrington 1993). The resprouting plants flowered within a month of the July fire, and seedlings were observed three months later. However, a few individuals have died following hot prescribed burns (J. Clutts, USFS, personal communication 1998). There was a different response among *E. longifolium* var. *gnaphalifolium* plants in a relict longleaf pine site encroached by sand pine, after the 50-year old sand pine was logged on March 9, 1995, followed by a prescribed burn in May. The fire was fast-moving and unexpectedly intense, even jumping a plowline. Thirty *E. longifolium* var. *gnaphalifolium* plants were selected before the logging and prescribed burn. Twenty plants with live basal rosettes were relocated afterward; ten had apparently died. Of the 20 live plants, 15 flowered. There may be a correlation between pre-fire flowering and post-fire mortality or flowering. Some of the plants that died had produced four flower stalks before the fire, while plants that had produced only one flower stalk before the fire sent up an average of six stalks afterward. Possibly, plants that recently flowered heavily lacked reserves to recover from the disturbance. Partial excavation around the roots of several dead plants showed that most of them had tap roots as large as those of plants that survived the fire. Another possibility is that the abrupt change from partial shade to direct sun stressed the plants. Rainfall, or more accurately, soil moisture, may have been a factor. Rainfall in May was close to the 10-year average, but local conditions were dry, as shown by the intensity of the fire (in northern Florida, plants often suffer water stress in spring as their rapidly increasing evapotranspiration outpaces the seasonal increase in rainfall). Rainfall in the wet months of June, July, and August was higher than the 10-year average. The USFS will continue monitoring *E. longifolium* var. *gnaphalifolium* (FWS 1996).

Literature Cited

Christman, S. 1988. Endemism and Florida's interior sand pine scrub. Final project report, Project no. GFC-84-101. Submitted to Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Christman, S. 1992. Biogeography of Florida scrub. Abstract and presentation, History and ecology of the Florida scrub: 1992 conference commemorating the 50th anniversary of Archbold Biological Station. Archbold Biological Station; Lake Placid, Florida.

Clutts, J. 1998. Comments on draft species account. January 27.

Gandoger, M. 1906. Le genre *Eriogonum* (Polygonaceae). Bulletin de la societe royale de botanique de Belgique 42(2): 183-201.

Kral, R. 1983. A report on some rare, threatened, or endangered forest-related vascular plants of the South. USDA Forest Service. Technical Publication R8-TP 2.

Menges, E. 1998. Comments on technical draft multi-species recovery plan for South Florida. February 5, 1998.

Myers, R. L., and S. E. Boettcher. 1987. Provisional fire management plan for a portion of the Tiger Creek Preserve, Florida. Report prepared for The Nature Conservancy; Winter Park, Florida.

Peroni, P.A., and W.G. Abrahamson. 1985. A rapid method for determining losses of native vegetation. Natural Areas Journal 5:20-24.

Reveal, J.L. 1968. Notes on the Texas *eriogonums*. Sida 3:195-205.

Rickett, H.W. 1967. Wild flowers of the U.S., vol. 2: the southeastern states (*Eriogonum longifolium* var. *gnaphalifolium*).

Small, J.K. 1903. Flora of the southeastern United States. Published by the author, New York.

Small, J.K. 1933. Manual of the southeastern flora. University of North Carolina Press; Chapel Hill, North Carolina.

U.S. Fish and Wildlife Service. 1996. Recovery plan for nineteen central Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Ward, D. 1979. Rare and endangered biota of Florida, vol. 5: Plants. University Presses of Florida; Gainesville, Florida.

Wunderlin, R. 1982. Guide to the vascular plants of Central Florida. University Presses of Florida; Gainesville, Florida.

Yahr, R. 1998. Comments on technical draft multi-species recovery plan for South Florida. February 5, 1998.

Recovery for the Scrub Buckwheat

Eriogonum longifolium (Nutt. var. *gnaphalifolium* Gandog.)

Recovery Objective: DELIST the species once recovery criteria are met**.**

South Florida Contribution: STABILIZE and increase the population**.**

Recovery Criteria

The South Florida recovery objective can be achieved when sites within the historic range of *E. longifolium* var. *gnaphalifolium* are adequately protected from further habitat loss, degradation, and fragmentation; when these sites are managed to maintain the scrub and sandhill communities to support *E. longifolium* var. *gnaphalifolium*; and when monitoring programs demonstrate that populations of *E. longifolium* var. *gnaphalifolium* on these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species. The recovery narrative identifies management recommendations, such as translocations, that are necessary to accomplish this objective.

Species-level Recovery Actions

S1. **Determine current distribution of *E. longifolium* var. *gnaphalifolium.*** A survey has not been made of the Lake Wales Ridge for this species, making defining a complete distribution in South Florida difficult.

S1.1. **Conduct surveys of *E. longifolium* var. *gnaphalifolium.***

S1.1.1. **Conduct additional surveys in Polk, Highlands, and Osceola counties**. New locations for this species may be found.

S1.1.2. **Continue surveys on protected lands.** New sites for listed species may be found on protected lands.

S1.2. **Maintain distribution of known populations and suitable habitat in GIS database.** Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, number of individuals, population sizes, and status. This information should also be used for project review and land acquisition activities.

S2. **Protect and enhance existing populations.** Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties has been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases is isolated.

S2.1. **Protect habitat through acquisition, conservation easements, or agreements with landowners.** The Warea Archipelago is a series of small properties that are being purchased through CARL that are designed to protect *E. longifolium* var. *gnaphalifolium* and the unique community in which it lives.

S2.2. **Protect populations on public lands.**

S2.3. **Use local or regional planning to protect habitat.** Utilize available regional and county planning processes to encourage protection of suitable unoccupied and occupied habitat, both of *E. longifolium* var. *gnaphalifolium.*

S2.4. **Continue *ex situ* conservation.** *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *E. longifolium* var. *gnaphalifolium.*

S2.4.1. **Conserve germ plasm.** The seed for this species is not presently in long-term storage.

S2.4.2. **Maintain *ex situ* collection.** Research ways to propagate *E. longifolium* var. *gnaphalifolium*.

S2.5. **Augment natural populations of *E. longifolium* var. *gnaphalifolium.***

S2.5.1. **Establish a protocol for reintroduction.** Records for source plants, techniques for establishing new populations, and protocols for monitoring are needed.

S2.5.2. **Locate potential (re)introduction sites.** Survey habitat within the historic range of *E. longifolium* var. *gnaphalifolium* and identify protected lands, both public and private, that will be suitable habitat.

S2.5.3. **(Re)introduce plants to protected sites.** Use plants under cultivation to (re)establish plants in suitable habitat.

S2.6. **Enforce available protective measures.** Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *E. longifolium* var. *gnaphalifolium* lives.

S2.6.1. **Initiate section 7 consultation when applicable.** Initiate section 7 consultations when Federal activities may affect this species.

S2.6.2. **Enforce take and trade prohibitions.** This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. **Continue research on life history characteristics of *E. longifolium* var. *gnaphalifolium*.** Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species more specific biological information is needed.

S3.1. **Continue research to determine biology and demographic information, such as numbers of sites and populations, numbers of individuals in a population, morphology, reproduction, recruitment, dispersal, growth, survival, and mortality.**

S3.2. **Continue research to assess management requirements of *E. longifolium var. gnaphalifolium*.** Continue to assess site-specific management requirements of *E. longifolium* var. *gnaphalifolium*. At this time, the survival and recovery of this species is dependent upon the implementation of site-specific management techniques that favor *E. longifolium* var. *gnaphalifolium*. Site-specific management guidelines should be provided to land managers.

S4. **Continue monitoring the existing populations of *E. longifolium* var. *gnaphalifolium*.**

S4.1. **Evaluate the effectiveness of the monitoring protocol used to assess population trends for *E. longifolium* var. *gnaphalifolium***. As more information is gained about *E. longifolium* var. *gnaphalifolium*, monitoring protocols may need to be altered to make use of new information.

S4.2. **Monitor and detect changes in demographic characteristics, such as growth, survival, mortality.** Herbivory, pollinators, disease, and injury should also be monitored. Characteristics such as reproduction, recruitment, and dispersal cannot truly be monitored in the wild at this time, but should be included as introductions make reproduction possible.

S4.3. **Monitor the effects of various land management actions on *E. longifolium* var. *gnaphalifolium*.** Assess any changes in demographic characteristics of *E. longifolium* var. *gnaphalifolium* in response to land management activities, such as prescribed fire, exotic plant control, *etc*.

S4.4. **Continue to work with private landowners.** The successful recovery of this species will be influenced by the participation of private landowners. To date a varying amount of support has been gained among the individual landowners.

S4.5. **Monitor introduced plants. Monitoring of reintroduced plants will be essential for assessing the status of new plants and their contribution to the population as a whole**. Compare adult survival, seedling production, germination rates, seed survival, seedling survival, and growth rates between transplanted and natural plants. Where monitoring indicates that introduction has been unsuccessful, reevaluate protocol and methodology developed.

S5. **Provide public information about *E. longifolium* var. *gnaphalifolium*.** It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed. Public outreach efforts must also continue to address the increasing concern that horticultural demand for rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *E. longifolium* var. *gnaphalifolium* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss has already occurred throughout the range of this species. Both development and fire suppression have decreased the available habitat.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *E. longifolium* var. *gnaphalifolium* populations by preventing damage from off-road vehicle use and collection, and by providing proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the high pine community. A variable interval in fire return and in season is important to mimic the natural fire regime.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat as compared to other communities in South Florida.

H1.2.3. Control access to areas where listed plants are growing. Collection, trampling, and off-road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *E. longifolium* var. *gnaphalifolium* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc*., on the habitats where *E. longifolium* var. *gnaphalifolium* occurs.

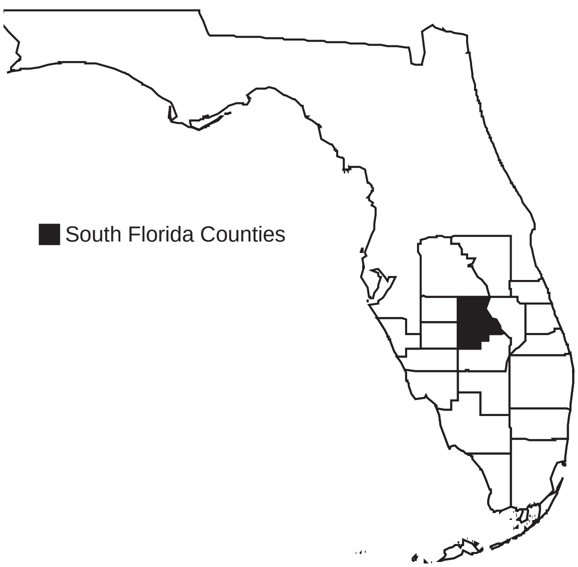
H5. Provide public information about high pine and its unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Department of Forestry, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Department of Forestry has been especially successful in disseminating knowledge about these unique communities.

Snakeroot

Eryngium cuneifolium Small

Federal Status:	**Endangered (January 21, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of snakeroot.



Eryngium cuneifolium has a very narrow geographic distribution in an area 39 km long in Highlands County. It is threatened by habitat loss and fire suppression; the small numbers of localities, combined with this species' requirement for nearly barren sand, renders it very vulnerable to future habitat loss. Measures being used to conserve this species include land acquisition and management.

This account represents a revision of the existing recovery plan for the snakeroot (FWS 1996).

Description

Eryngium cuneifolium is an aromatic perennial herb with a long, woody taproot, and persistent rosette of dark green. It usually has several erect, branching, flowering stems. It ranges from 0.25 to 0.5 m in height, rarely reaching as high as 0.9 m. The leaves are clustered at the base of the plant. The basal leaves are long, stalked, and shaped like narrow wedges, with 3 to 5 bristle-tipped teeth at the apex. Stem leaves are smaller and lack leaf stalks. The flowers are small, with white petals, filaments, styles and stigmas but powdery blue anthers form small heads, with bristly bracts. The sepals and petals are each about 1.5 to 2 mm long. The inferior ovary develops into a fruit about 1.5 to 2 mm long. The flowers and bristle bracts form heads 4 to 8 mm in diameter (Bell 1963, Wunderlin *et al*. 1981). Sterile plants are easily recognized in the field by their basal rosettes (Wunderlin *et al*. 1981). Flowering is from August to October (other *Eryngium* species, including *E. aromaticum* and *E. baldwinii* have blue flowers).

Taxonomy

Eryngium cuneifolium is most closely related to *E. aromaticum* (Bell 1963, Wunderlin *et al*. 1981). It was described by J.K. Small (1933) and its status as a species was upheld by O.R. Bell's (1963) review of the genus. Preparers of status reports (Wunderlin *et al*. 1981, Kral

1983) have also concurred that this is a distinct species. There are no synonyms in the botanical literature (Bell 1963, Wunderlin *et al*. 1981).

Other common names for this species include wedged-leaved button-snakeroot (Wunderlin *et al*. 1981) and semantic variations thereof.

Distribution

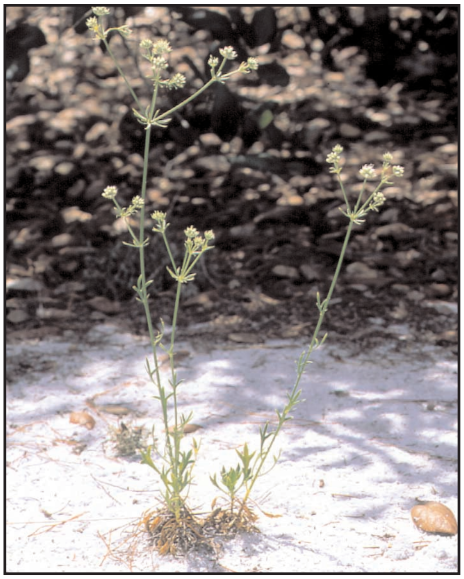
The present known distribution of *Eryngium cuneifolium* is greatest in southern Highlands County, near the town of Lake Placid. It occurs only on the southern Lake Wales Ridge (Figure 1). The northernmost site is on a dune on the south side of Lake Jackson in Sebring (FWS 1996). All other sites are in an area about 39 km long from the southern side of Josephine Creek to the southern tip of the Lake Wales Ridge. Christman (1988c) reports only about 20 localities, but even this number is misleading since he divided several larger sites. Johnson (1981) and Abrahamson *et al*. (1984) showed that Archbold Biological Station has about 90 rosemary balds. Only about 12 of them have *Eryngium cuneifolium* (E. Menges, Archbold Biological Station, personal communication 1989). A recent 16.2 ha addition to the Archbold property (acquired through a habitat conservation plan for the Florida scrub-jay) has abundant *Eryngium cuneifolium*, which apparently proliferated after the former owner cleared and root-raked the area. *Eryngium cuneifolium* is reported to occur at the site that is being acquired as a state park on the west side of Lake June in Winter (FWS 1996), but has not been relocated after several intensive searches (Archbold Biological Station, personal communication 1998). The past known distribution also included several sites in and around the town of Sebring, Highlands County (Wunderlin *et al.* 1981).

Habitat

Eryngium cuneifolium is a species of sunny sites that readily colonizes bare sand created by fire or other disturbance (Wunderlin *et al.* 1981, Abrahamson *et al.*1984). *Eryngium cuneifolium* occurs only on bare white sand in scrub, usually with rosemary.

Eryngium cuneifolium is one of the few herbs able to survive the inhibitive effects on growth or reproduction by chemicals secreted into the environment by rosemary (*Ceratiola ericoides*). *Eryngium cuneifolium* also survives in a harsh physical environment, with droughty soil and low nutrient levels. The plant readily colonizes new patches of bare sand created by fire or disturbance by its stout, woody taproot. Possible seed storage in the soil has not been investigated (Kral 1983, Richardson 1985).

Eryngium cuneifolium is restricted to sand or fine sand soils with little clay or silt, rapid permeability, and low available water capacity. At Archbold Biological Station the plant occurs in rosemary scrub, mostly on Psamment soils of the Archbold Series which are moderately well drained, acid (pH 4.2), and with low soil nutrient levels (phosphorus: trace; potassium 5.6 kg/ha). Other soils in the area are also infertile. A small portion of the rosemary scrub at Archbold has soils of the St. Lucie Series, which are deep fine sands. This appears to be the major series in which *E. cuneifolium* is found outside of Archbold Biological Station (Wunderlin *et al*. 1981, Abrahamson *et al*. 1984).




Snakeroot.
Original photograph by Jeff Ripple; original flower photograph by Steve Shirah.

Reproduction

Reproduction in *E. cuneifolium* is sexual. The species can reproduce readily by seed (Kral 1983). There seems to be no special seed-dispersal mechanism (other than gravity) and pollination is likely to be similar to that of other members of Apiaceae, most likely by generalist insects (Wunderlin *et al.* 1981, Kral 1983).

Germination and leafing dates are unknown. Budding is believed to occur in July. The plant flowers vigorously from September through October. Anthesis occurs from August to October (Wunderlin *et al*. 1981). Fruiting and seed dispersal is believed to occur between October and January (Wunderlin *et al.* 1981, Kral 1983). Seeds are mature in November (T. Race, personal communication 1996). Specimens have been collected in late November and December (Wunderlin *et al.* 1981).

Relationship to Other Species

This species is restricted to sand pine scrub vegetation, usually with much rosemary (*Ceratiola ericoides*) and inopina oak (*Quercus inopina*). The community is open, with herbs such as *Liatris ohlingerae, Hypericum cumulicola,* and *Lechea cernua*. *Cladonia* lichens cover more of the area between shrubs than do the herbs. The community burns to the ground at intervals greater than 15 years. The oaks resprout from the roots; rosemary and sand pine recolonize by seed. Fire in this vegetation is not a succession-initiating disturbance in the Clementsian sense (Abrahamson *et al.* 1984; Abrahamson 1984a, 1984b).

Various shrubs and trees may affect *Eryngium cuneifolium* by shading it; *Ceratiola ericoides* may affect *E. cuneifolium* through allelopathy (Wunderlin *et al.* 1981, Kral 1983, Richardson 1985). Generalist insects are probable pollinators (Wunderlin *et al.* 1981, Kral 1983).

Status and Trends

Eryngium cuneifolium is threatened primarily by the conversion of its scrub habitat to citrus groves or residential subdivisions. In Highlands County, 64.2 percent of the xeric vegetation (sand pine scrub, scrubby flatwoods, and southern ridge sandhills) present before settlement was destroyed by 1981. An additional 10.3 percent of the xeric vegetation was moderately disturbed, primarily by building roads to create residential subdivisions (Peroni and Abrahamson 1985). This species benefits from the effects of fires or mechanical clearing of trees and shrubs, which creates areas of bare, sunny sand that *E. cuneifolium* and other herbs can colonize (Wunderlin *et al.* 1981, Kral 1983). Therefore, fire prevention or fragmentation of the vegetation that prevents the spread of fire may indirectly threaten this species.

Eryngium cuneifolium is also vulnerable to destruction by off-road vehicles that pass through the open spaces between shrubs. Another past and present problem for *E. cuneifolium*, as for several other herbs of the same habitat, is that this species does not tolerate shading or extensive competition from other plants.

Management

Eryngium cuneifolium is currently protected at Archbold Biological Station and the State's Lake Placid Scrub, Gould Road and Lake Apthorpe preserves (Robert Burns, The Nature Conservancy, personal communication October 1989). It is also protected in the Bok Tower Gardens national endangered species collection. Acquisition of the Holmes Avenue tract for the state preserve system is proceeding. The plant is present on a right-of-way managed by Florida Power and Light Company (FWS 1996).

Eight years of demographic data have been collected for this species (E. Menges, Archbold Biological Station, personal communication 1998). *Eryngium cuneifolium* is short-lived, its populations crash following fire, and other forms of disturbance may have positive effects. Its microhabitat was shown to significantly affect its survival, growth, and fecundity over a 4-year period. This species is most abundant in gaps at larger distances from shrubs, particularly *Ceratiola ericoides* and *Calamintha*, both putative allelopathic species. As time-since-fire increases, open patches in rosemary scrub tended to close, and *Eryngium* underwent a rapid decline (Hawks and Menges 1996). Pedro Quintana-Ascencio's current studies on rosemary scrub may demonstrate that *Eryngium* is particularly sensitive to gap closure, even compared with other gap species such as *Hypericum cumulicola* and *Polygonella basiramia* (Menges and Kimmich 1995). The exacting habitat requirements of *Eryngium cuneifolium* mean that, despite large populations at several sites (possibly millions of individual plants in its range), its habitats must be managed aggressively to maintain the gaps that *Eryngium* needs. Eric Menges and his associates are experimenting with fire at Archbold Biological Station and Lake Apthorpe. *Eryngium cuneifolium* recovers from fire by resprouting and by seedling recruitment from the seed bank (Menges and Kimmich 1996).

Literature Cited

Abrahamson, W.G., A.E. Johnson, J.N. Layne, and P.A. Peroni. 1984. Vegetation of the Archbold Biological Station, Florida: an example of the southern Lake Wales Ridge. Florida Scientist 47:209-250.

Abrahamson, W.G. 1984a. Species responses to fire on the Florida Lake Wales Ridge. American Journal of Botany 71:35-43.

Abrahamson, W.G. 1984B. Post-fire recovery on the Florida Lake Wales Ridge associates vegetation. American Journal of Botany 71:9-21.

Bell, O.R. 1963. The genus *Eryngium* in the southeastern states. Castanea 28:73-79.

Florida Natural Areas Inventory. 1986. Florida database for element occurrences; Tallahassee, FL.

Johnson, Ann F. 1981. Scrub endemics of the central ridge, Florida. Unpublished report for: U.S. Fish and Wildlife Service; Jacksonville, Florida.

Hawks, C.V. and E.S. Menges. 1996. The relationship between open space and fire for species in xeric Florida scrubland. Bulletin. Torrey Bot. Club.

Kral, R. 1983. *Eryngium cuneifolium*. In: A report on some rare, threatened, or endangered forest-related vascular plants of the south. USDA Forest Service, technical publication R8-TP2.

Menges, E.S. and C.V. Hawks 1996. Interactive effects of fire and microhabitat on plants of Florida scrub.

Menges, E.S. and J. Kimmich. 1996. Microhabitat and time since fire: effects on demography of a Florida scrub endemic plant. American journal of Botany 93.

Menges, E. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30, 1998.

Peroni, P.A., and W.G. Abrahamson. 1985. A rapid method for determining losses of native vegetation. Natural Areas Journal 5:20-24.

Race, T. 1996. Letter to Brian Luprek, U. S. Fish & Wildlife Service, February 27, 1996.

Richardson, D. 1985. Evidence for allelopathy in sand pine scrub. Oral presentation to: Florida Native Plant Society, May 3, 1985. Based on: unpublished thesis, University of South Florida; Tampa, Florida.

Small, J.K. 1933. *Eryngium*. In: Manual of the southeastern flora. University of North Carolina Press; Chapel Hill, North Carolina.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery plan for nineteen central Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Wood, D.A. 1985. Official lists of endangered and potentially endangered fauna and flora in Florida. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Wunderlin, R.P., D. Richardson, and B. Hansen. 1981. Status report on *Eryngium cuneifolium*. Unpublished report for: U.S. Fish and Wildlife Service.

Recovery for the Snakeroot

Eryngium cuneifolium Small

Recovery Objective: **RECLASSIFY** to threatened.

Recovery Criteria

Eryngium cuneifolium may be reclassified from endangered to threatened when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations and sites needed to assure 20 to 90 percent probability of persistence for 100 years; when these sites, within its historic range, are adequately protected from further habitat loss, degradation, and fragmentation; when these sites are managed to maintain the rosemary phase of xeric oak scrub communities to support *E. cuneifolium*; and when monitoring programs demonstrate that populations of *E. cuneifolium* on these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies new ways of re-establishing populations of this species or expanding its current range.

Species-level Recovery Actions

S1. **Determine current distribution of *E. cuneifolium*.** This species has been relatively well surveyed and a distribution has been ascertained. Additional surveys will confirm the species' distribution and locate new sites.

S1.1. **Conduct surveys of *E. cuneifolium*.**

S1.1.1. **Continue surveys in Highlands County.** The Lake Wales Ridge has probably been adequately surveyed, though new sites for *E. cuneifolium* may still be found.

S1.1.2. **Continue surveys on protected lands.** New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites.

S1.2. **Maintain distribution of known populations and suitable habitat in GIS database.** Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review and in land acquisition activities.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties has been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. Protect habitat through acquisition, conservation easements, or agreements with landowners.

S2.2. Protect populations on public lands. Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. Use local or regional planning to protect habitat. Utilize available regional and County planning processes to encourage protection of suitable habitat, both unoccupied and occupied of *E. cuneifolium*.

S2.4. Conserve germ plasm. The Center for Plant Conservation provides long-term seed storage for this species. Long-term storage of seeds and live collections decreases the likelihood of extinction due to natural stochastic events. Germ plasm conservation also preserves genetic diversity and provides valuable information regarding the reproductive biology of rare species. The local abundance of this species makes an *ex situ* garden collection a low priority for this species.

S2.5. Enforce available protective measures. Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *E. cuneifolium* lives.

S2.5.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. Enforce take and trade prohibitions. This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. Conduct research on life history characteristics of *E. cuneifolium*. Continue the study of basic biology and ecology of this species. To effectively recover this species, more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as numbers of populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *E. cuneifolium*. Determine which natural populations can be stabilized or increased by habitat management. Data from surveys, research, and monitoring will yield information about *E. cuneifolium* sites and will provide factors contributing to any declines at each site. Site- specific management guidelines should be provided to land managers.

S4. Monitor existing populations of *E. cuneifolium*.

S4.1. Develop monitoring protocol to assess population trends for *E. cuneifolium*.

S4.1.1. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival and mortality. Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. Monitor the effects of various land management actions on *E. cuneifolium*. Assess any changes in demographic characteristics of *E. cuneifolium* in response to land management activities, such as prescribed fire, exotic plant control, *etc*.

S4.2. Develop a quantitative description of the population structure of *E. cuneifolium*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Include data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors).

S5. Provide public information about *E. cuneifolium*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. Care is needed, though, to avoid revealing specific locality information about *E. cuneifolium.*

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *E. cuneifolium* and other rare species requires a self-sustaining, secure, number of natural populations.

S6. Develop delisting criteria. Once reclassification is achieved, research and monitoring results may provide data necessary to develop delisting criteria.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both development and fire suppression have decreased the available habitat. To date, there are three protected sites for *E. cuneifolium* in Highlands County.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *E. cuneifolium* populations by preventing damage from off-road vehicle use and by providing proper management of habitat, including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. The scrub landscape is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation.

H1.2.2. **Control and eliminate exotic and invasive plants and animals.** Exotic plant and animal species are not yet a major threat in xeric scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *E. cuneifolium*.

H1.2.3. **Control access** to areas where snakeroot is growing. Trampling and off-road vehicles can severely threaten individual populations.

H2. **Restore areas to suitable habitat.** Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. **Restore natural fire regime.** Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery.

H2.2. **Enhance sites with native plant species.** Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. **Continue habitat-level research projects.** Study the response of *E. cuneifolium* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. **Monitor habitat/ecological processes.** Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc*., on the habitats where *E. cuneifolium* occurs.

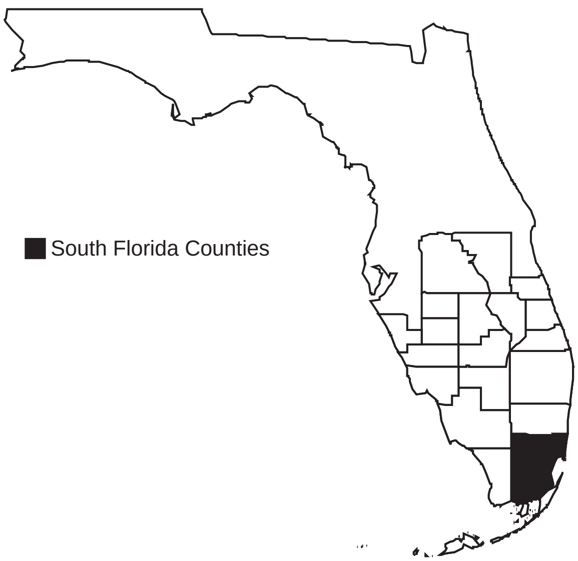
H5. **Provide public information about scrub and its unique biota**. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these efforts, the Lake Wales Ridge NWR would not have been created. The State's system of biological preserves depends for its funding and future success on a broad base of public understanding and support. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, the Florida Park Service, the Florida Native Plant Society and local garden clubs play crucial roles in increasing public appreciation of scrub, high pine vegetation, and their plant species.

Small's Milkpea

Galactia smallii H.J. Rogers ex Herndon

Federal Status:	**Endangered (July 18, 1985)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Table 1. County distribution of Small's milkpea.



Small's milkpea is endemic to the pine rocklands of Miami-Dade County. Throughout South Florida, most of the pine rocklands have been destroyed for residential housing, commercial construction, or agriculture. Less than 2 percent of the original pine rockland habitat of the Small's milkpea remains and most of that habitat occurs in small, isolated stands that are difficult to protect or manage. Continued habitat loss and fragmentation, fire suppression, and invasion by exotic plant species threaten the existence of Small's milkpea.

This account represents a revision of the existing recovery plan for the Small's milkpea (FWS 1988).

Description

Galactia smallii is a small, trifoliolate, perennial legume with small, purple flowers and a prostrate habit. The stems are grayish, due to a covering of short hairs, and grow up to 2 m long. The stem internodes are well-developed and have long, straight, soft hairs. The 1 to 2.2 cm long leaflets are broadly ovate to elliptic. The undersides of the leaves have long, soft, wavy hairs lying almost flat against the surface. The upper surface of the leaves are either hairless (glabrate) or have sparse, stiff hairs, lying flat on the surface (strigose). The inflorescences are 2 to 6 cm long with one to five flowers at the apex or along the axis. The flower buds are 5 to 7 mm long, and the calyx is about 7 mm long and loosely strigulose. The corolla is 11 to 12 mm long and pinkish purple or lavender. The legume is 3 to 4 cm by about 4 m in size and is strigulose or villosulous (Isley 1990).

There are five species of *Galactia* that occur in Miami-Dade County; four of these occur in pine rocklands (O'Brien and Koptur 1995). *Galactia smallii*, *G. pinetorum*, and *G. floridana* each have large flowers and a prostrate habit. *Galactia parvifolia* is a single, small-flowered species. *Galactia smallii* has been confused with *G. pinetorum* because the key characters given by Small (1903) to distinguish the two taxa were unstable. The two species are distinct, however, and can be separated by the nature of the pubescence on the stems (Herndon 1981). The pubescence on the stems of *Galactia smallii* is ascending or spreading-sericeous, while *G. pinetorum* is strigose, retrorse-appressed, and thin. The third large flowered milkpea, *G. floridana* has some intergrading with *G. smallii*, but Herndon (1981) feels their appearance in the field is strikingly distinct. *Galactia floridana* has conspicuously sericeous pubescence covering the stem and leaves, but the pubescence of *G. smallii* leaves is not apparent without close inspection (Herndon 1981).

Taxonomy

Small's milkpea was originally described as *G. prostrata* by Small in 1933. However, H.J. Rogers (unpublished dissertation, Duke University, 1949) discovered that this name is a homonym, unavailable for use, and suggested *G. smallii*. Since Rogers' proposal was never published, the incorrect name persisted. Herndon (1981) published Rogers' finding and proposed the name change to *G. smallii*.

Distribution

Galactia smallii occurs in the Redland pine rocklands of southern Miami-Dade County, Florida (O'Brien and Koptur 1995) (Figure 1). Its distribution is spotty because of the limited habitat available. The type locality is listed as near Silver Palm, Miami-Dade County, in an area now encompassed by Redland pine rocklands.

Habitat

Preliminary results of a study of the abundance, distribution, and habitat preferences of *Galactia* species in Miami-Dade County pine rocklands indicate that *G. smallii* prefers higher elevations and lower shrub cover than the more common *Galactia* species (O'Brien 1994). The distribution of *G. smallii* is correlated with soil depth and color in Redland pine rocklands. It does not occur in sites with a high amount of exotic plant cover, specifically, *Schinus terebinthifolius* and *Neyraudia reynaudiana* (O'Brien and Koptur 1995).

Reproduction

Small's milkpea is a perennial legume that usually flowers during the summer months. However, numerous flowers may occur following a burn at anytime throughout the year (Small 1933, and Long and Lakela 1971). Fire may synchronize and intensify flowering of plants in the burned area (A. Herndon, personal communication 1998). Its pollinators include three species of bees, one species of wasp, and the Cassius blue butterfly (*Leptotes cassius theonus*).

Relationship to Other Species

The pine rockland habitat where the Small's milkpea occurs is characterized by a canopy of slash pine (*Pinus elliottii* var. *densa*) and a shrub canopy of saw palmetto (*Serenoa repens*), wax myrtle (*Myrica cerifera*), poisonwood

Small's milkpea flower. *Original photograph by Steve Shirah.*

(*Metopium toxiferum*), and willow bustic (*Sideroxylon salicifolium*). Common herbaceous associates include *Schizachyrium sanguineum* var. *sanguineum, Schizachyrium gracile, Aster adnatus,* and *Acalypha chamaedrifolia.*

Status and Trends

Small's milkpea was listed as endangered because of the loss of pine rockland habitat to residential and commercial development (50 FR 29349). At the time of its listing, Small's milkpea was only known at two sites near Homestead in Miami-Dade County. A 1994 survey found Small's milkpea at seven additional sites on public land: Seminole Wayside, Navy Wells, Sunny Palms, Pine Island, Ned Glenn, Goulds, and the HRS site in Florida City/Miami-Dade County Park and Recreation Department is actively managing five of the six publicly owned sites.

Small's milkpea was also found in small numbers on privately owned pine rockland fragments. The privately owned sites are not managed, have become overgrown, and have high densities of exotic plants that threaten Small's milkpea on these sites (J. O'Brien, Florida International University, personal communication 1996). *Galactia smallii* is not known to occur on Long Pine Key in Everglades National Park (Herndon 1998).

By 1984, about 98 to 99 percent of Miami-Dade County's pine rocklands had been destroyed; that destruction continues today. Most of the remaining pine rocklands in this county are small fragments that are difficult to manage because of their size and proximity to residential housing. In addition, fire suppression and invasion by exotic plants also threaten the survival of Small's milkpea.

Management

The pine rocklands of Miami-Dade County have evolved and adapted to frequent fires (Snyder *et al.* 1990). After two to three decades of fire suppression, pine rocklands mature into tropical hammocks, which have only a few pines in the canopy (Snyder *et al*. 1990). Therefore, any management of pine rocklands to maintain the structure and composition of this vegetative community requires fire.

A fundamental question concerning the fire ecology of pine rocklands is how frequently they should burn and at what season of the year. Snyder *et al*. (1990) inferred historic burn regimes by looking at the time it takes for the herbaceous layer to be excluded from an area by shading (maximum time between fire) and the point when enough fuel is available to carry a fire (minimum time between fires). The minimum fire regime they found was 2 to 3 years and the maximum was 15 years. This wide range in fire frequencies would result in different forest structures and dynamics.

Based on this information, prescribed burns should be conducted in a mosaic pattern to manage pine rocklands. Presently the recommended burn regime is 3 to 7 years with summer fires generally preferred to winter. Summer fires are preferred since most of the lightning strikes (the historical cause of fires) occur in the summer months. In areas where fires have been suppressed for many years, the reintroduction of fire may have to be done in step-wise fashion. In some areas it may even include manual removal of some fuel to prevent a very hot fire.

Any prescribed fire management should include a monitoring program to determine the effectiveness of the prescription. Monitoring should include the species distribution (presence/absence), quantitative assessment of abundance or condition, and demographic information on individual plants (Menges and Gordon 1996). There should also be a component to the monitoring that captures the health of the community and species that occur in association with Small's milkpea (C. Kernan, Fairchild Tropical Garden, personal communication 1996).

Invasive exotic species, especially *Schinus terebinthifolius*, and *Neyraudia reynaudiana*, threaten Small's milkpea and other rare pine rockland plants. The control of exotic species in the pine rocklands is a very important part of maintaining the habitat, although it can be very costly, once exotics are established in an area. In most cases the control of exotics includes the use of manual labor, herbicides and prescribed fire. In heavily infested areas removal is very labor intensive, with a field crew pulling the plants by hand or cutting. Prescribed fire and herbicide treatments are then used to control the exotic plants. Once an area is cleared of exotics, proper management can reduce the costs of control and maintain the site relatively exotic free.

Management of pine rocklands in Miami-Dade County is problematic because most of the remaining habitat occurs in small fragmented areas surrounded by residential areas. These residential areas are often a source of exotic plant species that invade the pine rocklands. The small size of the pine rocklands make it easier for these exotics to invade. Controlling these invasive exotics will require an active strategy that should include a multi-lingual outreach program, which stresses the importance of invasive exotic control in areas surrounding pine rockland habitat. The pine rocklands in Everglades NP are managed by Park personnel for the benefit of the protected species. Exotic species control and fire management are ongoing planned activities in the Park's habitat management program.

Small's milkpea is easy to propagate. An *ex situ* population is maintained by the Center for Plant Conservation and Fairchild Tropical Garden in Miami and may be used to augment existing populations. Results of research by O'Brien and Koptur (1995) may provide useful information for choosing appropriate sites for possible reintroduction. Since the historic range of this species is poorly understood, it would be wise to delay introductions and reintroductions until more genetic information is available and a clear plan is devised. Fairchild Tropical Garden maintains an *ex situ* conservation collection of *G. smallii* at the Research Center. This collection needs to be expanded in order to build a genetically representative conservation collection. Fairchild Tropical Garden has identified propagation and cultivation methods. (D. Garvue, Fairchild Tropical Garden, personal communication, 1998.)

Literature Cited

Garvue, D., C. Kernan, and J. Kornegay. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30. 1998.

Herndon, A. 1981. *Galactia smallii*: A new name for *Galactia prostrata* Small. Rhodora 83:471-472.

Herndon, A. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30. 1998.

Herndon, A. 1998. Life history studies of plants endemic to Southern Florida, October 1, 1995 to April 30, 1998. Final report to the National Park Service under Cooperative Agreement No. CA5280-5-9019.

Isley, D. 1990. Vascular flora of the southeastern United States, vol. 3, part 2, Leguminosae (Fabaceae). University of North Carolina Press; Chapel Hill, North Carolina.

Kernan, C. 1996. Visit to Fairchild Tropical Garden research center. December 12, 1996.

Long, R.W. and O. Lakela. 1971. A flora of Tropical Florida. University of Miami Press; Miami, Florida.

Menges, E.S., and Gordon, D.R. 1996. Three levels of monitoring intensity for rare plant species. Natural Areas Journal. 16:227-237.

O'Brien, J.J. 1994. Research on South Florida *Galactia* (*Fabaceae*). Plant Conservation 8(1).

O'Brien, J.J., and S. Koptur. 1995. The ecology of rare and common *Galactia* species (Fabaceae) native to South Florida pine rocklands [abstract]. In: 1995 annual meeting of the Botanical Society of America and the American Institute of Biological Sciences, San Diego, California, USA, 6-10 August 1995. American Journal of Botany 82:6.

O'Brien, J.J. 1996. Telephone communication. 5 December 1996.

Snyder, J.R., A. Herndon, and W.B. Robertson, Jr. 1990. South Florida rockland. Pages 230-274 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

Small, J.K. 1933. Manual of the southeastern flora. University of North Carolina Press; Chapel Hill, North Carolina.

Small, J.K. 1903. Flora of the southeastern United States. Published by the author; New York, New York.

Snyder, J.R. 1986. The impact of wet season and dry season prescribed fires on Miami rock ridge pineland, Everglades National Park. Unpublished report (SFRC-86/06) prepared for the National Park Service, South Florida Research Center; Homestead, Florida.

U.S. Fish and Wildlife Service [FWS]. 1988. Recovery plan for five Florida pine rockland plant species. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Recovery for the Small's Milkpea

Galactia smallii

Recovery Objective: PREVENT EXTINCTION, then stabilize.

Recovery Criteria

Galactia smallii will, most likely, never reach a level at which reclassification could be possible. The objective of this recovery plan is to increase existing populations and prevent extinction. *Galactia smallii* may be considered stabilized when existing populations, within the historic range, are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression. These sites must also be managed to maintain pine rocklands to support *G. smallii*. Monitoring programs should demonstrate that populations of *G. smallii* on these sites support sufficient population sizes, are distributed throughout the historic range, and are sexually or vegetatively reproducing at sufficient rates to maintain the population.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be developed if new information identifies ways of re-establishing populations of this species to expand its distribution within its historic range.

Species-level Recovery Actions

S1. **Conduct surveys to determine distribution of pine rockland plants.** Pine rockland plants have been thoroughly surveyed in Miami-Dade County. However, other populations may be noted during acquisition and restoration program implementation. Fire may eliminate litter concealing listed species, or enable seeds in the seed bank to germinate. For that reason, pine rocklands that did not contain listed species when unmanaged should be resurveyed after fire events.

S1.1. **Inventory known populations.** Conduct thorough ground surveys to determine the distribution of *G. smallii.* Collect and archive herbarium voucher specimens for all populations. Initiate a quarterly monitoring program. Use existing standardized monitoring protocols developed by the Florida Natural Areas Inventory to record baseline data regarding the biology and ecology of *G. smallii.*

S1.2. **Search for additional populations of *G. smallii.*** Resurvey historic locations. Conduct thorough ground surveys to locate unrecorded individuals and populations of *G. smallii.*

S1.3. **Map distribution of known populations and suitable habitat.** Map populations, including obtaining GPS coordinates and developing GIS coverages.

S2. Protect and enhance existing populations. It is imperative for the recovery of pine rockland plants that populations not be lost.

S2.1. Augment natural populations of *G. smallii*, where appropriate. Many pine rockland plant species are in a precarious situation. *Ex situ* collections exist for *Galactia* spp. at Fairchild Tropical Garden. If possible, additional collections should be established. These may be used to cultivate pine rockland plants and augment sparse populations in protected areas. Experiments with reintroductions will be useful in the future, and could be essential for the recovery of pine rockland plant species.

S2.2. Continue work with *ex situ* propagation and seed banks. Seeds should continue to be banked for all the listed species possible, and should be identified precisely as to collection location.

S2.2.1. Conserve germplasm. Fairchild Tropical Garden maintains an *ex situ* conservation collection of *G. smallii* at its Research Center. This collection needs to be expanded in order to capture the genetic variation found in the wild. Fairchild Tropical Garden has identified propagation and cultivation methods. Continue work with *ex situ* propagation and seed storage banks. Identify seed storage potential and methods.

S2.2.2. Study the feasibility of translocating propagules into historically appropriate and protected natural habitats.

S2.3. Identify potential reintroduction sites and reintroduce *G. smallii* plants, where appropriate. Sites identified as suitable for reintroduction within the known historic range of each species should be surveyed and prepared to receive plants. Federal lands under proper management regimes may be good recipient sites. These sites should receive reintroduction stock.

S2.3.1. Use reintroduction protocols established by the conservation community.

S2.3.2. Monitor the experimental outplantings. Monitoring of reintroduced plants is essential for assessing the success of recovery efforts. Growth and survivorship should be measured.

S2.4. Enforce available protective legislation. State, Federal, and local regulations should be used to protect the pine rockland ecosystem and the listed plants.

S2.4.1. Initiate section 7 consultation when applicable. Section 7 of the Endangered Species Act applies to Federal activities which might impact listed species.

S2.4.2. Encourage implementation of management plans. Federal agencies are obligated under section 7(a)(1) of the Endangered Species Act to perform positive conservation programs for the benefit of listed species. Implementation of the Richmond Pine Rocklands Management Plan (DERM 1994) would constitute such a positive conservation program and should be implemented by the U.S. Army Reserve Center in Perrine, the U.S. Coast Guard site, the Department of Correction's Miami Correctional Center, and any other Federal agency property owner in this area.

S2.4.3. Continue to enforce take and trade prohibitions. The take and trade restrictions of the Federal Endangered Species Act and the Preservation of Native Flora of Florida Act protect *G. smallii*. Since these are inconspicuous plants, take and trade are nonexistent or uncommon.

S3. Conduct research on the biology of *G. smallii*. Additional information on the ecology and life history of pine rockland plants needs to be collected. Determine size and viability of all populations. Known populations of the listed pine rockland plants should be evaluated. Population viability needs to be investigated and determined for each listed plant species.

S3.1. Study the reproductive biology of *G. smallii*.

S3.2. Study the response of *G. smallii* to habitat management treatments.

S3.3. Study the fire ecology of *G. smallii.*

S3.4. Determine population size and viability of all populations.

S3.5. Characterize the habitat and identify suitable sites for experimental outplantings.

S3.6. Conduct genetic studies to document the genetic variation within and between populations.

S3.7. Apply and modify, if need be, reintroduction protocols established by the conservation community.

S4. Develop standardized monitoring. Standardized monitoring needs to be developed for listed pine rockland species in order to determine the effect of management actions on these species. Use existing standardized monitoring protocols developed by the Florida Natural Areas Inventory to record baseline data regarding the biology and ecology of *G. smallii.* Initiate quarterly monitoring program.

S4.1. Collect existing and historical data and place in a central location. Contact former researchers for historical data, gather information from herbaria and museums, and contact all present researchers to compile data and place in a GIS database in the FWS's South Florida Ecosystem Office. This location will allow all researchers access to both historic and current data, and provide the FWS with a means to monitor the success of recovery tasks.

S4.2. Convene a meeting of researchers and land managers. A meeting of current pine rockland researchers and land managers would enable the FWS to locate information sources and begin the process of compiling those data. The meeting would also afford cooperators an opportunity to discuss monitoring and management procedures and set realistic species level goals.

S4.3. Monitor status and success of all populations; **change management practices if so indicated**. Because of the varying vegetation conditions and fire histories, different management may be required at different pine rockland sites. Different prescribed burn intervals may be necessary for best results. Intervals should be adjusted over the years to promote pine re-establishment and hardwood reduction.

S4.4. Monitor reintroduction success and modify procedures as necessary. Plant reintroductions should be monitored to determine the success of the procedure. The goal of reintroduction should be to establish a viable population. Management of the reintroduction sites should be modified as necessary to improve results.

S5. Continue to provide public information about pine rocklands and their unique flora. Public support will increase the chances of recovery for these species. Informational and educational materials have been produced. DERM and Miami-Dade County Natural Areas Management have developed flyers, displays, newsletters, and press releases, and have held workshops with the general public. Organizations best able to carry out information and education programs include: Miami-Dade County Parks and Recreation Department, the Florida Native Plant Society, Everglades NP, and Miami-Dade County DERM. Support of local press coverage should continue. DERM has developed a web page that will also aid in disseminating information about this endangered plant community to the public.

Habitat-level Recovery Actions

H1. Continue to protect and prevent degradation of pine rockland plant habitat. The decline of the five listed pine rockland plants is due to the almost complete elimination or alteration of pine rocklands in South Florida. Without protection and proper management, the remaining rockland sites will be developed or will deteriorate.

H1.1. Protect pine rockland habitat. Acquisition of remaining private sites may be the only effective way to protect or conserve pine rockland habitat. Miami-Dade County's Environmentally Endangered Lands program and the State of Florida's CARL program have acquired over 450 acres of pine rocklands since 1990. It should be noted that public lands may still be subject to development for recreational, maintenance, or other purposes. Such disturbances, unless carefully planned, may directly destroy pine rockland and may secondarily result in exotic plant infestations as well as destructive human uses.

H1.2. Protect or acquire privately owned sites. Less-than-fee-simple acquisition should be used, where appropriate, as an alternative means of protecting pine rockland habitat. Covenants, as provided for under Miami-Dade County regulations, provide tax incentives for private landowners to protect pine rockland sites. A site owned by Florida Power and Light Company may be maintained through cooperation with that utility. This avenue of protection should also be pursued with the railroad company that owns the site of one of the three largest populations. Miami-Dade County DERM is developing a private lands management and grant program for pine rockland protection and restoration; this program should be implemented as soon as possible.

H1.3. Implement additional management to meet habitat needs.

H1.3.1. Eliminate human-caused degradation. Preventing trash dumping or other destructive human activities in pine rocklands is important. In order to accomplish this task, fencing and access restrictions may be necessary.

H1.3.2. Control invasive plant species, particularly exotics. Burma reed or persistent hardwoods need to be controlled and may require special techniques including herbicide, fire, mechanical, and hand clearing at most sites. Other management needs indicated by ongoing research should also be implemented.

H2. Restore areas to suitable habitat.

H2.1. Eliminate physical degradation of habitat and restore to optimal conditions. Physical degradation of pine rocklands continues to occur. Hurricane Andrew in 1992 killed most of the adult pines in the Richmond tract and at various sites throughout Miami-Dade County. The adult pines on Long Pine Key in Everglades NP were not as severely damaged (Herndon, 1980). The continued degradation of these areas should be curtailed and restoration of uneven-aged pine stands undertaken. Tubelings or direct seeding experiments may be used to accomplish this task. In order to use direct seeding techniques, collection of local pine seeds must continue.

H2.2. Continue to refine best management practices for pine rocklands. This would include development of fire management strategies that would best benefit pine rockland species.

H2.3. Management plans for sites including *G.smallii* should be implemented and modified as necessary for the benefit of this species. Without active fire and exotic plant management, pine rocklands will continue to disappear or degrade. Because of the highly fragmented and restricted nature of remaining pine rocklands in urbanized Miami-Dade County, intensive management may be necessary at many of the remaining sites.

H2.4. Continue to conduct prescribed burns. Prescribed fire should be conducted at sites where *G. smallii* occurs at the appropriate times of the year to lower fuel loads. Growing season burns should then be employed after fuel levels are under control. The response of *G. smallii* to prescribed burns should be studied. Special consideration must be incorporated when planning prescribed fire for pine rocklands invaded by Burma reed. Incorporate appropriate actions to minimize additional Burma reed infestations in these areas. Due to the highly urbanized lands surrounding some of the pine rockland sites, burning involves risks of smoke damage and annoyance, or worse, losing control of the fire. The Florida Division of Forestry has expertise in carrying out controlled burns in Miami-Dade County, and should be contacted to assist with burns. Fire management is necessary for all Federal and county lands. Miami-Dade County is composing a Strategic Fire Management Plan; this plan should be implemented once approved.

H3. Continue to investigate and refine the habitat needs of each species. The habitat needs of these species have been studied, but are still not completely understood. The pollination, germination, or other requirements have not been fully investigated. Research should address how light levels affect survival and how fire management affects light levels, reproduction, and regeneration of these species.

H4. Monitor habitat and ecological processes.

H4.1. Monitor sites with *G. smallii* restoration programs to determine success. A protocol developed by Fairchild Tropical Garden for monitoring plant communities at sites where *G. smallii* occurs should be implemented.

H4.2. Investigate fire history and incorporate into management strategies. Look at fire history for pine rocklands in Miami-Dade County, incorporate into GIS database and analyze relative to healthy populations. This exercise will provide adequate information on fire history and intervals in urbanized and non-urbanized settings and enable assessment of the appropriateness of proposed management regimes in Miami-Dade County.

H4.3. Develop a GIS database on the five listed pine rockland species and their habitats. Distribute the database to researchers, land managers, and conservationists.

H4.3.1. Assess the available GIS data.

H4.3.2. Create coverage of population locations.

H4.3.3. Acquire recent imageries of the sites.

H4.3.4. Distribute the coverages.

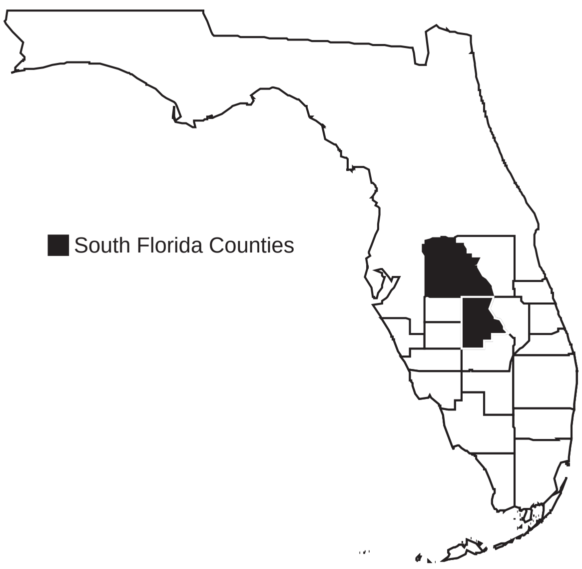
H5. Continue implementation of the fire education program and modify as necessary any fire management education program that has been developed. Future modifications to this program may include tri-lingual language (Spanish, English, and Haitian Creole).

Highlands Scrub Hypericum

Hypericum cumulicola (Small) P. Adams

Federal Status:	**Endangered (January 21, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of Highlands scrub



Hypericum cumulicola is a rare species that is endemic to the Lakes Wales Ridge in central Florida. It is only known from Polk and Highlands counties. Within those counties, it may occur in relatively large populations of hundreds or thousands of individuals. The scrub hypericum is threatened by habitat loss, isolation of populations, and fire suppression threats, factors which led to its listing as an endangered species on January 21, 1987. Measures being used to conserve this species include land acquisition and management.

This account represents a revision of the existing recovery plan for the Highlands scrub hypericum (FWS 1996).

Description

Hypericum cumulicola is a small, short-lived perennial herb reaching 20 to 70 cm in height. It is branched from the base and has a woody, fibrous root system. The stems are shorter and more numerous in winter and spring before reproductive stalks are differentiated. Usually there are three stems, but there can be as many as 17 stems on a healthy plant (Quintana-Ascencio and Morales-Hernández *in press*). During the reproductive season, all stems of mature individuals bear flowers and fruits. The leaves of *H. cumulicola* are opposite, simple, entire, and needle-like. Flowers are small, bisexual, and arranged in cymes. The calyx consists of five distinct sepals, while the corolla consists of five bright yellow petals shaped like the blades of a propeller. There are approximately 27 anthers. The gynoecium has three, sometimes four locules, and the ovary is superior with approximately 22 ovules aligned around the walls of the ovary (parietally). The style has three, sometimes four, white lobes. Fruits are small capsules, red when immature and dark purple at the time of dehiscence. Mature seeds are small and dark brown. This species, as other *Hypericum*, may contain hypericin, a promising compound with protective effect in the control of viral diseases in animals (Duke 1989).

Taxonomy

Hypericum is a predominantly temperate genus, and a member of the family Hypericaceae. This family is closely related to the Clusiaceae (Guttiferae), and some authorities include both groups together (Cronquist 1988). In central Florida, *H. cumulicola* is morphologically distinct from other species in its genus (Ward and Godfrey 1978). In 1924, Small first named the plant *Sanidophyllum cumulicola.* Later, Adams (1962) reassigned the species to the genus *Hypericum,* renaming it *Hypericum cumulicola*. *Hypericum cumulicola*'s closest relative in Florida is *H. gentianoides*, which is very similar morphologically, but branches repeatedly above the base versus only at the base for *H. cumulicola* (Archbold Biological Station, personal communication 1998).

Distribution

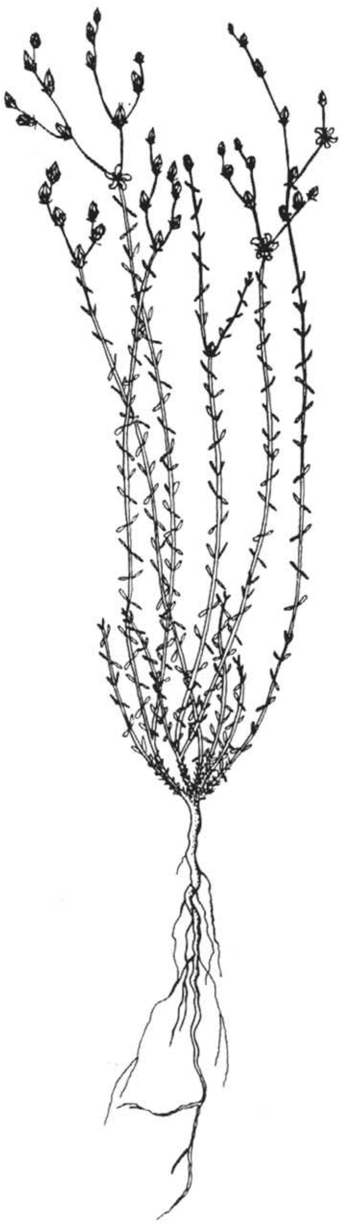
With the exception of one site on the Winter Haven Ridge at Lizzie Lake (Archbold Biological Station, personal communication 1998), *Hypericum cumulicola* is restricted to scrub on the Lake Wales Ridge in Polk and Highlands counties, from just north of Sunray, Polk County (FWS 1996) to the south end of the Lake Wales Ridge near Archbold Biological Station in Highlands County (Judd 1980) (Figure 1).

Habitat

Hypericum cumulicola is limited to upland areas with well-drained, sterile, white sands (Judd 1980). It is almost exclusively found in the sunny openings in rosemary balds. Rosemary balds are unique vegetative communities that occur as patches within the more expansive scrub ecosystem. These habitat patches provide suitable habitat for a number of rare scrub endemics (Christman and Judd 1990). Rosemary balds have a low fire frequency from 10 to 100 years (Johnson 1992, Myers 1990), while the surrounding scrubs are burned more frequently. *Hypericum cumulicola* occurs occasionally in openings in well-drained scrubby flatwoods or among turkey/oak scrubs in yellow sands (P. Ascencio-Quintana, Archbold Biological Station, personal communication 1995). Where found, it is locally common and can occur even in large groups of several thousand individuals (Judd 1980). Population increases of this species are associated with the occurrence of fires that may release local populations from competitive exclusion (Abrahamson 1984, Johnson and Abrahamson 1990, Quintana-Ascencio and Morales-Hernández *in press*, Quintana-Ascencio and Menges undated).

Reproduction

The stems of *Hypericum cumulicola* are branched, many-flowered, and indeterminate. There can be as many as 1,600 reproductive structures (fruits, flowers, or buds) per plant in large individuals by the end of the reproductive season (P. Quintana-Ascencio and M. Hernández *in press*). Flowers develop acropetally and are exposed one at a time or in small numbers (up to eight per branch) each day. The new flowers open early in the morning and the petals



Highlands scrub hypericum. *Original drawings by Lisa C. Magahee; original flower photograph by Steve Shirah.*

curl up by noon depending on the weather. Native solitary bees (*Dialictus* spp. and *Augochloropsis* spp.) appear to be the primary pollinators (M. Evans, Archbold Biological Station, personal communication 1995). Other visitors include *Geron* sp., *Copestilium nigrum*, and *Bombus* spp. Pollinator visitation occurs at similar rates regardless of flower or plant density (O. Boyle, Archbold Biological Station, personal communication 1996). The initial position of the styles and stamens in many individuals suggests the prevention of self-pollination, since they make an approximately 90° angle that separate each from the other at the time of pollen release. *Hypericum cumulicola* is self-compatible. The lower fruit set of flowers under an autogamous (isolated to avoid their contact to potential pollinators) experimental treatment, compared with flowers under manual self and outcross, and control treatments, suggests the important role of pollinators for pollen transfer in this species (M. Evans, Archbold Biological Station, personal communication 1995). There is an interval of approximately 25 days between fertilization and fruit dehiscence (O. Boyle, Archbold Biological Station, personal communication 1996). The mature purple capsules remain attached to the stem after releasing the seeds. Seeds do not show any obvious primary dispersal mechanism and probably are dispersed passively by gravity. This herb does not survive burning and population recovery requires the presence of buried seeds in the soil or their dispersal from nearby populations (Quintana-Ascencio, Dolan, and Menges, undated).

Reproduction in this species takes place between April and October, but most flowering and fruiting occurs between June and September, coinciding with the rainy season and daily thunderstorms typical of the region. Stems dry at the end of the reproductive season and new ones sprout from the base in late winter and early spring. Germination occurs from November through June, but most seedlings germinate between December and February. Plants reach maturity in as little as a year.

Relationship to Other Species

Gap size requirements of this herb appear to be intermediate (P. Quintana-Ascencio, Archbold Biological Station, personal communication 1995) in comparison with two other co-occurring rosemary scrub plants: *Eryngium cuneifolium*, restricted to large openings (Menges and Kimmich 1996), and *Polygonella basiramia*, found in large and small gaps between shrubs (Hawkes and Menges 1995).

Status and Trends

Hypericum cumulicola was listed as endangered under the ESA on January 21, 1987 (52 FR 2234). This species is threatened with habitat loss, fire suppression, and isolation of populations. Originally part of a more extensive xeric vegetation, remaining patches of Florida scrub have been increasingly isolated because of habitat destruction and degradation due to conversion for residential developments, ranches, and orange groves. In the last three decades approximately 90 percent of its habitat has been lost (Peroni and Abrahamson 1985, Richardson 1989).

Suppression of the natural burn regime has intensified the threats to this species. Where it still occurs, long unburned patches of habitat have experienced increases in shrub and lichen cover. Increased competition results in higher mortality and lower recruitment, and eventually the extirpation of *H. cumulicola* (P. Quintana-Ascencio, Archbold Biological Station, personal communication 1995). Suitable habitat for this species is often naturally patchy and occurs in a mosaic of other vegetation types. Extended periods without fire can result in the loss of some patches of suitable, occupied habitat. Increasing isolation may have an important detrimental effect on habitat colonization and the persistence of this species (Quintana-Ascencio and Menges undated).

Protected sites where *H. cumulicola* occurs include: Archbold Biological Station, Gould Road Preserve, Holmes Avenue Preserve, Lake Apthorpe Preserve, Lake Arbuckle State Preserve, Lake Arbuckle WMA, Lake June, Lake Wales Ridge SF, Placid Lakes, Saddle Blanket Lakes Preserve, Sun-N-Lakes Preserve, and Sun Ray.

Management

Hypericum cumulicola has evolved in xeric vegetative communities that are fire maintained. It inhabits a specific vegetative community that has a relatively long burn return interval compared to most other upland xeric communities. When fire does occur within rosemary balds, *H. cumulicola* responds favorably to the reduction in competing vegetation and is usually found in large numbers immediately following fire. These responses to fire and our knowledge of xeric community fire regimes should guide management efforts for this species.

It is clear that management of xeric uplands containing *H. cumulicola* should utilize fire to create vegetative mosaics within and adjacent to rosemary balds. Because of the inability to ignite rosemary balds during more frequent prescribed burns of adjacent scrub, some land managers have suggested that no specific efforts be made to manage rosemary balds. Instead, they recommend management efforts be directed toward other xeric uplands that require more frequent fires, suggesting that adjacent rosemary balds will burn as part of the landscape when they are capable of carrying fire.

Where fire has been used, improvements in *H. cumulicola* habitat quality have been noted. In instances where use of fire may not be appropriate, use of mechanical disturbances that decrease shrub and lichen cover may be a suitable management alternative. Mechanically altered sites should be monitored to assess the recovery of *H. cumulicola* and possible effects to other scrub species.

Literature Cited

Abrahamson, W.G., A.F. Johnson, J.N. Layne and P.A. Peroni. 1984. Vegetation of the Archbold Biological Station, Florida: an example of the southern Lake Wales Ridge. Florida Scientist 47:209-250.

Abrahamson, W.G. 1984. Species response to fire on the Florida Lake Wales Ridge. American Journal of Botany 71:35-43.

Adams, P. 1962. Studies in the Guttiferae. II. Taxonomic and distribution observations on North American taxa. Rhodora 64:231-242.

Archbold Biological Station. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September 30, 1998.

Boyle, O. 1996. Comment on species account. December 1996.

Christman, S.P, and W.S. Judd. 1990. Notes on plants endemic to Florida scrub. Florida Scientist 53:52-73.

Cronquist, A. 1988. The evolution and classification of flowering plants. The New York Botanical Garden; New York, New York.

Duke, J.A. 1989. An herb a day. St. John's-wort. The business of herbs 7:6-7.

Evans, M. 1995. FWS Multi-Species Recovery Team Meeting. December 6-8, 1995.

Hawkes, C.V., and E.S. Menges. 1995. Density and seed production of a Florida endemic, *Polygonella basiramia*, in relation to time since fire and open sand. American Midland Naturalist 133:138-148.

Hutchinson, J. 1969. Evolution and phylogeny of flowering plants. Academic Press; London, England.

Johnson, A.F., and W.G. Abrahamson. 1990. A note on the responses of species in rosemary scrubs on the southern Lake Wales Ridge. Florida Scientist 53:138-143.

Judd, W.S. 1980. Status report on *Hypericum cumulicola*. U.S. Fish and Wildlife Service; Jacksonville, Florida.

Lawrence, G.H.M. 1951. Taxonomy of vascular plants. Macmillan; New York, New York.

Menges, E. 1995. FWS Multi-Species Recovery Team Meeting. December 6-8, 1995.

Menges, E.S., and J. Kimmich. 1996. Micro-habitat and time since fire: effects on demography of *Eryngium cuneifolium* (Apiaceae), a Florida scrub endemic plant. American Journal of Botany, 83(2):185-191.

Peroni, P.A., and W.G. Abrahamson. 1985. A rapid method for determining losses of native vegetation. Natural Areas Journal 5:20-24.

Quintana-Ascencio, P. 1995. FWS Multi-Species Recovery Team Meeting. December 6-8, 1995.

Quintana-Ascencio, P.F., and E.S. Menges. 1996. Inferring metapopulation dynamics from patch-level incidence of Florida scrub plants. Conservation Biology 10:1210-1219.

Quintana-Ascencio, P.F., and M. Morales-Hernández. In press. Fire-mediated effects of shrubs, lichens and herbs on the demography of *Hypericum cumulicola* in patchy Florida scrub. Submitted to Oecologia.

Quintana-Ascencio, P.F., R.W. Dolan, and E. S. Menges. Undated. draft recruitment and fecundity of the Florida endemic *Hypericum cumulicola* in vacant and occupied patches with contrasting time-since-fire.

Quintana-Ascencio, P.F., and E.S. Menges. Undated. draft Survivorship, growth and fecundity of three narrowly endemic plants in competitive neighborhoods along a fire disturbance gradient.

Radford, A.E., H.E. Ahles, and C.R. Bell. 1964. Manual of the vascular flora of the Carolinas. The University of North Carolina Press; Chapel Hill, North Carolina.

Richardson, D. R. 1989. The sand pine scrub community: an annotated bibliography. Florida Scientist 52:65-93.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery Plan for Nineteen Central Florida Scrub and High Pineland Plants. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Ward, D.B., and R.K. Godfrey. 1978. Highlands scrub hypericum. Pages 34-35 *in* D. B. Ward and R.K. Godfrey ed. Rare and endangered biota of Florida. Plants, volume V. University Presses of Florida; Gainesville, Florida.

Wunderlin, R.P. 1982. Guide to the vascular plants of Central Florida. University Press of Florida; Tampa, Florida.

Recovery for the Highlands Scrub Hypericum

Hypericum cumulicola (Small) P. Adams

Recovery Objective: **STABILIZE,** then reclassify to threatened.

Recovery Criteria

Hypericum cumulicola may be considered stabilized when existing populations, within its historic range are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression. These sites must also be managed to maintain the rosemary phase of sandpine scrub to support *H. cumulicola*.

Once the existing populations are stabilized, *H. cumulicola* may be considered for reclassification to threatened. Reclassification will be considered when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations and sites needed to ensure 20 to 90 percent probability of persistence for 100 years; when these populations, within the historic range of *H. cumulicola* are adequately protected from further habitat loss, degradation, fragmentation, and fire suppression; when these sites are managed to maintain the rosemary phase of sandpine scrub to support *H. cumulicola*; when monitoring programs demonstrate that populations of *H. cumulicola* on these sites support sufficient population sizes; when those populations are stable and distributed throughout the historic range; and when *H. cumulicola* are sexually or vegetatively reproducing at sufficient rates to maintain the population.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *H. cumulicola.* This species has been relatively well-surveyed and a distribution has been ascertained. Additional surveys will confirm the species' distribution and locate new sites.

S1.1. Conduct surveys of *H. cumulicola*.

S1.1.1. Continue surveys in Polk and Highlands counties. The Lake Wales Ridge has probably been adequately surveyed, though new sites for *H. cumulicola* may still be found.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are acquired.

S1.2. **Maintain distribution of known populations and suitable habitat in GIS database.** Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. **Protect and enhance existing populations.** Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties has been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. **Protect habitat through acquisition, conservation easements, or agreements with landowners.**

S2.2. **Protect populations on public lands.** Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages. *Hypericum cumulicola* would require a burn regime that had an average burn cycle of around 20 years.

S2.3. **Use local or regional planning to protect habitat.** Utilize available regional and county planning processes to encourage protection of suitable, unoccupied, and occupied habitat of *H. cumulicola*.

S2.4. **Conserve germ plasm.** The seed for this species is not presently in long-term storage. Germplasm conservation preserves genetic diversity and provides valuable information regarding the reproductive biology of rare species. *Hypericum cumulicola* has a very high genetic diversity among populations. This unusual characteristic would require that any effort for seed storage be made of samples from a large number of populations. The local abundance of this species makes an *ex situ* garden collection a low priority for this species.

S2.5. **Enforce available protective measures.** Use local, State, and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *H. cumulicola* lives.

S2.5.1. **Initiate section 7 consultation when applicable.** Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. **Enforce take and trade prohibitions.** This species is protected by take provisions of the Endangered Species Act (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. Conduct research on life history characteristics of *H. cumulicola*. Continue the study of basic biology and ecology of this species. To effectively recover this species more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as numbers of populations, numbers of individuals in a population, recruitment, growth, survival, and mortality. The current research indicates that the seedbank may be the key for this species' survival.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *H. cumulicola*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring information on the localities of *H. cumulicola* sites will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers. Close coordination among land managers is essential in the development of adaptive management techniques.

S4. Monitor existing populations of *H. cumulicola*.

S4.1. Develop monitoring protocol to assess population trends for *H. cumulicola*.

S4.1.1. Monitor to detect changes in demographic characteristics, such as reproduction, seed dormancy, germination, recruitment, growth, dispersal, survival, and mortality. Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. Monitor the effects of various land management actions on *H. cumulicola*. Assess any changes in demographic characteristics of *H. cumulicola* in response to land management activities, such as prescribed fire, exotic plant control, *etc*. The number of individuals in a population is highly variable through the burn cycle.

S4.2. Develop a quantitative description of the population structure of *H. cumulicola*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) should also be included.

S5. Provide public information about *H. cumulicola*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private land owners be appropriately informed about this species. Care is needed, though, to avoid revealing specific locality information about where *H. cumulicola* is found.

S6. Develop delisting criteria. Once reclassification is achieved, research and monitoring results may provide data necessary to develop delisting criteria.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. *H. cumulicola* is particularly sensitive to habitat fragmentation from a genetic standpoint, as well as a metapopulation perspective. Both development and fire suppression have decreased the available habitat. To date, there are 13 protected sites for *H. cumulicola* in Polk and Highlands counties.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Prevent habitat damage from off-road vehicle use and provide proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation. *Hypericum cumulicola* is a species that needs a fire return interval of less than 20 years to safeguard against a failure in the seedbank.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *H. cumulicola*.

H1.2.3. Control access to areas where listed plants are growing. Trampling and off road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Continue habitat-level research projects. Study the response of *H. cumulicola* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, etc., on the habitats where *H. cumulicola* occurs.

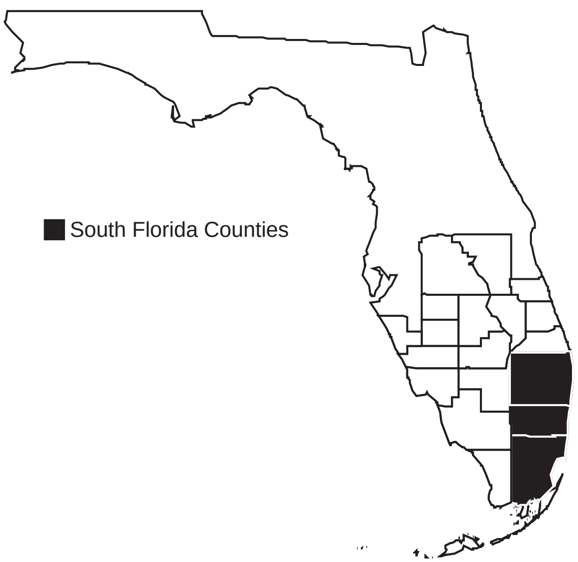
H5. Provide public information about scrub and its unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the South Florida Water Management District, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Beach Jacquemontia

Jacquemontia reclinata House

Federal Status:	**Endangered (Nov. 24, 1993)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of beach jacquemontia.



Jacquemontia reclinata is a member of the morning glory family (Convolvulaceae) that is restricted to the southeastern coast of Florida. Much of the primary habitat of this species, beach coastal strand and maritime hammock, has been destroyed or altered for residential and commerical construction. Fewer than 1,000 individual plants exist. They are found in small, widely separated populations in Dade, Broward, and Palm Beach counties, where habitat loss and modification place this species at a high risk of extinction. Habitat conservation and management and reintroduction efforts are needed to ensure the survival of this species.

This account represents a revision of the existing recovery plan for the beach jacquemontia (FWS 1995).

Description

Jacquemontia reclinata is a perennial vine which has a main stem with numerous laterals spreading out from a stout rootstock (Robertson 1971). These reclining, partly twining or ascending, slender stems are woody at the base and may twine over other plants (Robertson 1971, Austin 1979). The older leaves and stems of this species can be glabrous, but the pubescence makes younger leaves and stems appear whitish (Austin 1979). The leaves are entire, alternate, estipulate, spirally arranged, and almost always petiolate, reaching 1 to 3 cm in length and 0.5 to 2.5 cm in breadth (Small 1905, Robertson 1971, Austin 1979).

The flowers of this species are white to light pink and the sepals are persistent. The inflorescences can be axillary cymose or solitary with branches 8-40 mm long, usually not exceeding the leaves (Robertson 1971, Austin 1979). The fruit is a light brown capsule about 4-5 mm long (Small 1905, Robertson 1971). Additional physical descriptions of *J. reclinata* can be found in Small (1905) and Robertson (1971).

Though *J. havanensis* is closely related, *J. reclinata*'s main distinction is its ciliolate (marginal fringe of hairs) sepals and rather succulent leaves (Robertson 1971). This ciliolate on the outer sepals and fleshy leaves also distinguishes this species from *Jacquemontia curtissii*, which has hairless sepals and narrow leaves that are not fleshy (Austin 1979).

Taxonomy

There are approximately 100 species of the genus *Jacquemontia,* most of which are found in tropical and subtropical America (Robertson 1971). *Jacquemontia reclinata* is the only species found along the beaches of southeastern Florida (Austin 1979). *Jacquemontia reclinata* was first described from specimens collected in 1903 at northern Miami Beach (Small 1905). The original treatment of this taxon as a distinct species was upheld by Robertson (1971) during a review of the genus *Jacquemontia*.

Three other species are found in Florida: *J. curtissii* inhabits pinelands on the mainland, while *J. jamaicensis* and *J. pentantha* occur in the Florida Keys (Small 1933). Although Small (1933) considered *J. reclinata's* range to extend into the West Indies, Austin (1979) considered it endemic to the east coast of Florida.

Distribution

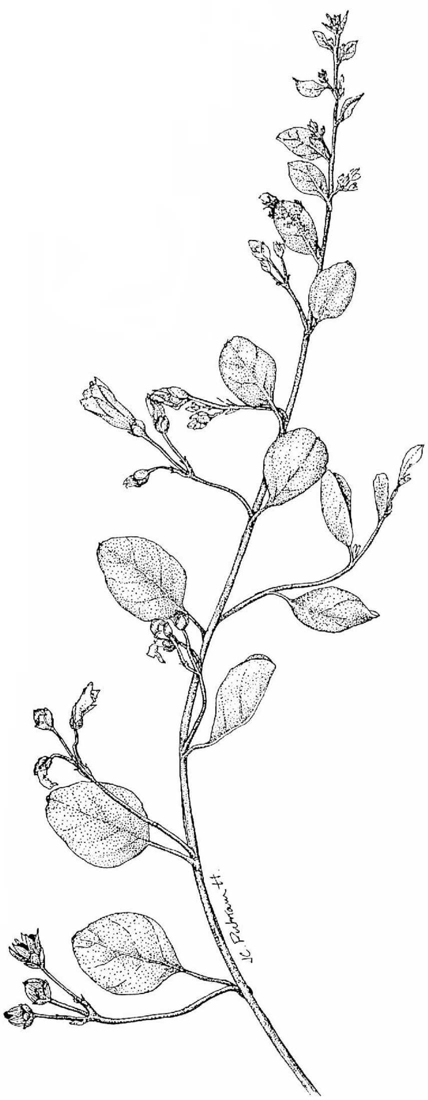
Jacuemontia reclinata is native to coastal barrier islands in southeast Florida from Biscayne Bay in Dade County northward to Palm Beach County (Austin 1979) (Figure 1). It was once found at several sites on Jupiter Island in Martin and Palm Beach counties, but due to habitat destruction associated with residential construction, it is no longer found north of Jupiter Inlet. One specimen, identified as *J. reclinata*, collected on BLM's Jupiter Inlet tract in 1993 may, in fact, actually be *Stylisma villosa*; Palm Beach County's Department of Environmental Resources Management is currently reexamining the population for a definite identification.

Habitat

Jacquemontia reclinata requires open areas that are typically found on the crest and lee sides of stable dunes (Austin 1979). *Jacquemontia reclinata* may also invade and restabilize maritime hammock or coastal strand communities that have been disturbed by tropical storms, hurricanes, and possibly fire. Common vegetative associates found with *J. reclinata* include sea grape (*Coccoloba uvifera*), cabbage palm (*Sabal palmetto*), poisonwood (*Metopium toxiferum*), Madagascar periwinkle (*Catharanthus roseus*), *Croton involucrata*, gopher apple (*Licania michauxii*), prickly pear cactus (*Opuntia* sp.), sandspurs (*Cenchrus* spp.), sea oats (*Uniola paniculata*) and other shrubs and dwarfed trees (Johnson *et al.* 1993, Lippincott 1990).

At Crandon Park, Dade County, *J. reclinata* exists on dune faces at the edge of shrubby hammocks. These plants apparently spread from rootstock centered under adjacent shrubs (C. Kernan, Fairchild Tropical Gardens, personal communication 1995). At Hugh Taylor Birch SRA, Broward County, *J. reclinata* is located in coastal scrub with little canopy cover and exposed sandy substrate. There, it receives protection from direct ocean winds and sea spray (Lippincott 1990).

Beach jacquemontia.
Original drawing by Jean C. Putnam; original photograph by Steve Shirah.



Reproduction

Jacquemontia reclinata flowers from November to May, but may vegetatively propagate at any time. The incidence or importance of vegetative propagation is not known at this time. At some sites, *J. reclinata* sets fruit and disperses seed prolifically (Robertson 1971); however, few seedlings or young plants are ever found near adult plants. Microhabitat conditions and locations relative to adult plants probably play a major role in providing suitable germination sites (D. Austin, Florida Atlantic University, personal communication 1997, C. Kernan, Fairchild Tropical Gardens, personal communication 1997). For example, at Crandon Park, naturally sown seeds had extremely low germination rates (unmeasurable) compared to seeds taken from this site and germinated under greenhouse conditions (70 percent). Findings from these investigations indicated that germination rates were highest in more organic soils in the shade, but that the seed viability was short-lived once sowed.

Seedling and young *J. reclinata* grow best when shaded. Under natural conditions, young plants are typically found growing in the shade of adjacent shrubs and trees. When mature, *J. reclinata* spread laterals from the rootstock into adjacent exposed sites (C. Kernan, Fairchild Tropical Gardens, personal communication 1997).

Relationship to Other Species

Jacquemontia reclinata typically grows on disturbed sites with exposed sand, and is found with plants such as Madagascar periwinkle, sand spurs, and sea grape. *Jacquemontia reclinata* occasionally occurs in the beach dune community with sea oats (Austin 1979, Johnson *et al.* 1993). Though we know little of the reproductive biology of this species, several observations of possible pollinator visitors from the Halictidae family have been made (D.

Austin, Florida Atlantic University, personal communication 1997, C. Kernan, Fairchild Tropical Gardens, personal communication 1997). It is not clear, however, whether these relationships are essential for the successful reproduction of *J. reclinata*. The loss of seeds to granivores has not been reported, but granivorous arthropods and small mammals are ubiquitous and are probably present on sites with *J. reclinata*.

In some locations, *J. reclinata* is adversely affected by competition with native and non-native plants. At Crandon Park *J. reclinata* did not regenerate because many areas that had previously provided suitable germination sites had been invaded by Bermuda grass (*Cynodon dactylon*) (C. Kernan, Fairchild Tropical Gardens, personal communication 1997). In other locations, shading from Brazilian pepper (*Schinus terebinthifolius*), Australian pine (*Casuarina equisetifolia*), carrotwood (*Colubrina asiatica*) and seagrape have restricted growth and reproductive success of *J. reclinata*.

Status and Trends

Loss of habitat to urbanization and beach erosion led to the listing of *J. reclinata* as endangered on November 24, 1993 (58 FR 62050). The vast majority of beach coastal strand and maritime hammock vegetation, the primary habitat of this species, has been destroyed by residential and commerical construction. Habitat within public lands has also been destroyed or degraded due to construction of parking lots, pedestrian routes, picnic areas, and other modifications for recreational uses. Additional habitat has been lost to beach erosion at some sites (Johnson *et al.* 1993, P. Davis, Palm Beach County DERM, personal communication 1997). The limited geographic distribution, fragmentation of remaining habitat, small sizes of *J. reclinata* populations, and possibility of stochastic natural events make it doubtful that many of the existing populations will persist for 100 years.

The barrier islands within the range of *J. reclinata* are entirely urbanized except for a few small parks and private estates. Johnson *et al.* (1993) inventoried all tracts of native coastal vegetation in southeast Florida that were four or more hectares in size. They found only 24 tracts of that description in the known range of *J. reclinata*, five of them entirely or mostly in private ownership. These tracts comprised approximately 87 ha of beach strand vegetation in public ownership, 10.5 ha in private ownership, and 26.7 ha of maritime hammock in public ownership.

In 1991, less than 1,000 individual plants of *J. reclinata* were known to occur on 12 sites (Austin 1991). Eleven of these sites were in public parks or recreation areas operated by State, county, or local governments in Palm Beach (8 sites), Broward (1 site), and Dade (2 sites) counties. The only known privately owned site, in Broward County, had just one plant (Johnson *et al*. 1993, Austin 1991).

A 1995 survey for *J. reclinata* located 450 to 600 plants at 10 sites in Dade and Palm Beach counties (C. Kernan, Fairchild Tropical Gardens, personal communication 1995). More than half of these plants were located at two sites: Red Reef Park in Palm Beach County and Crandon Park in Dade County. The remaining plants were scattered in populations of fewer than 50 individuals in Broward, Dade, and Palm Beach counties.

As of 1996, *J. reclinata* was known from only nine sites in Dade and Palm Beach counties (D. Garview, Fairchild Tropical Gardens, personal communication 1997, P. Davis, Palm Beach County Department of Environmental Resources Management, personal communication 1997). Eight of these sites contained natural populations, while one site was established from restoration efforts. Several previously known sites have been lost over the past several years, including re-established populations at Coral Cove Park and Gemini Gardens (private), and Juno Beach Park, Nasa (private). There may be an additional historic site in Palm Beach County added if future surveys confirm the presence of *J. reclinata*.

Since 1996, surveys have revealed that more *J. reclinata* colonies in Palm Beach County have been lost. Colonies are now known to exist at Carlin Park, Logggerhead Park, Red Reef Park, Red Reef Golf Course, South Beach Park, and South Inlet Park. Gemini Gardens, Atlantic Dunes Park and Spanish River Park were not included in those surveys (P. Davis, Palm Beach County Department of Environmental Resources Management, personal communication 1998).

Information from specific localities of *J. reclinata* suggest that the species is relatively secure at some sites but susceptible at others. For example, it was collected at South Coral Cove Park, Jupiter Island, Palm Beach County, in 1962, but was not found there in 1990 (Johnson *et al*. 1993). The disappearance from this site is due to severe beach erosion and shading from Australian pines (Johnson *et al*. 1993). Several specimens identified as *J. reclinata* from the Jupiter Lighthouse on the mainland opposite the southern tip of Jupiter Island have been subsequently identified as *J. curtissi* (P. Davis, Palm Beach County Environmental Resources Management, personal communication 1998). Land clearing for residential development has eliminated *J. reclinata* from other sites in this area (Austin 1979). Although apparently suitable habitat exists at Blowing Rocks Preserve and Hobe Sound NWR on Jupiter Island, *J. reclinata* has not been found there (Johnson *et al*. 1993).

Management

To ensure the survival of this plant, the remaining populations of *J. reclinata* on public lands will require careful, active management and a program of propagation, germplasm conservation, and augmentation. Basic demographic, pollination, seed dispersal, seed germination and seed establishment information is needed to effectively recover this endangered species.

Successful management of this species will require new surveys for sites that contain *J. reclinata*, complete knowledge of where it existed historically, and surveys for sites within its historic range that would be suitable for re-establishment. In addition, threats to existing and proposed sites posed by commercial and residential development and invasion of exotic species need to be addressed.

Because additional protection of beachfront property through fee title acquisition or easement is unlikely due to high real estate values, *J. reclinata* will be best protected and recovered through re-establishment efforts.

Greenhouse propagated plants were successfully reestablished to three sites in Crandon Park in 1989; however, two plants used in the Coral Cove Beach Dune Restoration Project in 1994 did not survive (P. Davis, Palm Beach County Department of Environmental Resources Management, personal communication 1994). Although this attempt was unsuccessful, we believe the recovery of this species can be partially accomplished through reestablishment as part of dune restoration projects. Dade County is planning to re-establish about 60 *J. reclinata* plants at Bill Baggs Cape Florida SRA, Key Biscayne, Dade County (L. Carter, Bill Baggs Cape Florida SRA, personal communication 1997). It is important to remember that *J. reclinata* should only be re-established in areas within its historic range. Restoration efforts should also consider using other plants that occur naturally with *J. reclinata,* so that more of a representative vegetative complex is recreated.

Some of the existing *J. reclinata* sites and many other potentially suitable recipient sites for *J. reclinata* translocation will require removal and control of exotic vegetation as part of the restoration process. It seems that this species does best in sparsely vegetated habitats, and that one of the factors responsible for its decline is the lack of sparsely vegetated areas that are typical of overwashed dunes (P. Davis, Palm Beach County Department of Environmental Resources Management, personal communication 1998). At Crandon Park, herbicides are being used on a few plots where *J. reclinata* is suppressed by St. Augustine grass, and the plants do not seem to be adversely affected. Fire may also play an important role in habitat maintenance for *J. reclinata* as demonstrated by the short-term response to a recent burn on Bear Cut Preserve on Key Biscayne, Dade County (C. Kernan, Fairchild Tropical Gardens, personal communication 1996). The long-term effects of burning will need to be analyzed over the next several years. Mowing or bush-hogging could also be used where fire cannot be safely utilized, or in areas where the plants currently exist as a result of mowing.

Literature Cited

Austin, D.F. 1979. Beach jacquemontia, *Jacquemontia reclinata*. Page 36 *in* D.B. Ward, ed. Rare and endangered biota of Florida, volume 5: plants. University Press of Florida; Gainesville, Florida.

Austin, D.F. 1991. Status report on *Jacquemontia reclinata* in Florida. Manuscript report to Florida Natural Areas Inventory; Tallahassee, Florida.

Austin, D. 1997. Electronic communication. 21 February 1997.

Carter, L. 1997. Telephone communication. 21 January 1997.

Davis, P. 1994. Memo to Robert Barron (Coastal Management Consultants) Palm Beach County Department of Environmental Resources Management, 5 January 1994.

Davis, P. 1997. Telephone communication. 14 January 1994.

Davis, P. 1998. Comments on technical/agency draft multi-species recovery plan for South Florida. September, 1998.

Johnson, A.F., J.W. Muller, and K.A. Bettinger. 1993. An assessment of Florida's remaining coastal upland natural communities: southeast Florida. Report to Florida Natural Areas Inventory; Tallahassee, Florida.

Kernan, C. 1995. Memo to David Martin. U.S. Fish and Wildlife Service, Jacksonville, Florida. 14 July 1995.

Kernan, C. 1996. Letter. 11 September 1996.

Kernan, C. 1996. Telephone communication. 26 February 1997.

Lippincott, C.S. 1990. Status report on *Jacquemontia reclinata* at Crandon Park, Key Biscayne, Dade County, Florida. Report to Florida Natural Areas Inventory; Tallahassee, Florida.

Robertson, K.R. 1971. A revision of the genus *Jacquemontia* (Convolvulaceae) in North and Central America and the West Indies. Ph.D. dissertation, Washington University; St. Louis, Missouri.

Small, J.K. 1905. Additions to the flora of subtropical Florida. Bulletin of the New York Botanical Garden 3:419-440.

Small, J.K. 1933. Manual of the southeastern flora. University of North Carolina Press; Chapel Hill, North Carolina.

U.S. Fish and Wildlife Service [FWS]. 1995. Draft recovery plan for beach jacquemontia (*Jacquemontia reclinata*). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Recovery for the Beach Jacquemontia

Jacquemontia reclinata House

Recovery Objective: **RECLASSIFY** to threatened.

Recovery Criteria

Jacquemontia reclinata may be considered for reclassification from endangered to threatened when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations and sites needed to ensure 20 to 90 percent probability of persistence for 100 years; when these sites, within the historic range of *J. reclinata*, are adequately protected from further habitat loss, degradation, and fragmentation; when these sites are managed to maintain the coastal strand to support *J. reclinata*; and when monitoring programs demonstrate that populations of *J. reclinata* on these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species.

Jacquemontia reclinata may be considered for delisting when there is an adequate number of geographically distinct, self-sustaining populations throughout its historic range to ensure 95 percent probability of persistence for 100 years. The recovery identifies management recommendations, such as translocations, that are necessary to accomplish this objective. Additional criteria for delisting will need to ensure persistence of the species for 100 or more years, and will be defined once this species is reclassified.

Species-level Recovery Actions

S1. Determine the distribution of beach jacquemontia.

S1.1. Conduct surveys in areas where beach jacquemontia is known to exist to determine the status of known populations.

S1.2. Survey for additional natural populations in Palm Beach, Broward, and Dade counties. Locate search sites by using historical aerial photos to determine the original extent and location of potential *Jacquemontia reclinata* habitat in combination with overlays of maps showing existing land use.

S1.3. Maintain distribution data in GIS database. Maintaining distribution data for *J. reclinata* in a GIS database will provide information on the status and trends of the species over time.

S2. Protect and enhance existing populations.

S2.1. Protect any existing populations on private land through acquisition, conservation easements, or agreements with landowners. All but one of the currently known populations are located on public land in public parks or recreation areas operated by State, county, or local governments. Additional populations located by surveys on private land should be protected through acquisition, conservation easements or agreements.

S2.2. Inform State, county, and city agencies of natural populations of *Jacquemontia reclinata* on public lands and provide information on conservation methods and management practices for these populations. Some of the larger populations may be stabilized by appropriate habitat conservation measures. Smaller isolated populations may need to be augmented with greenhouse-raised seedlings.

S2.3. (Re)establish *Jacquemontia reclinata* where appropriate.

S2.3.1. Establish protocols for restoration of *Jacquemontia reclinata*, including maintaining records for source plants, developing techniques for establishing new populations, and establishing methodology for monitoring newly established plants.

S2.3.2. Locate potential (re)introduction sites within the historic range on protected lands, including public land and conservation easements on private land.

S2.3.3. (Re)introduce plants to protected sites using plants under cultivation. Before reintroductions begin, site-specific ecological data must be gathered to determine within-site reasons for *Jacquemontia reclinata's* decline so that effective site-specific management can be implemented.

S2.3.4. Re-establish plants as part of dune restoration efforts. *Jacquemontia reclinata* should be used along with other native vegetation as part of dune restoration projects in areas of suitable habitat within its historic range.

S2.4. Continue *ex situ* conservation as a means of preserving genetic diversity, preventing loss of the species, and determining ecological characteristics and habitat management needs. The ultimate goal is to restore *Jacquemontia reclinata* to self-sustaining populations in a functioning ecosystem.

S2.4.1. Send seeds to the seed bank at the U.S. Department of Agriculture Forest Service Northern Plains Area National Seed Storage Laboratory in Fort Collins, Colorado. These should be a genetically representative sample of the remaining natural populations of *Jacquemontia reclinata.* This is best achieved by including samples from all remaining populations.

S2.4.2. Continue propagation and development of successful horticultural methods that have been initiated by Fairchild Tropical Garden in Miami, Florida. Fairchild has germinated wild-gathered seed and maintained plants of *Jacquemontia reclinata* for more than 5 years. The plants have flowered and borne fruit. Greenhouse-raised seedlings have been transplanted successfully to the field. Successful propagation of this species from stem cuttings has also been achieved at Fairchild.

S2.4.3. Establish and maintain an *ex situ* collection to prevent loss of natural populations and diversity due to natural disasters, habitat destruction, unfavorable management practices, or failure of long-term viability of stored seeds. Collection of seeds and cuttings from each wild population of *Jacquemontia reclinata* should adhere to the guidelines established by the Science Advisory Council of the Center for Plant Conservation (CPC). The collection should be managed to represent and maintain the genetic integrity of each natural population. This collection will provide a source for restocking natural populations and establishing new populations in appropriate habitat within the historical range of *J. reclinata.* The FWS has provided some initial funding to Fairchild Tropical Garden for this purpose. Additional funding should be made available for development and maintenance of this *ex situ* collection.

S2.5. Enforce available protective measures. Employ local, State, and Federal regulations to protect *Jacquemontia reclinata* from overcollection, and to protect maritime hammock and coastal strand vegetation where *J. reclinata* is found.

S2.5.1. Initiate section 7 consultation when applicable. Section 7 of the ESA applies to Federal activities which might affect listed species. Few consultations are anticipated. Consultations concerning beach renourishment projects may occur; however, strategies to avoid and minimize impacts to *Jacquemontia reclinata* populations would most likely be possible.

S2.5.2. Enforce take and trade prohibitions. *Jacquemontia reclinata is* protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from land owned by the Federal government; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by Florida rules regulating removal of plants from State lands. Violation of these State prohibitions (including Florida criminal trespass law) is also a violation of the ESA.

S3. Conduct research on life history characteristics and requirements for reproduction.

S3.1. Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *Jacquemontia reclinata*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring will provide information on the localities of *Jacquemontia reclinata* sites, and on the factors contributing to any declines at each site. Site-specific management guidelines should be provided to land managers.

S3.4. Determine response to habitat changes and management manipulations based on site-specific research and monitoring. Recent work by Fairchild Tropical Garden at Crandon Park suggests that *Jacquemontia reclinata* seed germination is being suppressed. Field experiments should demonstrate whether adult plants released from St. Augustine grass competition will begin to reproduce and whether seeds planted in moist microsites free of St. Augustine grass and exotic species competition will germinate at high rates. Rebuilding depleted populations from greenhouse-raised seedlings also should be field tested.

S3.5. Develop a quantitative description of the population structure of *Jacquemontia reclinata.* This description will provide a baseline for monitoring population dynamics in response to natural environmental change and management treatments. The position of each individual plant in each surviving population should be located by triangulation from permanent stakes and each plant identified with coded metal tags. Data recorded should include stage class (seed, pre-establishment seedling, established seedling, juvenile, adult, reproducing adult), size, morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, soil organic content, soil sample analysis, distance from strand line, and position on dune profile) should also be collected.

S3.6. Conduct population viability and risk assessment analyses to determine the numbers of *Jacquemontia reclinata* plants, sites, and populations needed to ensure persistence of the species for 100 years into the future.

S4. Monitor populations of *Jacquemontia reclinata.*

S4.1. Map and monitor natural populations to maintain an inventory of naturally reproducing populations and help determine habitat characteristics and natural environmental changes affecting *Jacquemontia reclinata* survival.

S4.1.1. Develop a monitoring protocol to assess population trends.

S4.1.2. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival, and mortality. Also monitor for pollinators, herbivory, disease, and injury.

S4.1.3. Monitor the effects of land management activities. Assess any changes in demographic characteristics as in **4.1.2.** in response to land management activities such as exotic plant control.

S4.1.4. Monitor introduced plants for survival, productivity, and growth to compare with data from natural populations.

S4.2. Assess management requirements. Determine which natural populations can be stabilized and increased by habitat management and which populations need to be augmented, either from other natural populations or from the *ex situ* collection. Monitoring and research should yield detailed habitat maps of all *Jacquemontia reclinata* sites, maps of tagged individuals, and analyses of within-site factors involved in *J. reclinata* decline at each site to be made available to site managers. Site-specific management guidelines based on research should be provided to site managers.

S5. Provide public awareness about additional threats to *Jacquemontia reclinata*. The public needs to be made aware that Federal and State regulation of endangered plants does not address the horticultural use of *Jacquemontia reclinata,* and that ornamental use of endangered plants can threaten the genetic integrity of natural populations. This concern has led to suggestions that endangered species should not be commercially available, or that records should be kept of sources and out-planting locations for horticultural projects, just as for conservation projects, so that introductions and resulting population dynamics can be reconstructed. The goal of the recovery process is to restore listed species to a point where they are secure, self-sustaining components of their ecosystem and can be delisted. Commercial production and horticultural use of an endangered species on private land would contribute little to that goal.

S6. Refine delisting criteria once reclassification is achieved, and adequate research and monitoring data are available to develop these criteria.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat.

H1.1. Prevent direct destruction of habitat.

H1.1.1. Construction of roads, parking lots, buildings, and other structures should be set back behind primary dunes and outside of *Jacquemontia reclinata* habitat.

H1.1.2. Prevent or eliminate human access to dunes. Provide dune crossovers (boardwalks) and signage at essential beach access points to avoid dune erosion and blowouts.

H1.1.3. Enforce regulations prohibiting use of motor or man-powered vehicles on beaches and dune habitat.

H1.2. Continue extirpation or control of exotic plant species, such as Australian pine, carrotwood, and Brazilian pepper, that have invaded and altered the remnants of South Florida's strand vegetation. Eliminating invasive vegetation would open up areas to *Jacquemontia reclinata,* which prefers disturbed and sunny areas. Dormant seeds in the soil may be one explanation of the apparent movement of this species from one disturbed area to another. Removal of exotics from known or potential *J. reclinata* habitats may stimulate the revival of nonproductive or apparently extirpated populations of *J. reclinata.*

H2. Restore beach dune habitat through dune building and stabilization projects. Include *Jacquemontia reclinata* with other native vegetation for dune restoration projects that are proposed within its historic range.

H3. Conduct habitat-level research projects. Study the response of *Jacquemontia reclinata* to various land management practices, such as prescribed fire regimes, vegetative thinning, and exotic vegetation control.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions (prescribed fire, exotic plant control) to assess the long-term response of *Jacquemontia reclinata*.

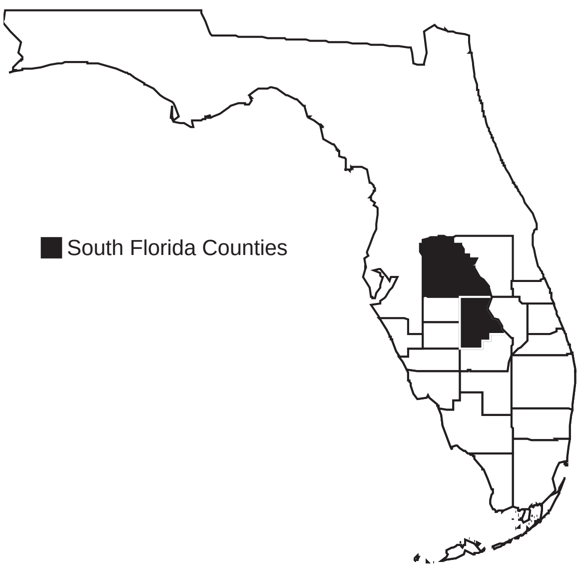
H5. Provide public information about coastal ecosystems. Public education is essential to develop a general understanding and support for protection and restoration efforts in threatened dunes, coastal strand, and maritime hammock ecosystems. Removal of exotic plant species and maintenance of open spaces are necessary management practices to facilitate the recovery of *Jacquemontia reclinata* and protect coastal ecosystems. Control and removal of vegetation on public lands is often misunderstood by the general public. Specific information on *J. reclinata* biology and management requirements can also be provided once these are defined. This information can be disseminated through signs, brochures, and displays in visitors centers on public lands and nature centers.

Scrub Blazing Star

Liatris ohlingerae (Blake) Robinson

Federal Status:	**Endangered (July 27, 1989)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of the scrub blazing star.



The scrub blazing star belongs to the aster family (Asteraceae) within a genus of perennial herbs that live in open, usually fire-maintained, habitats. Two species and one variety of *Liatris* are endemic to Florida; another species of *Liatris* is endemic to Florida and the Bahamas. The scrub blazing star was listed as an endangered species in 1989 due to habitat loss. The principal cause of decline of central Florida's upland vegetation is conversion of habitat for agricultural, commercial, residential, and recreational purposes.

This account represents a revision of the existing recovery plan for the scrub blazing star (FWS 1996).

Description

The scrub blazing star (*Liatris ohlingerae*) is a long-lived perennial herb having a thickened, cylindric root. Its stems are erect, usually unbranched, and it can grow up to 1 m tall. Its leaves are fleshy and narrow (1 to 2.5 mm), and generally 3 to 8 cm long (Wunderlin *et al*. 1980). Flower heads are well separated on the stem with individual disc flowers up to 1 cm broad; the inflorescences are up to 3 cm across. The corollas are bright purplish-pink in color. The broad flower heads and narrow leaves distinguish *L. ohlingerae* from the eight other *Liatris* species in central Florida.

Taxonomy

Blake (1923) placed *L. ohlingerae* in the blazing star genus, naming it *Lacinaria ohlingerae*. Small (1924) created a new genus for this plant, which became *Ammopursus ohlingeri*. Robinson (1934) reinstated the scrub blazing star in the large genus of the blazing stars as *Liatris ohlingerae.* Gaiser's (1946) treatment of *Liatris*, and Cronquist's (1980) floristic treatment of the aster family in the Southeast retains this plant in the genus *Liatris*, although Lakela (1964) argued in favor of reinstating *Ammopursus* as a genus containing only one species.

Distribution

Liatris ohlingerae is endemic to the Lake Wales Ridge in Highlands and Polk counties (Figure 1). During comprehensive surveys in the mid-1980s, the scrub blazing star was found at 93 localities, 71 of them in Highlands County (Christman 1988). The species' range extends from Lake Blue in Polk County (FWS 1996), south along the Lake Wales Ridge to Archbold Biological Station at the south end of the Ridge in Highlands County.

Habitat

The scrub blazing star is one of the endemic plants found in rosemary balds. It is also found along the ecotone between these balds and surrounding scrub habitats on white or (rarely) on yellow sands (Christman and Judd 1990). It can also be found scattered in surrounding scrub. Rosemary balds are a unique community type within the scrub ecosystem. They are represented by small "islands" separated from each other, often by considerable distances. These "islands" provide suitable habitat for a number of scrub endemics (Christman and Judd 1990) that have evolved within the well-drained, droughty, low-nutrient soils. These limiting habitat conditions have resulted in a vegetative complex whose above ground biomass is sparse and does not support frequent fires. Rosemary balds typically burn every 40 to 100 years (Johnson 1982, Myers 1990), while the surrounding scrubs burn more frequently. Fire may either burn a section of rosemary scrub or it may sweep through the entire bald (Herndon 1996). The ecotone between rosemary balds and surrounding scrub is a dynamic vegetative complex dependent on the frequency and intensity of fire.

Herndon (1996) found that *L. ohlingerae* has important microhabitat requirements, particularly its preference for shade. Unlike most other scrub endemics, *L. ohlingerae* appears to thrive in lightly shaded areas. Generally, *L. ohlingerae* is found in highest densities on the lower slopes of rosemary balds especially where low, thin-canopied scrub oaks (*Quercus chapmanii*, *Q. geminata*, and *Q. inopina*) or patches of palms (*Sabal etonia* and *Serenoa repens*) dominate the vegetation and where patches of open sand exist. These habitat conditions are also frequently found under individual sand pine (*Pinus clausa*) crowns, but never in dense groves of sand pines.

Over time, however, shady microhabitats are not fixed within rosemary balds. Large-scale disturbance such as intense fire may change the mosaic pattern of scrub vegetation and thus decrease the amount of shade in scrub habitat. Twenty-five percent of *L. ohlingerae* are found in open areas in direct sun while 25 percent are found along the edges of canopies in partial shade. Half of the plants are typically found under canopies of other rosemary bald vegetation.

Reproduction

Liatris ohlingerae requires cross-pollination to reproduce. Butterflies, especially skippers (Hesperiidae), are thought to be the primary pollinators, although other insects may also contribute to pollination (FWS 1996).

Scrub blazing star.
Original photograph by Betty Wargo; original flower photograph by Steve Shirah.

Flowering and fruiting in this species all more abundant in shaded microhabitats. Individuals in open and edge habitats only produce one-quarter as many mature flower heads (Herndon 1996). The seeds of this species are short-distance wind dispersers, with bristles and hairs that assist in "planting" the seeds correctly. Low germination on leaf litter-covered soil suggests that many seeds in shade (the favored microhabitat) may get trapped in the leaf litter and fail to sprout or die shortly after sprouting (Herndon 1996).

Herndon (1996) found that the number of buds on *L. ohlingerae* plants is highly variable from year to year, from site to site, and from plant to plant. His study revealed an overall germination rate of 21 to 62 percent and hypothesized that the difference could be attributed to climatic factors such as rainfall and temperature. However, the factor most affecting germination rates was not the environmental conditions or where the plants were located, but the soil conditions in the vicinity of the plant. Seeds on bare sand had a higher germination rate, 30 percent in contrast with 21 percent for all of the plots. Though no difference in germination rates were observed in relation to light intensity, survival of seedlings was greater in the shaded sites.

There seems to be a high survival rate among germinated seedlings. In Herndon's (1996) study, 11 of 18 naturally germinated seedlings survived until the end of the study. The juvenile stage lasted more than two growing seasons. After one growing season, most of the seedlings had one to two basal leaves (some had three). The leaves were less than 2 mm wide and lacked a prominent midrib. Many plants have been tagged for 5 years without signs of senescence; this plant's life span is likely measured in decades.

According to Herndon (1996), the growth of new basal leaves begins in March and the elongation of stems begins in April. Flowering and fruiting occurs from summer through fall. Flowering begins in May and June, but the peak occurs in August with a rapid decline toward the middle of September. The seeds start to disperse in August and peak in October. Each plant produces approximately eight filled (presumably viable) seeds a year. The plant's above ground parts die back in October to November or by the first freeze. *Liatis ohlingerae* can remain in a dormant state through at least one growing season.

The seedling growth rate for *L. ohlingerae* is slow compared to most other scrub endemics. Many others grow to reproductive maturity in only one season, while the juvenile stage for *L. ohlingerae* was found to be at least 2 years by Herndon (1996). Interestingly, cultivated *L. ohlingerae* mature to flowering in 8 months. Limited water and nutrients are believed to be responsible for the difference between wild populations and cultivated ones (Herndon 1996).

Relationship to Other Species

In contrast to other rosemary scrub endemics, *L. ohlingerae* prefers shade and is not as productive in sunny, open gaps. It occupies areas that would be too overgrown for other scrub endemics.

Some rosemary bald endemics, such as *Ceratiola ericoides*, (sand heath) produce chemicals that have allelopathic effects. *Liatris ohlingerae* probably is not affected by these chemicals, since it commonly grows under rosemary bushes (Herndon 1996). However, *L. ohlingerae* is missing from dense stands of *Ceratiola.* Herndon (1996) found the shade of dense stands of *C. ericoides* was more limiting than their allelopathic effects. However, single or widely spaced *C. ericoides* were not dense enough to preclude *L. ohlingerae* (Herndon 1996).

L. ohlingerae is restricted to the rosemary community and surrounding ecotones, while *L. laevigata* is found commonly in both rosemary balds and surrounding scrub. This indicates that the burn frequency may determine the habitat preference of these two species (Herndon 1996). *Liatris chapmanii* is distributed on roadsides at Archbold Biological Station in Highlands County, but it is not found in rosemary balds in this area. Both habitats appear to be similar in that they lack competing vegetation; however, the habitat selection of *L. ohlingerae* may be based on a favoritism for lightly shaded areas (Herndon 1996) on very well drained sands of ancient scrub.

Herndon (1996) also found that herbivory is a limiting factor for flower production, noting that flower-bearing vegetation would not be replaced if lost late in the season or if topped multiple times throughout the growing season. However, stems eaten early in the season will likely be replaced and produce flowers. An endemic grasshopper *(Melanoplus tequestae)* has been frequently observed on *L. ohlingerae* and may be an important herbivore. White-tailed deer (*Odocoileus virginianus*) and eastern cottontail (*Sylvilagus floridanus*) are also suspected of grazing on *L. ohlingerae*.

In addition to losses due to herbivory, 30 percent of all buds are destroyed by borers. The smaller buds are destroyed by an excavator that consumes the ovaries. On larger buds, a lepidopteran borer is responsible for entering the bud at an unknown stage and consuming the ovaries. These buds reach mature size, but fail to open. Overall, 42 percent of buds failed to reach maturity. Of those, 30 percent was due to herbivory and the remaining 12 percent had an unknown cause. Herndon (1996) noticed that herbivory rates vary with microclimate. In open areas stems are lost more frequently to herbivory (54 percent of the buds were lost, compared to 42 percent in the shaded microhabitats).

Status and Trends

Liatris ohlingerae was listed as endangered on July 27, 1989, due to rapid habitat loss associated with land clearing for agricultural, residential, and commercial purposes (54 FR 31190). Most remaining scrub habitat continues to be degraded due to fire suppression.

It has been estimated that Florida's scrub habitat has been reduced between 60 and 75 percent since settlement of the region. The most recent evaluations of scrub in central Florida indicate that only about 11,000 ha remain. Much of that scrub habitat is fragmented and has become overgrown due to fire suppression (Christman 1988, Christman and Judd 1990). In Highlands County, it was estimated that about 74 percent of scrub habitat had been lost by 1981. Because rosemary balds are typically higher and potentially more attractive for human uses than the surrounding landscape, it is possible that these sites may have sustained greater loss than other central Florida ridge communities.

Although *L. ohlingerae* was reported from 93 scrub sites in the late 1980s, the number of individuals within these sites may have been underestimated. Herndon (1996) suggested that it is difficult to survey *L. ohlingerae* with accuracy because the species is cryptic when not in bloom; it has a tendency to live nestled among other species. Topped individuals may be overlooked during flowering, and a proportion of individuals are not active in a given season. Even with inaccurate surveys, Herndon (1996) believed the population stable with no evidence of immediate decline. He reached this conclusion because the mortality of adult plants is low and the species can withstand moderate habitat succession without declining.

The scrub blazing star may have been extirpated from at least one site; it has not been seen at the Tiger Creek Preserve since 1992 (FWS 1996). Since regular monitoring plans are not in place, it is possible that other localized extirpations have occurred. Aside from the obvious adverse effects occurring from the direct loss of habitat, a multitude of other factors resulting from habitat fragmentation and fire exclusion may be acting individually or synergistically to reduce the viability of scrub endemics, including *L. ohlingerae*.

Though mortality of *Liatris ohlingerae* appears to be low, recruitment and colonization rates are severely limited, as indicated by the number of seedlings in the vicinity of adult plants. *L. ohlingerae* occurs sparsely over the landscape and is highly clumped within rosemary balds. Connectivity between the islands of habitat is very important to this species due to its cross-pollination needs. Lack of connectivity or loss of pollinators may be responsible for loss of *L. ohlingerae* at some isolated sites.

The genus *Liatris*, especially *L. spicata*, is economically important as a source of garden perennials and cut flowers. Though easily grown from seed, there is no widespread demand for *L. ohlingerae* in the horticultural trade (54 FR 31190), even though it may be taken opportunistically.

Litris ohlingerae is or soon will be protected at a number of public and private scrub sites, including The Nature Conservancy's Saddle Blanket Lakes, Tiger Creek, Lake Apthorpe Preserves and Archbold Biological Station. The species is or will be protected within State-owned lands including the Catfish

Creek site; Lake Arbuckle tract of the Lake Wales Ridge SF; Highlands Hammock SP, Gould Road, and Holmes Avenue acquisitions. The FWS has protected several *L. ohlingerae* sites through establishment of the Lake Wales Ridge NWR. This species is represented in the Center for Plant Conservation's National Collection at Bok Tower Gardens and in long-term seed storage at Fort Collins, Colorado.

Management

Liatris ohlingerae occurs as individual plants or scattered individuals on rosemary balds and ecotones adjacent to rosemary balds. Effective management of rosemary balds and adjacent ecotones will require long-term protection, development and implementation of appropriate fire regimes. Though dependent on site-specific characteristics, we know generally that rosemary balds should burn every 40 to 60 years, while oak scrub should burn every 15 to 20 years. Under natural conditions, we expect oak scrub to burn up to and occasionally into rosemary balds. Over time, however, unburned rosemary balds develop canopies that are dense enough to support fire. While we have a basic understanding of the management requirements for rosemary balds and oak scrub, we know little of the requirements for rosemary bald-oak scrub ecotones. However, appropriate management of ecotone habitats will probably be achieved as we gain a better understanding of the management requirements for surrounding rosemary bald and oak scrub communities. Because ecotones are dynamic areas with vegetative mosaics that change over time depending on fire frequency and intensity and other natural stochastic events, it is unlikely that specific management prescriptions can be developed independently of surrounding scrub habitats. The habitat requirements of *L. ohlingerae* suggest that it prefers a burn frequency shorter than that of the rosemary bald but longer than the surrounding oak scrub.

Liatris ohlingerae is not abundant in rosemary balds because early seral stages do not provide sufficient shade. Following devastating fires, rosemary bald endemics generally recover via the seed bank (Menges and Kohfeldt 1995). Several years are then required to replace shade-bearing vegetation. For example, limited shade may be afforded to the scrub blazing star by *Ceratiola* or *Pinus clausa*. Mature individuals of these species may be killed by fire and must then recover from seedlings. The temporal lag of little or no shade is not suitable for the re-establishment of *L. ohlingerae*.

Vegetation occurring on the ecotone of rosemary balds and surrounding scrub reacts differently to fire events. These species typically respond to ground-clearing fires by re-sprouting (Menges and Kohfeldt 1995). Re-sprouting results in the re-establishment of shade-bearing vegetation within one to several years. *Liatris ohlingerae* may become re-established more rapidly under these conditions (Abrahamson 1984).

Whether a substantial number of adult *L. ohlingerae* plants are killed by a fire event is an important question that cannot yet be answered. We believe that recently burned areas may suffer more herbivory and produce fewer viable seeds than unburned areas. However, unless fire directly kills plants, these effects would not lead to a large change in the population. Herndon (1996) estimates that the rosemary bald slopes examined in his study have been burned about every 20 years.

To assess the response of *L. ohlingerae* to land management practices effectively, and to more accurately quantify the *L. ohlingerae* population, Herndon (1996) recommends that five sites with tagged individuals (approximately 200 individuals each) be surveyed and regularly monitored. Changes in mortality rate are critical to any monitoring effort, and may require excavation and inspection of the taproot to verify mortality. If excavation is not possible, the mortality should not be assumed as many plants simply are not active during some years. Mortality can be assumed if individual plants are inactive for three consecutive years.

Additional information is needed on the effects of fire and other episodic events on the survival of this species. Though mortality appears to be low once plants are established, recruitment of juveniles is limited. Information on the genetic diversity and genetic viability of this species needs to be investigated. If a population is found to be excessively uniform, population augmentation may be considered.

Literature Cited

Abrahamson, W. G. 1984. Species responses to fire on the Florida Lake Wales Ridge. American Journal of Botany. 71:9-21.

Blake, S. F. 1923. Two new composites from Florida. Bulletin of the Torrey Botanical Club. 50:203-205.

Christman, S. P. 1988. Endemism and Florida interior sand pine scrub. Final report for contract no. GFC-84-11, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Christman, S. P. and W. S. Judd. 1990. Notes on plants endemic to Florida scrub. Florida Scientist 53(1):52-73.

Conquist, A. 1980. Vascular flora of the southeastern United States, vol. I : Asteraceae. University of North Carolina Press; Chapel Hill, North Carolina.

Herndon, A. 1996. Life history of *Liatris ohlingerae* (Asteraceae), an endangered plant endemic to the Lake Wales Ridge, Florida. Final report, project number NG91-016, Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Gaiser, L. O. 1946. The genus *Liatris*. Rhodora 48:165, 216, 273, 331, 393.

Johnson, A. 1982. Some demographic characteristics of the Florida rosemary *Ceratiola ericoides* Michx. American Midland Naturalist 10:170-174.

Lakela, O. 1964. Systematic status of *Ammopursus ohlingerae* (Compositae). Sida 1:240-247.

Menges, E.S. and N. Kohfeldt. 1995. Life history strategies of Florida scrub plants in relation to fire. Bulletin of the Torrey Botanical Club 122:282-297.

Myers, R.L. 1990. Scrub and high pine. Pages 150-193 *in*: R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

Robinson, B.L. 1934. Records preliminary to the general treatment of the Eupatoriaceae XI. Contributions to the Grey Herbarium 104:3-49.

Small, J.K. 1924. Plant novelties from Florida. Bulletin of the Torrey Botanical Club 51:379-393.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery plan for nineteen central Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Wunderlin, R. P., D. Richardson, and B. Hansen. 1980. Status report on *Liatris ohlingerae*. U.S. Fish and Wildlife Service; Jacksonville, Florida.

Recovery for the Scrub Blazing Star

Liatris ohlingerae (Blake) Robinson

Recovery Objective: **RECLASSIFY** to threatened.

Recovery Criteria

Liatris ohlingerae may be reclassified from endangered to threatened when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations and sites needed to assure 20 to 90 percent probability of persistence for 100 years; when these sites, within the historic range of *L. ohlingerae*, are adequately protected from further habitat loss, degradation, and fragmentation; when these sites are managed to maintain the rosemary bald of the xeric oak scrub community to support *L. ohlingerae*; and when monitoring programs demonstrate that these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *L. ohlingerae*. This species is difficult to survey. It is easily overlooked when not in bloom and does not grow in the typical open gaps of scrub. A thorough survey is needed to determine the distribution for this species. Survey efforts should be focused from August through October.

S1.1. Conduct surveys for additional populations of *L. ohlingerae*.

S1.1.1. Continue surveys in Polk and Highlands counties. Although the Lake Wales Ridge has been well surveyed, new sites may still be found.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are acquired.

S1.2. Maintain distribution of known populations and suitable habitat in a GIS database. Use the database to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection.

S2.1. Protect populations on private land through acquisition, conservation easements, or agreements with landowners.

S2.2. Protect populations on public lands. Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. Continue *ex situ* conservation. *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of a species. These collections will be instrumental in the recovery of *L. ohlingerae*.

S2.3.1. Conserve germ plasm. The seed of this species is not presently in long-term storage.

S2.3.2. Maintain *ex situ* collection. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *L. ohlingerae* as part of the National Collection.

S2.4. Enforce available protective measures. Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *L. ohlingerae* is found.

S2.4.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.4.2. Enforce take and trade prohibitions. This species is protected by take provisions of the ESA Act (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. Conduct research on life history characteristics. Though recent work has greatly increased the base of knowledge for this species, more work on its basic biology and ecology is necessary for effective recovery.

S3.1. Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, dormancy, survival, and mortality.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. **Conduct research to assess management requirements of *L. ohlingerae*.** Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring will provide information on the factors which contribute to population declines. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S4. **Monitor existing populations of *L. ohlingerae*.**

S4.1. **Develop monitoring protocol to assess population trends for *L. ohlingerae*.** Since recruitment may be uncommon, the lifespan of adult plants is a key parameter.

S4.1.1. **Monitor to detect changes in demographic characteristics, such as reproduction, seed dormancy, germination, recruitment, growth, dispersal, survival, and mortality**. Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. **Monitor the effects of various land management actions on *L. ohlingerae*.** Assess any changes in demographic characteristics of *L. ohlingerae* in response to land management activities, such as prescribed fire, exotic plant control, *etc*.

S4.2. **Develop a quantitative description of the population structure of *L. ohlingerae*.** This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) should also be included.

S5. **Provide public information about *L. ohlingerae*.** It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. Care is needed, though, to avoid revealing specific location information.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *L. ohlingerae* and other rare species requires a self-sustaining, secure, number of natural populations.

S6. **Develop delisting criteria.** Once reclassification is achieved, research and monitoring results may provide data necessary to develop delisting criteria.

Habitat-level Recovery Actions

H1. **Prevent degradation of existing habitat.** Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there are nine sites that are either protected or proposed for acquisition.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. Little xeric scrub habitat remains for this species; any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *L. ohlingerae* populations by preventing habitat damage from off-road vehicle use, and overcollection, and by providing prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval of frequency and seasonality is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To replicate this landscape pattern, sites should be burned in a mosaic when possible. This species is probably resilient to a range of fire regimes.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of this species.

H1.2.3. Control access to areas where listed plants are growing. Collection, trampling, and off-road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore a natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites, a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *L. ohlingerae* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc*., on the habitats where *L. ohlingerae* occurs.

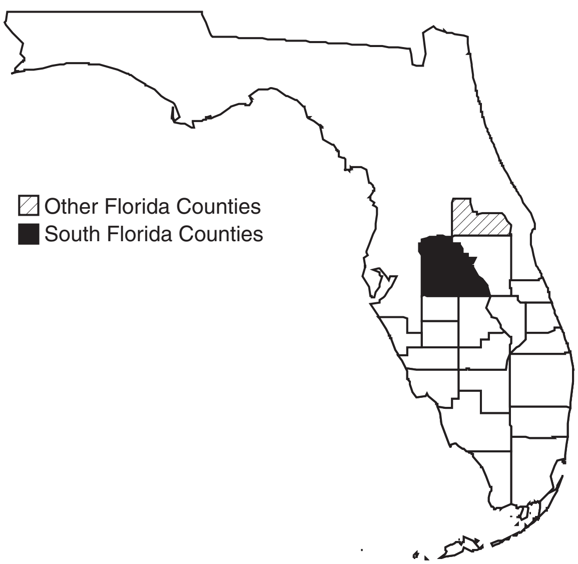
H5. Provide public information about scrub and its unique biota. Educational programs, especially those conducted by Archbold Biological Station, have been successful. Without these efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing programs by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the SFWMD, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Scrub Lupine

Lupinus aridorum (McFarlin ex Beckner) Isley

Federal Status:	**Endangered (April 7, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. County distribution of scrub lupine.



Lupinus aridorum is an herb endemic to Orange and Polk counties, Florida. The species is unusual among central Florida scrub plants because it is absent from the Lake Wales Ridge. Like many other scrub species, however, it is threatened by loss of habitat due to land conversion for agriculture and residential construction. Habitat protection and management on public lands and acquisition of unprotected sites are important for the survival of this species in the wild.

This account represents South Florida's contribution to the existing recovery plan for the scrub lupine (FWS 1996).

Description

Lupinus aridorum is a woody, perennial herb, with sprawling stems up to 1 m long. The leaves are obovate-elliptic, 4 to 7 cm long and 2 to 4 cm wide. The base and end of the leaf are rounded with a sharp point at the leaf's end. The petioles are 2.0 to 4.5 cm long and the stipules are very small or absent. A silvery pubescence covers the leaves and stems. The flowers are a pale flesh-colored pink and are 4 to 5 cm long. The upper petal (standard) has a black center surrounded by a maroon area. They are arranged in racemes with stalks 4 to 13 cm long. Each raceme has 5 to 14 flowers, but up to 25 on occasion (Stout *in press*). *Lupinus aridorum* fruits are long, woody, and elliptical with a pointed end. It is differentiated from *L. villosus*, the only other pink flowering lupine, in that *L. aridorum* is not prostrate, has hairs on the leaves and stem, and is the only upright pink-flowering lupine in Florida.

Taxonomy

Until being named *L. aridorum* in 1982, this taxon was identified as *L. diffusus* and *L. westianus* (52 FR 11172). Isley (1986, 1990) evaluated the systematics of *L. aridorum* in his floristic treatment of the pea family (Fabaceae) in the Southeast and concluded that *L. aridorum* belongs to the same species as *L. westianus* of the Gulf Coast of northwest

Florida, which differs mainly in flower color (blue). Isley's taxonomic status for the central Florida plant is *L. westianus* var. *aridorum* (McFarlin ex Beckner) Isley. However, the former classification *L. aridorum* was used to list the species (52 FR 11172), and will be used here to maintain consistency.

Distribution

The scrub lupine was first collected in 1900 in Orange County, Florida. It was not collected again until it was found in Polk County in 1928 and 1937. Renewed survey efforts in the early 1970s and the early 1980s greatly expanded the knowledge of the species distribution in both Orange and Polk counties (Figure 1).

Scrub lupine is now known from two distinct areas. In western Orange County (Orlando area) it is found on the southern Mount Dora Ridge from the Apopka-Plymouth area south, past Lake Buena Vista. In South Florida it is found in north-central Polk County on the Winter Haven Ridge near Auburndale and Winter Haven.

Habitat

The scrub lupine grows primarily on well-drained sandy soils of the Lakewood or St. Lucie series (Wunderlin 1984). These soils are very dry and have very little organic accumulation (Lowe *et al*. 1990). The sands are white or occasionally yellow and generally support sand pine scrub (Wunderlin 1984). They are also quite acidic with a pH from 4.0 to 4.5 (J. Stout, University of Central Florida, personal communication 1996).

The natural habitat for *L. aridorum* is believed to be sand pine and rosemary scrub (J. Stout, University of Central Florida, personal communication 1996). Scrub lupine probably existed in sunny gaps until succession of the scrub resulted in excessive shading and closure of open, sunny patches. After long periods without disturbance, gap specialists usually become less common in scrub communities. Regrowth of *L. aridorum* after fire or other disturbances occurs from seedbanks stored in the sand.

Most of the sites where *L. aridorum* is now found are moderately to severely disturbed by soil scraping, road construction, land clearing, or off-road vehicles (Stout *in press*). With these disturbances and associated vegetative responses, it is difficult to determine what the "natural" vegetative cover may have been. However, Wunderlin (1984) found the predominant overstory for this species to be sand pine (*Pinus clausa*), longleaf pine (*Pinus palustris*), and occasionally turkey oak (*Quercus laevis*). The shrub layer tends to be sparse at *L. aridorum* sites; however this may be a result of manmade disturbances to the soil. Shrub species most frequently found in association with *L. aridorum* include rosemary (*Ceratiola ericoides*), scrub live oak (*Quercus geminata*), rusty lyonia (*Lyonia ferruginea*), *Palafoxia feayi*, tallowwood (*Ximenia americana*), and an occasional cabbage palm (*Sabal palmetto*). The herbaceous layer is mostly wiregrass (*Aristida beyrichiana*).

Scrub lupine.
Original photograph by Steve Shirah; original flower photograph by R. Wunderlin.

Reproduction

The scrub lupine has been found in bloom between March and May. The seed pods mature by June, and the seeds fall off the plant and take root nearby or remain in a long-lived seedbank (T. Race, Bok Tower Gardens, personal communication 1996, J. Stout, University of Central Florida, personal communication 1996). Recent information indicates the plant may bloom from one to three times throughout its life, though few seeds are produced the first year (J. Stout, University of Central Florida, personal communication 1996). Pollinators of this species are unknown.

Relationship to Other Species

The scrub lupine is found in open disturbed areas in sand pine and rosemary scrub communities of central Florida. Other federally listed species found in association with *L. aridorum* are Florida bonamia (*Bonamia grandiflora*), papery whitlow-wort (*Paronychia chartacea*), sandlace (*Polygonella rnyriophylla*), and scrub plum (*Prunus geniculata*) (52 FR 11172). The scrub lupine will not grow near rosemary (*Ceratiola ericoides*) because of rosemary's allelopathic effects J. Stout, University of Central Florida, personal communication 1996).

Status and Trends

Like many other Florida scrub endemics, *L. aridorum* has suffered from habitat loss due to urban and agricultural expansion. Currently, most of the estimated 1,000 individuals of this species occur in habitats that have already been highly-modified or are threatened by future land clearing for residential housing; road construction and maintenance; pedestrian, horse, and off-road vehicles; and conversion to pasture land. Throughout much of its range, the scrub lupine is afforded little protection; it occurs on fewer than 2 ha of public land (excluding road rights-of-ways) (Stout *in press*). The limited distribution of *L. aridorum* makes it especially vulnerable to loss of habitat. As a result of these threats, this species was federally listed as an endangered species on April 7, 1987 (52 FR 11172).

In South Florida, only six sites are inhabited by *L. aridorum.* They are in Polk County, near Winter Haven and Auburndale. The sites near Auburndale are threatened by land clearing to support a rapidly growing human population. Presently only small tracts of scrub remain among expanses of residential development. Polk County sites total only about 380 ha (Christman 1988). Although they are not in South Florida, the status of the 10 sites inhabited by *L. aridorum* in Orange County are important to evaluate the pressures on this species. All 10 sites are between the City of Orlando and Walt Disney World. Orlando has been, and continues to be, one of the most rapidly growing cities in Florida. The portion of the species' range in western Orange County is largely urbanized, with many of the remaining sites composed of small remnants of the original scrub, including vacant residential lots and the right-of-ways of the Florida Turnpike. These are also rapidly expanding communities whose human population growth threatens the continued existence of *L. aridorum*.

Although the species is not abundant or well-distributed, the seeds of *L. aridorum* may be numerous in many locations in which it historically grew. This species may persist only in the form of a seed bank in many heavily vegetated scrubs (J. Stout, University of Central Florida, personal communication 1996). In most known localities, *L. aridorum* grows aggressively following soil disturbance, because of the open patches of bare sand resulting from these disturbances. Since fire and other sources of disturbance have been excluded from many scrub sites, succession and the subsequent growth of other scrub vegetation probably have out-competed *L. aridorum* in many historic localities. Even though seed sources may be available in many of these locations, vegetative surveys rarely locate seeds, and these potential sources of plants are overlooked and rarely considered when reviewing areas for acquisition or protection needs.

The scrub lupine is short-lived and declines after flowering (Beckner 1982, J. Stout, University of Central Florida, personal communication 1996). This reproductive cycle, combined with the susceptibility of the plant to root rot both in the wild and when cultivated, limits conservation options (FWS 1996). Furthermore, the species does not transplant well, even when very young (FWS 1996), but it can be propagated from seed sown *in situ*. The same characteristics that make conservation of this species difficult, make it unprofitable in the horticultural trade. However, collection of the plants' showy, pink flowers may be a potential problem in some areas.

Management

The small number of sites from which the scrub lupine is known make it particularly vulnerable to disturbance, habitat degradation, and natural disasters. The scrub lupine is known only from early successional stages of sand pine scrub, indicating that it is intolerant of competition. It is apparent that management actions must provide for open, early successional patches of habitat in sand pine scrub in order for this species to persist. Natural sand pine scrub historically was subjected to intense, infrequent burns roughly every 30 to 80 years. Unfortunately, many of the sites now occupied by *L. aridorum* occur in human-disturbed sites from which fire has been excluded and, therefore, cannot readily be managed by fire. These sites lack enough ground level fuel to carry fire or are in the vicinity of residential areas where fire management would be difficult. Although we believe fire would be an important management tool, we have no examples of the effects of fire on *L. aridorum* (Stout *in press*).

The scrub lupine would probably benefit from fire or mechanical clearing because these activities would reduce competition by creating areas of bare sand and sunny open patches favored by this species. Based on our rudimentary knowledge of the fire dynamics of scrub vegetation, we believe that the most appropriate prescribed burning schedules for this species will be those that eliminate woody plant competition, but not frequent enough to impair the fire sensitive scrub lupine. In situations where use of prescribed fire is not possible, mechanical clearing (primarily mowing) of overgrowth may be suitable to manage for scrub lupine. Mechanical clearing can probably be used more frequently than fire since this technique is less likely to disturb herbs, forbs and low-growing shrubs, including the scrub lupine.

In addition to implementation of the management techniques described above, we believe that introduction of *L. aridorum* into suitable but unoccupied habitat will be required to ensure recovery of this species. Since scrub lupine is susceptible to root rot and does not transplant well, we suggest that population augmentation include only direct sowing of seed at suitable sites. In some cases, augmentation may only require that naturally occurring stored seeds be disturbed in order to stimulate germination (I. J. Stout, University of Central Florida, personal communication 1996).

Literature Cited

Anonymous. 1990. Scrub lupine. Pages 265-266 *in* D. Lowe, J. Matthews, C. Moseley, eds. The official World Wildlife Fund guide to endangered species of North America, vol. 1. Beacham Publishing, Incorporated; Washington D.C.

Beckner, J. 1982. *Lupinus aridorum* J.B. McFarlin ex Beckner (Fabaceae), 2 new species from central Florida. Phytologia 50:209-211.

Christman, S. P. 1988. Endemism and Florida's interior sand pine scrub. Final report to Florida Game and Fresh Water Fish Commission, contract no. GFC-84-101; Tallahassee, Florida.

Isley, D. 1986. Notes on Leguminosae: Papilionoideae of the southeastern United States. Brittonia 38:352-359.

Isley, D. 1990. Vascular flora of the southeastern United States, vol. 3, part 2. Leguminosae (Fabaceae). University of North Carolina Press; Chapel Hill, North Carolina.

Stout, I.J. and J.F. Charba. 1992. Conservation biology of scrub lupine. Research proposal presented to Fish and Wildlife Service; Jacksonville, Florida.

Stout, I.J. In press. Scrub lupine (*Lupinus aridorum*) (McFarlin ex Beckner) Isley. Manuscript submitted to the Florida Committee on Rare and Endangered Plants and Animals, second edition, plant volume. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida.

Stout, I.J. 1996. Telephone conversation. 9 October, 1996.

Stout, I.J. 1997. Telephone conversation. 10 January, 1997.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery plan for nineteen central Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Race, T. Letter. 27 February, 1996.

Wunderlin, R.P. 1984. Endangered and threatened plant survey, *Lupinus aridorum*. Unpublished status report prepared under contract no. 14-16-0004-82-013. U.S. Fish and Wildlife Service; Jacksonville, Florida.

Recovery for the Scrub Lupine

Lupinus aridorum (McFarlin ex Beckner) Isley

Recovery Objective: PREVENT EXTINCTION, then stabilize.

South Florida Contribution: PREVENT EXTINCTION, then stabilize.

Recovery Criteria

The scrub lupine may never reach a level at which reclassification could be possible. The objective of this recovery plan is to contribute toward increasing existing populations and preventing extinction. This species may be considered stabilized when existing populations, within the historic range, are adequately protected from further habitat loss, degradation, and exotic plant invasion. These sites must also be managed to maintain openings to support *L. aridorum*.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *L. aridorum*. This species has an extremely restricted range. In South Florida, it is found only in northern Polk County off the Lake Wales Ridge. This species is found in a fast growing urbanizing area and essentially all of its habitat has been converted from the natural state.

S1.1. Conduct surveys for additional populations of *L. aridorum*.

S1.1.1. Survey scrub habitat in scrub communities having the Lakewood or St. Lucie soil series. This is the only listed scrub endemic that does not occur on the Lake Wales Ridge. Adequate survey work has not been conducted off the Lake Wales Ridge; therefore, occupied sites for this species may exist. Areas with new disturbance or road sides may reveal a hidden seedbank.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are acquired.

S1.2. Maintain distribution of known populations and suitable habitat in a geographic information system database. Use the database to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. Protect habitat through acquisition, conservation easements, or agreements with landowners.

S2.2. Protect populations on public lands. Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. Use local or regional planning to protect habitat. Utilize available regional and county planning processes to encourage protection of suitable, unoccupied, and occupied habitat of *L. aridorum*.

S2.4. Continue *ex situ* conservation. *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs. These collections will be instrumental in the recovery of *L. aridorum*.

S2.4.1. Conserve germ plasm. The seed for this species is not presently in long- term storage.

S2.4.2. Obtain an *ex situ* collection. Disease makes an *ex situ* population for this species very difficult. However, plans for such a population should not be discarded because the information received from a cultivated population is often valuable to the recovery of listed species.

S2.5. Develop protocol for evaluating reintroduction sites and methodology for introducing this species. (Re)introduction for this species may be necessary for its continued survival. It grows readily from seed and may already be present in certain overgrown scrub sites in the form of a seed bank.

S2.6. Enforce available protective measures. Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *L. aridorum* is present.

S2.6.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.6.2. Enforce take and trade prohibitions. This species is protected by take provisions of the Endangered Species Act (including prohibitions against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from state lands.

S3. Conduct research on life history characteristics of *L. aridorum*. Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as number of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality. These kinds of data exist from one site in western Orange County. A second population near Winter Haven is now under study.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis. These analyses will determine the numbers of plants, sites, and subpopulations/populations, and the spatial distribution needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *L. aridorum*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring information will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers. Close coordination among land managers is essential in the development of adaptive management techniques. All known populations of *L. aridorum* are associated with soil-surface disturbances; not a single site has experienced fire in over 50 years. Thus direct observations of the species' response to fire cannot be made under present conditions. Fire must have been the means by which openings in the scrub were established, yet frequent fire could be damaging to a population. More information is needed on the response to management activities for this species.

S4. Monitor existing populations of *L. aridorum*.

S4.1. Develop monitoring protocol to assess population trends for *L. aridorum*.

S4.1.1. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival and mortality. Also monitor for pollinators, herbivory, disease and injury.

S4.1.2. Monitor the effects of various land management actions on *L. aridorum*. Assess any changes in demographic characteristics of *L. aridorum* in response to land management activities, such as prescribed fire, exotic plant control, *etc*.

S4.2. Develop a quantitative description of the population structure of *L. aridorum*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) may provide insight for management.

S5. Provide public information about *L. aridorum*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private land owners be appropriately informed about this species. Care is needed, though, to avoid revealing specific locality information about where *L. aridorum* is found.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. The public should be informed that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *L. aridorum* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. There is one newly acquired site for *L. aridorum* in Polk County, at the Lake Wales Ridge NWR. More sites must be protected to ensure the safety of this species.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Preventing habitat damage by off-road vehicle use and overcollection, and provide proper management of habitat, including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches are necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned to create a mosaic when possible to allow for variation.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *L. aridorum*.

H1.2.3. Control access to areas where listed plants are growing. Collection, trampling, and off-road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites, a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *L. aridorum* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation with herbicides.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc*., on the habitats where *L. aridorum* occurs.

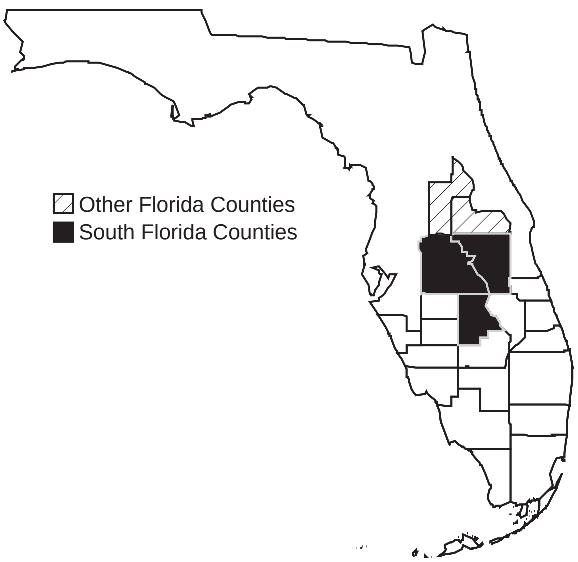
H5. Provide public information about scrub and its unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the South Florida Water Management District, the Florida Native Plant Society, and local garden clubs are crucial for increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Britton's Beargrass

Nolina brittoniana Nash

Federal Status:	**Endangered (April 27, 1993)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. County distribution of Britton's beargrass.



Britton's beargrass is a long-lived species of Agavaceae. It is found from the south end of the Lake Wales Ridge in Highlands County north to Orange County and northern Lake County. It is a relatively widespread scrub species with highest concentrations in Polk and Highlands counties. This species is threatened by habitat loss or modification due to land conversions for agriculture and development.

This account represents South Florida's contribution to the existing recovery plan for Britton's beargrass (FWS 1996).

Description

Britton's beargrass (*Nolina brittoniana*) is a perennial that grows from a short, thick, fleshy, bulblike rootstock. The leaves are 1 to 2 m long and 6 to 13 mm wide, forming a rosette with the youngest leaves upright and the oldest lying nearly flat on the ground. The flowering stem, usually solitary, grows 1 to 1.5 m tall from the rosette in April. The inflorescence is a panicle with about 6 to 20 branches. When in bloom, the branches are covered with small, white flowers, making the plant very conspicuous (Wunderlin *et al*. 1980, Kral 1983). The flowers are moderately fragrant when open (The Nature Conservancy 1995). *N. brittoniana* has symmetrical fruits, triangular in cross-section. The species is generally dioecious (*i.e*., male and female flowers on separate plants), but a few exceptions have been documented.

A similar species, *Nolina atopocarpa,* may occur in the vicinity of *Nolina brittoniana. N. atopocarpa* can be distinguished from *N. brittoniana* by its shorter leaves, flowers that are greenish rather than white, and fruits that are asymmetric (FWS 1996).

Taxonomy

The genus *Nolina*, which belongs to the agave family, is centered in western North America (Mabberley 1987). There are three species of *Nolina* that represent an eastern element in the flora. There are two species in Florida (*N. brittoniana*, and *N. atopocarpa*) and one restricted to Georgia and South Carolina (*N. georgiana*) (FWS 1996). *Nolina brittoniana* was described by Nash in 1895 from a specimen collected in Lake County near Eustis, Florida (Bartlett 1909).

Distribution

Nolina brittoniana occurs from the south end of the Lake Wales Ridge in Highlands County north to Orange County near Orlando and northern Lake County (FWS 1996). An apparently isolated locality was reported from Hernando County, north of Tampa, in 1961 (Wunderlin *et al*. 1980); however this population has not been relocated (R. Yahr, Archbold Biological Station, personal communication 1998). In 1994 there was an unconfirmed report from Brevard County on the east coast. Herbarium records indicate that the historic range of *N. brittoniana* extended north into Marion County. The present range (Figure 1) is concentrated in Polk and Highlands counties with smaller numbers occurring in Lake, Osceola, and Orange counties (FWS 1996).

Habitat

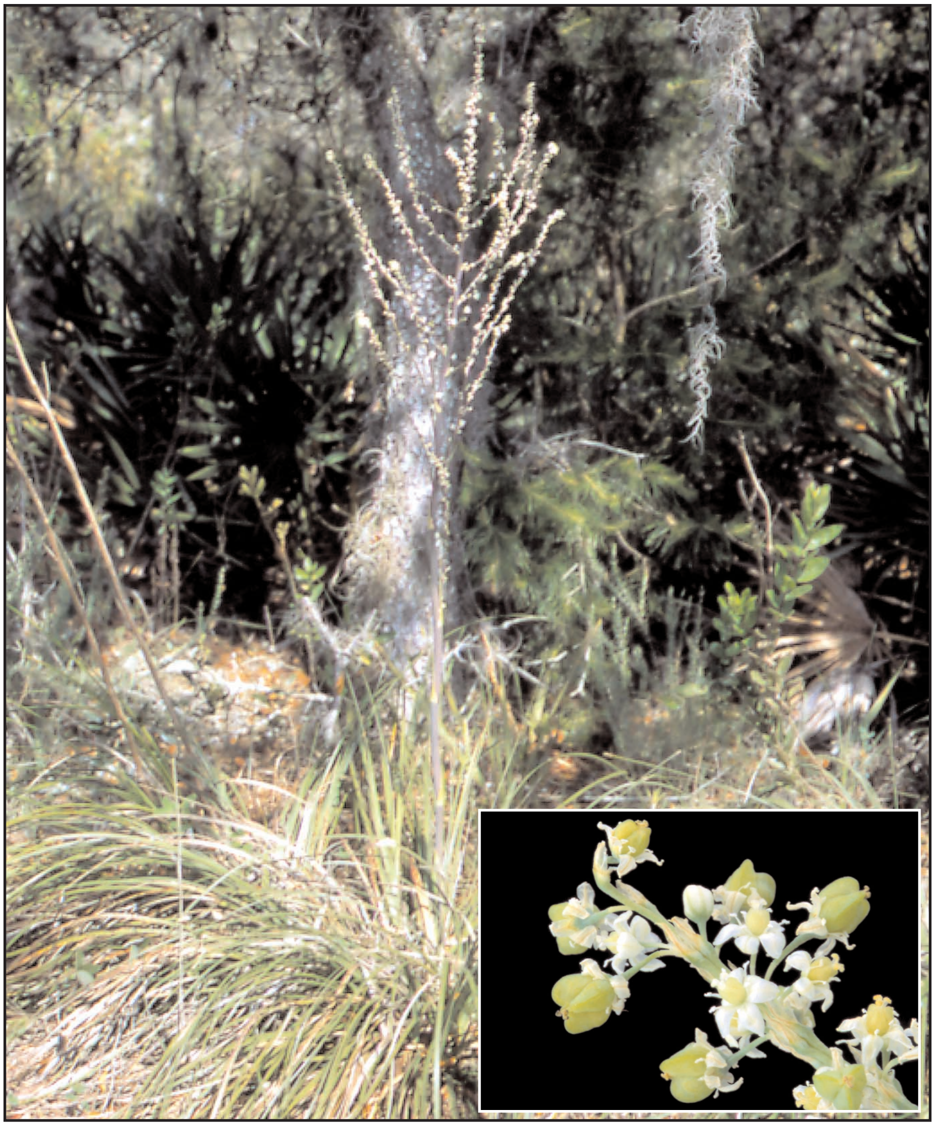
N. brittoniana occurs in a wide range of habitat types, from relatively open scrub to hammocks with closed canopies. It has been reported in scrub, high pine and occasionally in hammocks (Christman 1988). At Lake Wales Ridge SF it was reported in a dense oak grove where trees were 2 to 4 m tall with a very dense thicket of vegetation in the understory (C. Weekly, Lake Wales Ridge SF, personal communication 1996). The wide range of habitat types that *N. brittoniana* occupies are very different in appearance, physiognomy, species composition, fire dynamics, and land use history, but are closely linked ecologically and historically (Myers 1990). In all habitats where *N. brittoniana* occur, the soil is droughty and infertile, and all are considered upland sites (Myers 1990, C. Weekly, Ridge SF, personal communication 1996). These habitats are also fire-maintained and fire-dependent ecosystems that are presumably replaced by hardwoods in the absence of fire (Myers 1990).

Reproduction

Britton's beargrass normally has either all male or all female flowers. There are a few cases where a plant will have both male and female flowers. A recent study by Menges *et al*. (1996) reconfirmed Small's (1933) report of it being "polygamo-dioecious."

Britton's beargrass only produces seeds through pollination, not apomictically. It flowers from early March to mid-May. The male plants shed their pollen in the early morning (The Nature Conservancy 1995). The female flowers exude nectar about 24 hours after opening during the evening or before sunrise (The Nature Conservancy 1995). Britton's beargrass exhibits a generalist pollination syndrome, being pollinated throughout the day by a variety of visitors. At Archbold Biological Station and Lake Apthorpe Preserve there were 34 pollinators from six different families observed visiting *N. brittoniana* plants (Menges *et al*. 1996).

Britton's beargrass.
Original photograph by Betty Wargo; original flower photograph by Steve Shirah.



Flowering of *N. brittoniana* peaks 1 year after burning. Flowering quickly drops during the second year post burn (Menges *et al*. 1996). At the Lake Apthorpe Preserve, 75 percent of the population flowered the year after burning (Menges *et al*. 1996). This dropped to 13 percent 2 years following a burn (Menges *et al*. 1996).

Although *N. brittoniana* responds to fire with increased flowering, recruitment does not follow. Dr. Gordon (The Nature Conservancy, personal communication 1997) feels there are several possibilities for the lack of recruitment: sterile seeds, high seed predation, or delayed germination (seed bank). Studies on the demographics of *N. brittoniana* are continuing and the lack of recruitment is an issue in the research. Plants bear abundant seed, hundreds of seeds per flowering plant, which are easily germinated. These characteristics make propagation of this species easy.

Relationship to Other Species

Nolina brittoniana is typically associated with evergreen oaks such as *Quercus geminata*, *Q. myrtifolia*, *Q. chapmanii*, and *Q. inopina*. Saw palmetto (*Serenoa repens*), and various shrub heaths, *Osmanthus*, *Lyonia*, *Garberia*, *Ilex*, and *Polygonella* also occur with this species. The herbaceous layer is usually dominated by several xerophytic members: *Aristida stricta*, *Aristida spiciformis*, *Helianthemum nashi*, *Rhynchospora megalocarpa*, *Stillingia sylvatica*, *Polygonella fimbriata*, and *Sisyrinchium solstitiale* (Wunderlin *et al*. 1980). *Nolina brittoniana* occurs in association with several rare and/or federally listed species: *Polygala lewtonii*, *Polygonella myriophylla*, *Polygonella basiramia*, *Paronychia chartacea* ssp. *chartacea*, *Persea humilis*, *Liatris ohlingerae*, *Hypericum cumulicola*, *Conradina brevifolia*, *Calamintha ashei*, *Bonamia grandiflora*, and *Ilex opaca* var. *arenicola* (Wunderlin *et al*. 1980).

Status and Trends

Nolina brittoniana was listed as endangered because of habitat loss from agricultural and residential development. Two-thirds of the original scrub habitat has been destroyed and the remainder is threatened by agriculture and residential development (Christman 1988). Peroni and Abrahamson (1985) reported that about three-quarters of the upland habitats (scrub, scrubby flatwoods, and high pine) on the Lake Wales Ridge in Highlands County had been lost to agricultural development or subdivided for residential development by 1983. The Lake Wales Ridge continues to experience population growth and expansion of citrus groves, resulting in further destruction of scrub habitats. Fire exclusion is also degrading much of the remaining scrub habitat. Overgrown scrub can shade this species, which results in a reduction in sexual reproduction (Wunderlin, *et al*. 1980). *Nolina brittoniana* can remain vigorous in fire-suppressed habitat, but the trends of populations under these conditions are unknown (Reese and Orzell 1995).

In recent surveys, about 500 plants were found at The Nature Conservancy's Lake Apthorpe Preserve. This suggests that the species does not always occur as scattered individuals. In other surveys, *N. brittoniana* was found in overgrown habitats that were probably not surveyed previously (Christman 1988, C. Weekly, pers. comm. Arbuckle SF, 1996). In 1989, the total number of *N. brittoniana* was estimated to be less than 1,000 plants (Muller *et al*. 1989).

Management

Like many of Florida's ecosystems, scrub is pyrogenic and its flora and fauna have developed adaptations to fire (Myers 1990). The mosaic of scrub habitats is attributed to variable fire frequencies and patchiness of burn-intensity (Myers 1990). *Nolina brittoniana* occupies a wide range of habitat types that are very different in appearance, physiognomy, species composition, fire dynamics, and land-use history, but are closely linked ecologically and historically (Myers 1990). The habitats all have similar soil characteristics (droughty and infertile), are upland sites, and are fire-maintained and fire-dependent ecosystems that are presumably replaced by hardwoods in the absence of fire (Myers 1990; C. Weekly, Ridge SF, personal communication 1996).

Studies have shown that *N. brittoniana* responds to fire with increased flowering one year post fire (Menges *et al*. 1996). This is important in that it represents a pulse of reproduction and potentially, recruitment of new individuals to the population. Although *N. brittoniana* can persist in an area that has experienced fire suppression for many years, it may only exist in a vegetative state under these conditions. Adequate fire management is needed at protected sites to maintain population diversity.

Nolina brittoniana is protected and managed in eight to 10 areas in an attempt to recover scrub species. It is also present in most of the tracts targeted for acquisition by the State and FWS in Polk and Highlands counties. The recovery team participants recommended that the species be reclassified to threatened after 25 sites have been protected for 20 years. Reclassification required that half of these sites be larger than 202 ha (499 acres) and the rest at least 4 ha (10 acres). The protected sites must also represent the plant's entire geographic range. In an ongoing study of the demography, breeding system, and genetics of *N. brittoniana*, Menges *et al*. (1996) discusses the use the spatial locations of *N. brittoniana* to analyze the geographic factors affecting genetic variation. The spatial data will also be used to evaluate the success of currently protected lands and proposed reserve systems in preserving the genetic diversity of *N. brittoniana* and other scrub endemics.

Literature Cited

Bartlett, H. 1909. *Nolina* in the South Atlantic States. Rhodora. 11:80-82.

Christman, S. 1988. Endemism and Florida's interior sand pine scrub. Final project report submitted to Florida Game and Fresh Water Fish Commission, Nongame Wildlife Program Project GFC-84-101; Tallahassee, Florida.

Gordon, D. 1997. Telephone communication. 20 June 1997.

Kral, R. 1983. A report on some rare, threatened, or endangered forest-related vascular plants of the South. Technical Publication R8-TP 2, U.S. Forest Service; Atlanta, Georgia.

Mabberley, D.J. 1987. The plant-book. Cambridge University Press; Cambridge, England.

Menges, E., D. Gordon, R. Dolan. 1996. Demography, breeding system, and genetics of *Nolina brittoniana*. Final report to the Florida Division of Forestry; Tallahassee, Florida.

Muller, J.W., E.D. Hardin, D.R. Jackson, S.E. Gatewood, and N. Caire. 1989. Summary report on the vascular plants, animals and plant communities endemic to Florida. Nongame Wildlife Program technical report no. 7. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Myers, R.L. 1990. Scrub and high pine. Pages 150-193 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University Presses of Florida; Gainesville, Florida.

Peroni, P.A. and W.G. Abrahamson. 1985. A rapid method for determining losses of native vegetation. Natural Areas Journal 5:20-24.

Reese, G.A. and S. Orzell. 1995. A natural areas inventory of Lake County, Florida: Summary report. Final report to the Florida Natural Areas Inventory; Tallahassee, Florida.

Small, J.K. 1933. Manual of the southeastern flora. University of North Carolina Press; Chapel Hill, North Carolina.

The Nature Conservancy. 1995. Element stewardship abstract for *Nolina brittoniana* - Britton's Bear-grass. The Nature Conservancy; Arlington, Virginia.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery Plan for nineteen central Florida scrub and high pineland plants. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Weekly, C. 1996. Telephone conversation. 10 December 1996.

Wunderlin, R.P., D. Richardson, and B. Hansen. 1980. Status report on *Nolina brittoniana*. U.S. Fish and Wildlife Service; Jacksonville, Florida.

Yahr, R. 1998. Comments on multi-species recovery plan for South Florida. February 5, 1998.

Recovery for the Britton's Beargrass

Nolina brittoniana Nash

Recovery Objective: DELIST the species once recovery criteria are met**.**

South Florida Contribution: STABILIZE and increase the population.

Recovery Criteria

The South Florida recovery objective can be achieved when sites, within the historic range of *N. brittoniana*, are adequately protected from further habitat loss, degradation, and fragmentation; when these sites are managed to maintain the seral stages of high pine and xeric oak scrub communities to support *N. brittoniana*; and when monitoring programs demonstrate that these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species. This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution and status of *N. brittoniana*. Some portions of *N. brittoniana*'s range have been well surveyed yet a total distribution has not been ascertained for this species. A thorough survey is needed to determine the distribution of this species.

S1.1. Conduct surveys for populations of *N. brittoniana*.

S1.1.1. Survey scrub habitat in Osceola County. Adequate survey work has not been performed off the Lake Wales Ridge. Sites on private property cannot be protected without survey knowledge.

S1.1.2. Continue surveys in Polk and Highlands counties. This species is found sparsely in scrub, high pine, and hammock. During surveys, this species could be overlooked. Many sites with *N. brittoniana* may still be undiscovered.

S1.1.3. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. **Maintain distribution of known populations and suitable habitat in GIS database.** Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. **Protect and enhance existing populations.** Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. **Protect privately owned habitat through acquisition, conservation easements, or agreements with landowners.**

S2.2. **Protect populations on public lands.** Develop management guidelines that allow for an appropriate fire regime for *N. brittoniana* habitats that includes a mosaic of successional stages.

S2.3. **Use local or regional planning to protect habitat.** Utilize available regional and county planning processes to encourage protection of suitable habitat, both unoccupied and occupied, of *N. brittoniana*.

S2.4. **Continue *ex situ* conservation.** *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species.

S2.4.1. **Conserve germ plasm.** The seed for this species is not presently in long-term storage.

S2.4.2. **Maintain *ex situ* collection**. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *N. brittoniana* as part of the National Collection.

S2.5. **Enforce available protective measures.** Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *N. brittoniana* lives.

S2.5.1. **Initiate section 7 consultation when applicable.** Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. **Enforce take prohibitions.** This species is protected by trade provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. Continue research on life history characteristics of *N. brittoniana.* Although recent work has answered some life history questions, much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species, more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, gender structure, recruitment, dispersal, growth, survival, and mortality.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *N. brittoniana*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring information on the localities of *N. brittoniana* sites will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S4. Monitor existing populations of *N. brittoniana*.

S4.1. Develop monitoring protocol to assess population trends for *N. brittoniana*.

S4.1.1. Monitor to detect changes in demographic characteristics, such as gender structure, clonal growth, reproduction, recruitment, growth, seed dormancy, germination, dispersal, survival, and mortality. Also monitor for pollinators, herbivory, disease and injury.

S4.1.2. Monitor the effects of various land management actions on *N. brittoniana*. Assess any changes in demographic characteristics of *N. brittoniana* in response to land management activities, such as prescribed fire, exotic plant control, *etc.*

S4.2. Develop a quantitative description of the population structure of *N. brittoniana*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) should also be included.

S5. Provide public information about *N. brittoniana*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *N. brittoniana* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there are 19 protected sites for *N. brittoniana* in Polk and Highlands counties.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *N. brittoniana* populations by preventing damage from off-road vehicle use and overcollection, and by providing proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible. *N. brittoniana* can withstand a wide range of fire frequencies within its diverse habitats.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *N. brittoniana*. Cogon grass is present in some of the high pine and hammock habitats with *N. brittoniana*.

H1.2.3. Control access to areas where listed plants are growing. Trampling and off-road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *N. brittoniana* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation. Although recently studied, questions still exist on management reactions. For example after a burn, the plants experience a flowering peak one year post burn, but no recruitment increase has been detected. More information is needed on the response to management activities for this species.

H4. **Monitor habitat/ecological processes.** Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc*., on the habitats where *N. brittoniana* occurs.

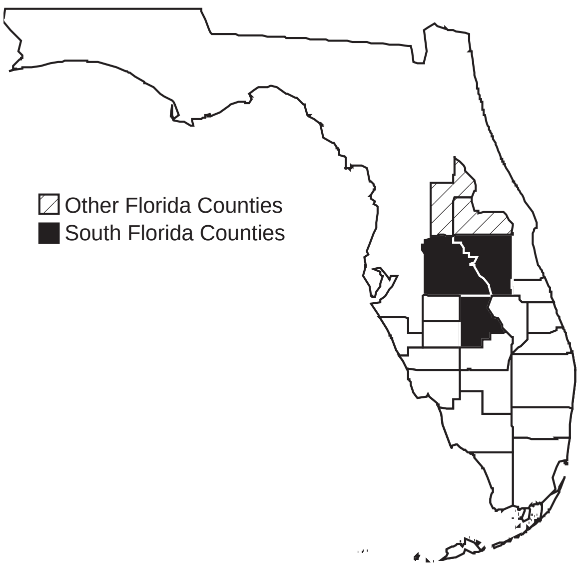
H5. **Provide public information about scrub and its unique biota**. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the SFWMD, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Papery Whitlow-wort

Paronychia chartacea Fern

Federal Status:	**Threatened (January 21, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of the papery



Paronychia chartacea (=*Nyachia pulvinata*) is a member of the pink family, Caryophyllaceae. *Paronychia chartacea* is a short-lived dioecious herb, forming small mats. There are two geographically isolated subspecies of this small herb: *P. chartacea* ssp. *chartacea* in central Florida and the recently described *P. chartacea* ssp. *minima* in northwestern Florida. Both subspecies are federally listed as threatened. Like many of the other Lake Wales Ridge endemic scrub plants, this species was listed because of habitat loss to agricultural, commercial, residential, and recreational purposes.

This account represents a revision of the existing recovery plan for the papery whitlow-wort (FWS 1996).

Description

The papery whitlow-wort is mat-forming with many bright yellowish-green branches radiating flatly from a strong taproot (Kral 1983, Small 1933). The stems are 5 to 20 cm long and are wiry. The leaf blades are sessile, 1.5 to 3.0 mm long, ovate to triangular-ovate in shape, and strongly revolute. It has numerous small cream-colored to greenish flowers (Small 1933, FWS 1996) that produce a very thin-walled utricle (Kral 1983).

There are two geographically isolated subspecies of this small herb: *P. chartacea* ssp. *chartacea* in central Florida and *P. chartacea ssp. minima* L. Anderson in the Florida panhandle. Much of the distinction between the two subspecies is a matter of degree (Anderson 1991). The *P. chartacea* ssp. *minima* is somewhat less pubescent than ssp. *chartacea*. There are also differences in their base stems, leaf width, and flower cluster (Anderson 1991).

Taxonomy

The papery whitlow-wort was first named by Small (1925) as *Nychia pulvinata*. In 1936 Fernald transferred the species to the genus *Paronychia* as *P. chartacea* because the name *P.*

pulvinata was pre-empted (Anderson 1991). In 1991 Anderson formally described two geographically distinct subspecies, *P. chartacea* ssp. *chartacea* and *P. chartacea* ssp. *minima*. The subspecies P. *chartacea* ssp. *minima* was formally described by Anderson (1991), several years after *P. chartacea* had been listed as a threatened species. Because the entire species was listed as threatened, the newly described subspecies is also protected.

Distribution

P. chartacea ssp. *chartacea* is endemic to the scrub community on the Lake Wales Ridge (Kral 1983), in Highlands, Polk, Osceola, Orange, and Lake counties (Anderson 1991) (Figure 1). The subspecies *P. chartacea* ssp. *minima* occurs in the karst region of the Florida panhandle, Washington and Bay counties.

Habitat

The natural habitat for the papery whitlow-wort on the Lake Wales Ridge (that is for *P. chartacea* ssp. *chartacea*) is rosemary scrub, which is also known as the rosemary phase of sand pine scrub (Abrahamson *et al.* 1984, Christman 1988, Menges and Kohfeldt 1995). At Archbold Biological Station, rosemary scrubs are found only on the higher ridges and knolls in the intra-ridge valley at 40 to 50 m in elevation, and are largely restricted to St. Lucie and Archbold soil types (Abrahamson *et al.* 1984), both well-drained white sands (Carter *et al.* 1989). The fire cycle in rosemary scrub can range from 10 to as long as 100 years (Johnson 1982, Myers 1990). Rosemary scrub is dominated by Florida rosemary (*Ceratiola ericoides*) and oak species (*Quercus chapmannii*, *Q. geminata*, *Q. inopina*) with occasional sand pine *(Pinus clausa*). Abrahamson *et al.* (1984) provides a full description of the rosemary scrub habitat. The shrub matrix is interspersed with open sandy areas that contain a cover of herbs and lichens (Abrahamson *et al.* 1984, Hawkes and Menges 1996). These gaps are more persistent in rosemary scrubs than in scrubby flatwoods (Hawkes and Menges 1996).

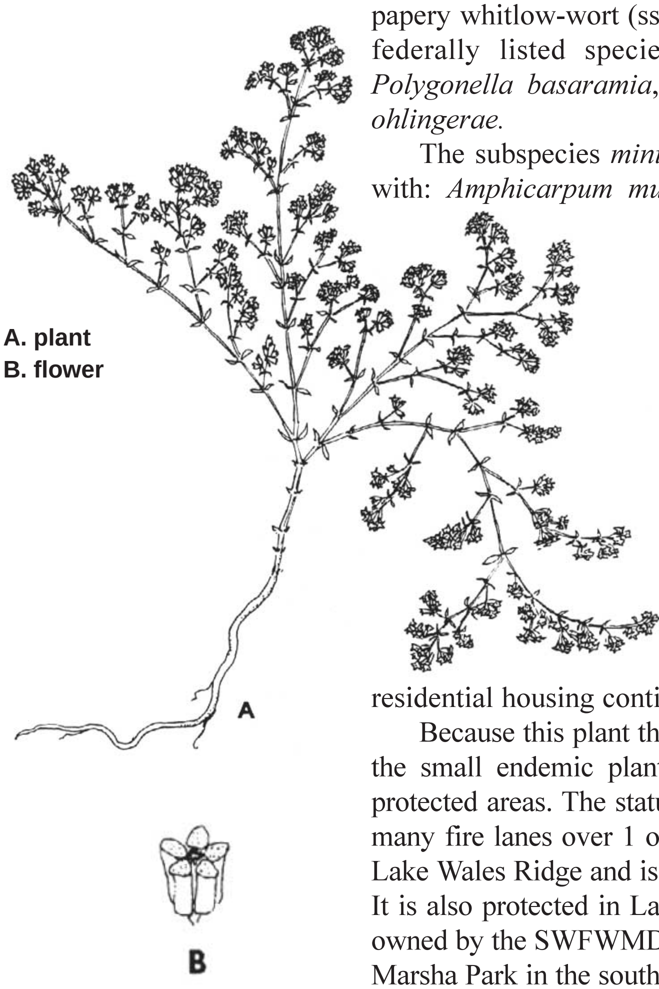
Within these scrub communities, papery whitlow-wort is more abundant in disturbed, sandy habitats such as road rights-of-way and recently cleared high pine (Abrahamson *et al.* 1984, Christman 1988, FWS 1996). In rosemary scrub paper whitlow-wort can become very abundant after a fire or on disturbed sites such as along fire lanes or trails (FWS 1996, Johnson and Abrahamson 1990).

The subspecies *P. chartacea* ssp. *minima* occurs in the Florida panhandle in coarse white sand along margins of karst lakes (Anderson 1991). It is apparently favored by mild disturbance. It often occurs in nearly pure stands (Anderson 1991).

Reproduction

Anderson (1991) notes that *P. chartacea* ssp. *chartacea* has repeatedly been described as an annual, but states that it is often a short-lived perennial. Observations at Bok Tower Gardens indicate that *P. chartacea* ssp. *chartacea* behaves, both in the garden and in the wild, as a short-lived perennial. The

Papery whitlow-wort. *Image adapted from an original drawing by Anna-Lisa King.*



A. plant
B. flower

subspecies *P. chartacea* ssp. *minima* is strictly an annual (Anderson 1991). Flowering and fruiting occur in late summer or fall (Anderson 1991) and the seeds mature in September or October (T. Race, Bok Tower Gardens, personal communication 1996).

Relationship to Other Species

In rosemary scrub, the papery whitlow-wort is found in association with 37 vascular plants and seven species of reindeer lichens (Johnson and Abrahamson 1990). In a study of the responses of species to fire in rosemary scrub, Johnson and Abrahamson (1990) identified two groups of this species: seeders and sprouters, and a third group that they were uncertain about. The papery whitlow-wort was considered a seeder along with 11 other species (Johnson and Abrahamson 1990, Ostertag and Menges 1994). Johnson and Abrahamson (1990) have also found that the papery whitlow-wort appeared in post burn plots of rosemary scrub when it was rare or absent prior to the burn. The papery whitlow-wort was displaced by rosemary and reindeer lichens within about 9 to 12 years post fire (Johnson and Abrahamson 1990). The papery whitlow-wort (ssp. *chartacea*) occurs in association with several other federally listed species: *Bonamia grandiflora*, *Hypericum cumulicola*, *Polygonella basaramia*, *Cladonia perforata, Eryngium cuneifolium, Liatris ohlingerae.*

The subspecies *minima* can occur in nearly pure stands or in association with: *Amphicarpum muhlenbergianum*, *Bulbostylis barbata*, *B. ciliatifolia*, *Chrysopsis lanuginosa*, *Eriocaulon lineare*, *Hypericum lissophloeus*, *H. reductum*, *Lachnanthes carolinianam*, *Lachnocaulon anceps*, *Paronychia patula*, *Polypremum procumbens*, *Rhexia salicifolia*, *Rhynchospora globularis*, *Sagittaria isoetiformis*, and *Xyris longisepala*.

Status and Trends

The loss of scrub habitat is the primary reason the papery whitlow-wort is listed as a threatened species (52 CFR 2234). More than two-thirds of the historic scrub habitat of this plant was destroyed by 1980 (Christman 1988). Land conversion for citrus and residential housing continues to diminish scrub habitats.

Because this plant thrives in fire lanes and along sand roads, it is the last of the small endemic plants of the Lake Wales Ridge to disappear from fire-protected areas. The status of this species could be assessed by examining it in many fire lanes over 1 or 2 years (FWS 1996). It is ubiquitous in scrub on the Lake Wales Ridge and is protected in all of the biological preserves in this area. It is also protected in Lake County at the Crooked Lake site near Lake Louisa owned by the SWFWMD (FWS 1996) and in Orange County at Lakes Cain and Marsha Park in the southwest Orlando area.

Management

The density of *P. chartacea* ssp. *chartacea* increases in relation to available open space (Hawkes and Menges 1996, Menges and Kohfeldt 1995). Open spaces are commonly found in rosemary scrub after fire and in fire lanes and trails. The rosemary scrub has developed with periodic disturbances and the available open space and frequencies of disturbances are likely to influence the species composition (Hawkes and Menges 1996). Densities of *P. chartacea* ssp. *chartacea* decrease with time after fire, and it is displaced from rosemary scrub within 9 to 12 years post fire (Johnson and Abrahamson 1990, Hawkes and Menges 1996). Because it thrives in fire lanes, along sand roads, and trails, it is the least likely of the rare scrub plants to go extinct.

Management for *P. c.* ssp. *chartacea* will require the development of long-term burning regimes that mimic the natural fire cycles of rosemary scrub. There are complex relationships among fire, open space, and plant distributions within a xeric scrub that are essential for fire management and need to be studied further (Hawkes and Menges 1996). Management practices for rosemary scrub should include the fire requirements for all scrub flora and fauna (Hawkes and Menges 1996).

The species' tendency to colonize disturbed areas along easily accessible State road cuts and rights of way can result in over-estimation of the species abundance and health. On publicly managed lands, we caution against using species presence or abundance in altered habitats as the benchmark with which management decisions are made. Instead, management decisions should be made that maintain or enhance the dynamic diversity of Florida's scrub vegetation.

Literature Cited

Abrahamson, W., A. Johnson, J. Layne, and P. Peroni. 1984. Vegetation of the Archbold Biological Station, Florida: An example of the Southern Lake Wales Ridge. Florida Scientist. 47(4):209-250.

Anderson, L. 1991. *Paronychia chartacea* ssp. *minima* (Caryophyllaceae): a new subspecies of a rare Florida endemic. Sida 14(3): 435-441.

Christman, S. 1988. Endemism and Florida's interior sand pine scrub. Final project report, project no. GFC-84-101. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Hawkes, C., and E. Menges. 1996. The relationship between open space and fire for species in a xeric Florida shrubland. Bulletin of the Torrey Botanical Club 123(2):81-92.

Johnson, A.F,. and W.G. Abrahamson. 1990. A note on the fire responses of species in rosemary scrubs on the southern Lake Wales Ridge. Biological Sciences 53(2).

Kral, R. 1983. A report on some rare, threatened, or endangered forest-related vascular plants of the South. USDA Forest Service. Technical publication R8-TP 2.

Menges, E.S., and N. Kohfeldt. 1995. Life history strategies of Florida scrub plants in relation to fire. Bulletin of the Torrey Botanical Club 122(4):282-297.

Menges, E.S., and Hawkes, C. 1997.

Ostertag, R., and E.S. Menges. 1994. Patterns of reproductive effort with time since last fire in Florida scrub plants. Journal of Vegetation Science 5:303-310.

Peroni, P.A., and W.G. Abrahamson. 1985. A rapid method for determining losses of native vegetation. Natural Areas Journal 5:20-24.

Race, T. 1996. Letter. February 27, 1996.

Small, J.K. 1933. Manual of the southeastern flora. University of North Carolina Press; Chapel Hill, North Carolina.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery plan for nineteen central Florida scrub and high pineland plants. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Recovery for the Papery Whitlow-wort

Paronychia chartacea Fern

Recovery Objective: **DELIST** the species once recovery criteria are met.

Recovery Criteria

Paronychia chartacea may be delisted when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations and sites needed to assure 95 percent probability of persistence for 100 years; when these sites, within the historic range of *P. chartacea*, are adequately protected from habitat loss, degradation, and fragmentation; when these sites are managed to maintain the rosemary phase of xeric oak scrub communities to support *P. chartacea*; and when monitoring programs demonstrate that these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species.

Species-level Recovery Actions

S1. Determine current distribution of *P. chartacea*. Some portions of *P. chartacea*'s range have been well surveyed yet a total distribution has not been ascertained for this species. A thorough survey is needed to determine the distribution for this species.

S1.1. Conduct surveys for additional populations of *P. chartacea*.

S1.1.1. Continue surveys in Polk, Osceola, and Highlands counties. The Lake Wales Ridge has probably been adequately surveyed, though new sites for *P. chartacea* may still be found.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. Maintain distribution of known populations and suitable habitat in GIS database. Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, has been isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. Protect privately-owned habitat through acquisition, conservation easements, or agreements with landowners.

S2.2. Protect populations on public lands. Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. Use local or regional planning to protect habitat. Utilize available regional and county planning processes to encourage protection of suitable habitat both unoccupied and occupied of *P. chartacea*.

S2.4. Continue *ex situ* conservation. *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *P. chartacea*.

S2.4.1. Conserve germ plasm. The seed for this species is not presently in long term storage.

S2.4.2. Maintain *ex situ* collection. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *P. chartacea* as part of the National Collection.

S2.5. Enforce available protective measures. Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *P. chartacea* lives.

S2.5.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. Enforce take and trade prohibitions. This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. Conduct research on life history characteristics of *P. chartacea*. Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species, more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *P. chartacea*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring information will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques. This species experiences a dramatic increase in flowering the first year after a burn, yet can bloom up to 30 years without fire. More information is needed on the response to management activities for this species.

S4. Monitor populations of *P. chartacea*.

S4.1. Develop monitoring protocol to assess population trends for *P. chartacea*.

S4.1.1. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival, and mortality. Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. Monitor the effects of various land management actions on *P. chartacea*. Assess any changes in demographic characteristics of *P. chartacea* in response to land management activities, such as prescribed fire, exotic plant control, *etc*.

S4.2. Develop a quantitative description of the population structure of *P. chartacea*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Collect data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors).

S5. Provide public information about *P. chartacea*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. Care is needed, though, to avoid revealing specific locality information about *P. chartacea.*

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *P. chartacea* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. This species is ubiquitous in the scrub preserves in Polk and Highlands counties.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *P. chartacea* populations by preventing damage from off-road vehicle use, over collection, and provide proper management of habitat including prescribed fire.

H1.2.1. Perform prescribed fires. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches are necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *P. chartacea*.

H1.2.3. Control access to areas where listed plants are growing. Collection, trampling, and off road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *P. chartacea* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation..

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, etc., on the habitats where *P. chartacea* occurs.

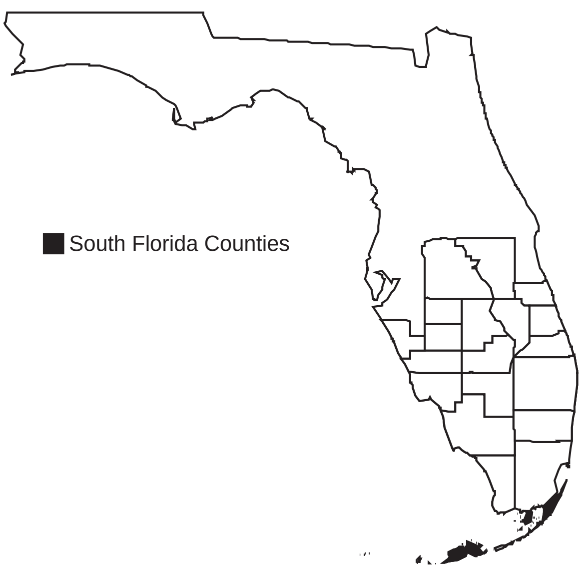
H5. Provide public information about scrub and its unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the South Florida Water Management District, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been successful in disseminating knowledge about these unique communities.

Key Tree-cactus

Pilosocereus robinii (Lemaire) L. Benson

Federal Status:	**Endangered (July 19, 1984)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. Florida distribution of the Key tree-cactus; within the U. S. this species is found only in the Florida Keys.



Pilosocereus robinii is a large, tree-like cactus known in the U.S. only from the Florida Keys. The Key tree-cactus produces large white flowers and a purplish-red fruit. It is a member of the rare and declining tropical hammock communities on Upper and Lower Matecumbe, and Long and Big Pine keys. Populations formerly found on Key West and Windley and Boca Chica keys are believed to be extirpated. As early as 1917, this cactus was on the edge of being extinct as a result of habitat destruction. The Key tree-cactus was listed as endangered because of severe population declines caused by destruction of its habitat for commercial and residential development.

This account represents a revision of the existing recovery plan for the Key tree-cactus (FWS 1986).

Description

The Key tree-cactus is a large, tree-like cactus with erect columnar stems, reaching 10 m in height. At maturity, the plants are either much-branched (in variation *robinii*), or remaining few-branched (in variation *deeringii*). The stems of the tree-cactus are cylindrical, green, succulent, and 5 to 10 cm thick, with nine to 15 prominent ribs. Areoles bear 15 to 30 acicular spines that are up to 2 cm long and are thickly pubescent when young. Flowers are solitary in the upper areoles, nocturnal, and 5 to 6 cm long. The outer perianth segments of the flowers are green, with tips pointed (in variation *robinii*) or rounded (in variation *deeringii*). The inner perianth segments of the flowers are white. The style is slightly exserted (in variation *robinii*) or included (in variation *deeringii*). The fruit of the Key tree-cactus is globose, depressed, and 3.5 to 4.0 cm in diameter. The coat of this fruit is thin, leathery, bright red, and splits open at maturity. The seeds are small, hard, shiny black, and set in a soft, white pulp (Benson 1982, Britton and Rose 1937, Small 1931).

Taxonomy

Torrey and Gray first referred to the species in 1838 as *Cereus peruvianus* (L.) Miller. Chapman later referred to a tree-cactus species occurring in Key West as *Cereus monoclonos* D.C. Lemaire (Chapman 1860). Lemaire (1864) referred to a tree-cactus he considered endemic to the northwestern coast of Cuba as *Pilocereus robinii*. The species was later described as two separate species in *Cephalocereus*. *Cephalocereus keyensis* Britton and Rose was described from plants collected in Key West (Britton and Rose 1909). *Cephalocereus deeringii* Small was described from plants found growing on Lower Matecumbe Key (Small 1917). In 1957, Leon and Alain retained the genus *Pilocereus* for this species and treated it as endemic to Cuba. The genus *Pilocereus* was rejected on nomenclatural grounds by Byles and Rowley (1957) who proposed *Pilosocereus* as a replacement. This change was taken up by Liogier (1969).

More recently, Benson (1969), citing the uncertainties of genetic boundaries within the ceroid cacti, transferred the species into an inclusive *Cereus*. Benson identified *Cephalocereus keyensis* with *Cereus robinii* var. *robinii* and treated *Cephalocereus deeringii* as a distinct subspecies, *Cereus robinii* var. *deeringii* (Benson 1969). This treatment was confused by Long and Lakela (1971) who equated *Cephalocereus keyensis* with *Cereus robinii* var. *deeringii* and *Cephalocereus deeringii* with *Cereus robinii* var. *robinii*. Benson (1982) has since published a book covering the species, in which he maintains his original treatment. D.F. Austin (1984) has published some observations on the species in which he questions the distinctiveness of the two varieties.

The genus *Pilosocereus* was reinstated by Kartesz and Gandhi (1991), who transferred *Cereus robinii* (Lemaire) L. Benson var. *deeringii* (Small) L. Benson to *Pilosocereus robinii* (Lemaire) Byles and Rowley var. *deeringii* (Small) Kartesz and Gandhi.

Distribution

The Key tree-cactus is found in the coastal hammocks of the Florida Keys (Avery 1982,Benson 1982, Britton and Rose 1937, Small 1917, 1921) (Figure 1), and in the coastal thickets of the Matanzas and Habana provinces of Cuba (Benson 1982, Britton and Rose 1937). The historical distribution of this species in the Florida Keys—which included populations that are now extinct on Key West, Boca Chica, and Windley Keys—has been substantially diminished by the destruction of populations occurring in the Lower Keys, particularly Key West (Avery 1982, Britton and Rose 1937, Small 1917, 1921). Key tree-cactus populations presently occur on Upper Matecumbe Key (two populations), Lower Matecumbe Key (one population), Long Key (three populations), and Big Pine Key (two populations) (Adams and Lima 1994).

Habitat

The Key tree-cactus grows in a narrow range of plant associations which include tropical hardwood hammocks and a thorn-scrub association known locally as a “cactus hammock.” Hardwood hammocks inhabited by the species are typically in an early stage of succession following disturbance (Avery [no

Key tree-cactus.
Original photograph by Kalani Cairns.

date], Small 1917, 1921). Dominant tree species include *Bumelia salicifolia, Bursera simaruba, Coccoloba diversifolia, Ficus aurea, Krugiodendron ferreum, Metopium toxiferum*, and *Piscidia piscipula*. The lower story of the canopy typically contains small trees of the dominant species and plants of *Amyris elemifera, Ateramnus lucidus, Bumelia celastrina, Capparis flexuosa, Eugenia foetida, Guapira discolor, Pithecellobium guadelupense, Randia aculeata*, and *Zanthoxylum fagara* (Austin 1980, Weiner 1979). These hardwood hammocks are upland communities which are flooded only rarely (during major storms) and are mesic in character (Weiner 1979).

The thorn-scrub, "cactus hammock" association occurs at relatively low elevations in the Keys and is prone to more frequent flooding. Consequently, the canopy of this vegetative community is lower and more open than hardwood hammocks. *Conocarpus erectus* and *Ximenia americana* are the most typical dominant tree species (Weiner 1979). *Cereus gracilis, Cereus pentagonus*, and *Opuntia dillenii* are common associates of the Key tree-cactus in these habitats. The Key tree-cactus is found on high sites within cactus hammocks that are rarely flooded. These sites support the hardwood hammock species listed above, but rarely are extensive enough to allow the development of hardwood hammocks.

The hardwood hammocks and cactus hammocks in which Key tree-cactus is presently known to grow are all developed on coral rock. Key tree-cactus grows well on well-drained upland sites with little or no soil development. Mineral soil is represented, if at all, by a very thin (<1 cm) layer of rock rubble, calcareous sands or calcareous marl (Austin 1980). A layer of leaf litter 1 to 2 cm thick is typically present (Austin 1980). Deeper accumulations of soil may be found in pockets and crevices in the rock. These soils are classified as Histosols (Soil Conservation Service 1975) and are placed in the "catch-all" rockland groups (Jones 1948). No detailed work has been done on soil types in the Keys due to their small area, agricultural insignificance, and the lack of well-developed soils. Hammocks on Key West and Boca Chica Key, where Key tree-cactus grew in the past, were located on oolitic limestone. Soil conditions at these sites were not recorded, but were probably similar to those listed above.

The Key tree-cactus grows in small, isolated patches or clumps. The patches may consist of a single plant, or a group of plants may cover an area of tens of square meters (Austin 1980, Small 1917). When many plants are found in a clump, most, if not all, of the separate stems represent vegetative offshoots of one or a few founders.

Reproduction

Long-distance dispersal and establishment of new Key tree-cactus populations is dependent upon the production of seedlings. However, reproduction within a single population (a clump) is mostly, if not entirely, vegetative (Adams and Lima 1994). Vegetative reproduction is commonly observed as a result of old stems being knocked to the ground. This reproductive strategy (formation of clonal clumps from rooted wind-thrown branches) also accounts, in part, for the clumped distribution of the species (Adams and Lima 1994). Pollination agents are unknown but may include sphingid moths (Adams and Lima 1994). The Key tree-cactus can set fruit in the absence of large pollinators (Hennessey and Habeck 1994).

The Key tree-cactus can flower year-round, but July, August, September, and October are peak flowering periods (Adams and Lima 1994, Hennessey and Habeck 1994). Mature flowers develop in approximately 12 to 14 days, and many flowers may occur simultaneously on a single pseudocephalium (Adams and Lima 1994). Seed dispersal, based on one observation, occurs in August (Austin 1980, Avery [no date.]). Seed dispersal by birds such as *Cardinalis cardinalis* is indicated for this species (Austin 1980). The effective dispersers would be those fruit-eating birds which favor openings in the woods.

Relationship to Other Species

Ants (*Crematogaster ashmeadii* and *Solenopsis abdita*) prey upon the fruit, pulp, and seeds of *P. robinii* (Adams and Lima 1994). The endangered Key deer (*Odocoileus virginianus clavium*) has been observed to feed on and damage Key tree-cactus. Foraging behaviors of the Key deer may be an important cause of windthrow or plant dispersal in the cactus hammock (Hennessey and Habeck 1994).

Status and Trends

The Key tree-cactus was federally listed as endangered on July 19, 1984 (49 FR 29237), because of severe population declines caused by destruction of upland areas in the Keys for commercial and residential development activities. Populations of the Key tree-cactus have most likely always been uncommon and widely scattered (Small 1917, 1921). Several populations of Key tree-cactus have been eliminated over the last 70 years by development (Austin 1980, Avery [n.d.]; Small 1921, 1924). Key West once held a large population of this species (Britton and Rose 1937, Small 1917). The last plants apparently died when the final remnants of the original forest were cleared on the island during the 1920s (Small 1921). Plants on nearby Boca Chica Key (Britton and Rose 1937) presumably shared the same fate. Populations reported for Windley and Lower Matecumbe keys (Small 1917) were presumed to have been destroyed (Avery 1982); although the population on Lower Matecumbe Key was recently rediscovered (Adams and Lima 1994). In recent years, a population of *P. robinii* on Long Key was destroyed when the hammock where it grew, just east of the town of Layton, was cleared for development.

A 1991-1993 survey throughout the Florida Keys found 624 key tree-cactus plants (3,360 stems) distributed among eight populations on four of the Keys—Upper Matecumbe, Lower Matecumbe, Long Key, and Big Pine Key. The population on Upper Matecumbe Key is seriously threatened by residential and commercial construction and there is no flowering occurring. The status on Lower Matecumbe Key is uncertain; there is no flowering occurring and the location is a private lot. The population on Big Pine Key is considered stable because it is protected and producing viable seed. Plants on Long Key that are protected may be considered stable; however, status of other plants is uncertain at this time.

Threats

The Key tree-cactus has probably always been rare in Florida. The primary cause for this rarity seems to be the rather restrictive habitat requirements of the species. It grows only on lightly shaded, upland sites. This habitat is not common on the Keys, and, furthermore, is transient in nature. The habitat preferred by Key tree-cactus occurs primarily in disturbed patches of hammock (Avery [no date], Small 1917, 1921). The location of these patches changes with time as disturbed areas re-grow and new sites are disturbed.

By far, the major threat to the continued existence of this cactus in Florida is habitat loss for the construction of commercial facilities and residential housing on the upland areas in the Keys. This construction activity has been directly responsible for the destruction of several Key tree-cactus populations over the past seven decades (Austin 1980, Avery [no date], Britton and Rose 1937, Small 1921, 1924). An additional threat to the survival of this species is the environment it occupies; a possible catastrophic event in the Keys could further reduce its population size.

Management

The survival and recovery of the Key tree-cactus depends on protecting the remaining tropical hardwood hammock areas throughout the Keys. The original recovery plan recommended reclassification of this species to threatened when four vigorous self-sustaining populations throughout the Keys were established. Seven self-sustaining populations were needed to be established to delist the species (FWS 1986). Presently, two self-sustaining sites are in existence: one is on Big Pine Key in the cactus hammock, and the other is on Long Key. The National Audubon Society identified areas of tropical hardwood hammocks throughout the Keys for proposed acquisition by the State of Florida that are necessary to preserve the biological diversity of the hammock ecosystem. The FWS believes that protection, conservation, and management of these areas is critical to the survival and recovery of the Key tree-cactus.

Data on the autecology of the Key tree-cactus has been provided by Hennessey and Habek (1991) and Austin (1980, 1984). Hennessey and Habek (1991) conducted preliminary studies on the reproductive biology of the Key tree-cactus, while Austin (1980) provided information on the taxonomy, extant populations, herbarium specimens, and biotic associates. Additional research conducted by Adams and Lima (1993, 1994) has provided an inventory of all extant populations. Current management includes research on the reproductive biology and the establishment of an *ex situ* germ plasm. This germ plasm collection can later be used to make reintroductions and gain additional life history information.

The National Key Deer Refuge manages Key tree-cactus habitat through: (1) the control of exotic plants (primarily Brazilian pepper, *Asiatic colubrina*, and C*asuarina*) (2) law enforcement patrolling of areas to prevent collectors from illegally taking specimens, (3) the prohibition of aerial application of mosquito spraying to avoid impacts on pollinators, and (4) prohibition of human access to areas occupied by the Key tree-cactus.

Literature Cited

Adams, R.M., and A.N. Lima. 1994. The natural history of the Florida keys tree cactus, *Pilosocereus robinii*. U.S. Fish and Wildlife Service; Jacksonville, Florida.

Adams, R.M., and A.N. Lima. 1993. The distribution of tree cacti in the Florida Keys, including spatial distribution and demographics of a population at Southeast Point, Big Pine Key, Florida. A report to the U.S. Fish and Wildlife Service.

Austin, D.F. 1984. A resume of the Florida taxa of *Cereus*. Florida Scientist 47:68-72.

Austin, D.F. 1980. *Cereus robinii* var. *robinii* and *Cereus robinii* var. *deeringii*. *in* Austin, D.F., C.E. Naumann, and B.E. Tatje, Endangered and threatened plant species survey in Southern Florida and the National Key Deer and Great White Heron national wildlife refuges. U.S. Fish and Wildlife Service, Atlanta, GA.

Avery, G.N. 1982. *Cereus robinii* in Florida. Report in files of Florida Natural Areas Inventory office; Tallahassee, Florida.

Avery, G.N. Undated. Notes on South Florida plants. Manuscript in the library of Fairchild Tropical Garden; Miami, Florida.

Benson, L. 1969. The cacti of the United States and Canada - new names and nomenclatural combinations. I. Cactus and Succulent Journal 41:124-127.

Benson, L. 1982. The cacti of the United States and Canada. Stanford University Press; Stanford, California.

Britton, N.L., and J.N. Rose. 1909. The genus *Cereus* and its allies in North America. Contribution to the United States National Herbarium 12:413-437.

Britton, N.L., and J.N. Rose. 1937. The *Cactaceae*, 2nd edition. Dover Publications Incorporated; New York, New York.

Byles, R.S., and G.D. Rowley. 1957. *Pilosocereus* Byl. and Rowl. nom. gen. nov. (*Cactaceae*). Cactus and Succulent Journal 19:66-69.

Chapman, A.W. 1860. Flora of the Southern United States. 1st Edition. Ivison, Blakeman and Company; New York, New York.

Hennessey, M.K., and D.H. Habeck. 1994. Observations on reproduction of an endangered cactus *Cereus robinii* (Lemaire) L. Benson. Florida Scientist 57(3):93-101.

Jones, L.A. 1948. Soils, geology, and water control in the Everglades region. Bulletin no. 442, University of Florida Agricultural Experimental Station; Gainesville, Florida.

Kartesz, J.T., and K.N. Gandhi. 1991. Nomenclatural notes for the North American Flora. No. VIII. Phytologia 71(4):269-280.

Lemaire. 1864. Illustr. Hort. XI 1:Misc. 74.

Leon, H., and H. Alain. 1957. Flora de Cuba. Part 3. 1974 reprint. Otto Koeltz Science Publishers; Koenigstein, FDR.

Liogier, A.H. 1969. Flora de Cuba Supplement. 1974 reprint. Otto Koeltz Science Publishers; Koenigstein, FDR.

Long, R.W., and O. Lakela. 1971. A flora of tropical Florida. University of Miami Presses; Miami, Florida.

Small, J.K. 1917. The tree cacti of the Florida Keys. Journal of the New York Botanical Garden 18:199-203.

Small, J.K. 1921. Old trails and new discoveries. Journal of the New York Botanical Garden 22:25-40, 49-64.

Small, J.K. 1924. The land where spring meets autumn. Journal of the New York Botanical Garden 25:53-94.

Small, J.K. 1931. *Cephalocereus deeringii* - Deerings tree-cactus. Addisonia 16:39-40, pl. 532.

Soil Conservation Service. 1975. Soil taxonomy. Agriculture handbook no. 436, U.S. Department of Agriculture; Washington, D.C.

Torrey, J., and A. Gray. 1838. A Flora of North America. Reprinted (1968). Hafner Press; New York, New York.

U.S. Fish and Wildlife Service [FWS]. 1986. Key tree-cactus recovery plan. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Ward, D.B. 1979. Rare and endangered biota of Florida, vol. 5: Plants. University of Florida Presses; Gainesville, Florida.

Weiner, A.H. 1979. The hardwood hammocks of the Florida Keys. National Audubon Society and the Florida Keys Land Trust; Tavernier, Florida.

Recovery for the Key Tree-cactus

Pilosocereus robinii (Lemaire) L. Benson

Recovery Objective: RECLASSIFY to threatened.

Recovery Criteria

The Key tree-cactus has experienced local extirpations and is vulnerable to extinction as a result of habitat loss and other anthropogenic factors. Consequently, the objective is to reclassify the Key tree-cactus from endangered to threatened by protecting and managing its habitat in the Keys, restoring potential habitat, and increasing the size of its population. This objective will be achieved when: further loss, fragmentation, or degradation of suitable, occupied habitat has been prevented; when native and non-native nuisance species have been reduced by 80 percent; when all suitable, occupied habitat on priority acquisition lists is protected either through land acquisition or cooperative agreements; when potential habitat on protected lands is restored or rehabilitated for the Key tree-cactus; when stable populations of the Key tree-cactus are distributed on secure sites within its historic range (including two on Upper Matecumbe, one on Lower Matecumbe, three on Long Key and two on Big Pine Key); and when three, additional, stable populations have been established on Windley Key, Boca Chica Key, and Key West. These populations will be considered demographically stable when they exhibit sexual reproduction and have a rate of increase (r) equal to or greater than 0.0 as a 3-year running average for 6 years.

Species-level Recovery Actions

S1. Conduct surveys to determine the distribution and status of *P. robinii*. Known *P. robinii* populations occur in coastal hammocks on Upper Matecumbe Key, Lower Matecumbe Key, Long Key, and Big Pine Key (Adams and Lima 1994), but other populations may exist. Survey historic range and determine distribution and status of *P. robinii*. Conduct surveys on private lands first since these are most likely to be vulnerable to disturbance.

- **S1.1. Inventory known populations**. Conduct thorough ground survey. Collect and archive herbarium voucher specimens for all populations. Initiate a quarterly monitoring program. Use standardized monitoring protocols to record baseline data regarding the biology of *P. robinii*.
- **S1.2. Search for populations of *P. robinii*.** Resurvey historic locations. Conduct thorough ground surveys to locate unrecorded individuals and populations of *P. robinii.*
- **S1.3. Map distribution of known populations and suitable habitat.** Map populations, including obtaining GPS coordinates and developing GIS coverages.

S2. Protect and enhance existing populations. The remaining population sites must be protected as the first step toward recovery. These sites are currently the only ones which will offer assurance of supporting the species. Plant stocks for expansion of the population must come from the remaining specimens.

S2.1. Minimize and eliminate disturbance or mortality to *P. robinii.*

S2.2. Continue to enforce take prohibitions. The take restrictions of the ESA and the Preservation of Native Flora of Florida Act protect *P. robinii*.

S2.3. Conserve germ plasm.

S2.3.1. Center for Plant Conservation-designated sites such as Fairchild Tropical Garden maintain *ex situ* conservation collections of *P. robinii*. These collections need expansion to fully represent genetic variation in the wild. Identify seed storage potential and methods and continue to identify propagation and cultivation protocols.

S2.3.2. Study the feasibility of translocating propagules into historically appropriate and protected natural habitats.

S2.3.3. Identify potential reintroduction sites.

S2.3.4. Use reintroduction protocols established by the conservation community.

S2.3.5. Monitor the experimental outplantings. Monitoring of reintroduced plants is essential for assessing the success of recovery efforts. Growth and survivorship will be measured.

S3. Conduct research on the biology of *P. robinii.*

S3.1. Study the reproductive biology of *P. robinii*.

S3.2. Conduct genetic studies to document genetic variation within and between populations.

S3.3. Determine population size and viability of all populations.

S3.4. Study the response of *P. robinii* to habitat management treatments.

S3.5. Characterize the habitat and identify suitable sites for experimental outplantings.

S4. Monitor *P. robinii* populations. Annual monitoring is the primary means to determine whether management practices are effective and what changes are needed. Inventories should detect changes in health, abundance, distribution, and threats.

S4.1. Conduct long-term monitoring of the status of *P. robinii.* Use existing monitoring protocols to record baseline data regarding the biology and ecology of *P. robinii,* its presence/absence, range and distribution, degree of abundance, and health every year until recovered. Determine the effect of management actions on *P. robinii*.

S4.2. Monitor the status of known pollinators. Once pollinators are determined, monitor the status of their populations, distribution, and habitat. Include pollinators in the development of management strategies and reserve design.

S4.3. Collect and archive existing and historical data.

S5. Increase public awareness and instill stewardship. Develop informational materials and host public workshops to increase awareness about *P. robinii* and instill a sense of stewardship for the protection of this endangered species. Conduct outreach efforts on national wildlife refuge properties and the State Recreation Area, through the Monroe County school system, and through press releases to emphasize the importance of the plant community, the conservation ethic, and Federal and State regulations and laws, including penalties for collection and vandalism.

S5.1. Prepare informational material for the general public. Distribute materials at visitor information centers and local chambers of commerce.

S5.2. Inform Federal and State personnel regarding the presence of *P. robinii*, its protection under the ESA, methods to manage populations, and ways to minimize impacts.

S6. Establish reclassification and delisting criteria. Develop measurable reclassification criteria based on the factors that would produce a stable or increasing population, including total population size, number of subpopulations, habitat condition and availability, and level of threats. Evaluate and monitor *P. robinii*'s status in relation to reclassification criteria. Refine recovery goals. It is necessary to establish a realistic recovery objective for the species based on its biological characteristics. Recovery objectives should be re-evaluated and revised as necessary. Determine additional actions necessary to achieve the recovery objective. These actions must include legal protection, research, habitat protection, and other management strategies necessary to achieve recovery.

Habitat-level Recovery Actions

H1. Conserve existing habitats. The survival and recovery of *P. robinii* depends on preserving enough suitable habitat to achieve the recovery goals. The habitat of *P. robinii* must be maintained, including the plant species diversity of the hammock and the ecological integrity of the individual site. Coordinate with regulatory and land management authorities and private entities to ensure their actions will not affect the cactus or its habitat.

H1.1. Acquire habitat. Acquire and protect occupied habitat within historic range. Acquire the plant's suitable unoccupied sites that contain habitat associations important to *P. robinii*.

H1.1.1. Continue Federal acquisition efforts. Continue to acquire habitat within the National Key Deer Refuge boundaries. The Land Protection Plan for National Key Deer Refuge recommends fee title acquisition of *P. robinii* habitat within the approved refuge boundary. Acquire and incorporate private sites into the National Key Deer Refuge.

H1.1.2. Support State acquisition efforts. Continue to support the acquisition of state lands by programs such as Florida's Conservation and Recreation Lands (CARL) program.

H1.1.3. Support and encourage land acquisition by non-governmental agencies. Habitat not listed for Federal, State, or county acquisition may become available for private purchase and management by such organizations as The Nature Conservancy and Florida Keys Land Trust.

H1.2. Protect and manage *P. robinii* on private and public lands. The recovery of *P. robinii* depends on active protection and management of both occupied and unoccupied habitat on private and public lands. Protect and manage habitat through conservation agreements with landowners, exotics removal, enhancement, and selective canopy removal for light requirements. Coordinate with county and State agencies to develop and implement appropriate management practices.

H1.2.1. Prevent detrimental land-use changes within hardwood hammocks. Ensure proposed land use changes on sites supporting *P. robinii* are consistent with recovery of this species. Coordinate with Monroe County and State agencies on land-use guidelines.

H1.2.2. Prevent land clearing. Clearing of hammocks destroys existing and potential cactus habitat. Prohibit activities that injure or kill *P. robinii* or disturb occupied habitat.

H1.2.3. Prevent disturbance of surface mining. Rock mining within hardwood hammocks destroys the vegetation and may disturb the freshwater lens. Prohibit surface mining that impacts *P. robinii* and its habitat.

H1.2.4. Prevent subsurface saltwater intrusion. Fracturing of the limestone substrate by blasting or excavating channels allows salt water to enter the hammocks resulting in destruction of hammock species.

H1.2.5. Fence or barricade areas. Protect sites by fencing gates or other means to exclude potential collectors and vandals from occupied habitat. Coordinate with private landowners as well.

H1.2.6. Remove invasive exotic vegetation. Invasion of hardwood hammocks by exotic vegetation such as Brazilian pepper and Australian pine threatens the ecological integrity of the hammock ecosystem. Remove individual exotic plants.

H2. Restore areas to suitable habitat. The integrity of hardwood hammocks is important to protect existing populations and provide for future reintroduction sites. Restore and create habitat in areas occupied by *P. robinii* or in proposed reintroduction sites.

H2.1. Eliminate physical degradation of habitat and restore to optimal conditions.

H2.2. Implement management plans for sites including *P. robinii* and modify as necessary for the species.

H2.3. Continue to refine management practices for *P. robinii* and its habitat. *P. robinii* grows well in hardwood forests with an open canopy. As tropical hardwood hammocks mature, or as natural thinning occurs, the suitability for *P. robinii* is altered. Enhance suitable habitat by creating an open canopy. Investigate other habitat management practices that may benefit *P. robinii*.

H3. Conduct research on habitat-level ecological processes. *P. robinii* grows in lightly shaded, well-drained sites and often occurs in disturbed patches of hammock. Investigate the relationship of *P. robinnii* to its habitat.

H3.1. Assess important characteristics of *P. robinii* habitat. Major requirements for successful growth of *P. robinii* include an open canopy and freedom from frequent floods or frequent fires.

H3.2. Develop a GIS database on *P. robinii* and its habitats. Distribute the database to researchers, land managers, and conservationists. Estimate canopy cover and shadiness. Correlate growth forms with plant-specific conditions and recent fire and hurricane history. Determine what constitutes optimal canopy cover.

H3.2.1 Assess the available GIS data.

H3.2.2. Create and distribute coverages of population locations.

H3.2.3. Acquire recent imageries of the sites.

H3.3. Investigate the effect of habitat change. Alterations in canopy cover, light levels, and hydrology will affect growth and survival rates. Investigate natural and human-induced effects on hammocks and evaluate the response in terms of canopy, successional retardation, increased susceptibility to windthrow, and changes in species composition.

H3.3.1. Evaluate patterns of habitat response to hurricanes and the implications on *P. robinii* populations. Identify the effects of past hurricanes on hardwood hammocks and make predictions of likely responses to future hurricanes. Determine what information is needed to help evaluate the effects of a future hurricane on hammocks and *P. robinii*.

H3.3.2. Investigate the relationships of exotic vegetation. Exotic vegetation can outcompete and inundate certain hammock species. Determine the effects exotic vegetation have on hardwood hammocks and *P. robinii*.

H3.4. Determine the level of habitat fragmentation. Populations of *P. robinii* presently occur on Upper Matecumbe Key (two populations), Lower Matecumbe Key (one population), Long Key (three populations), and Big Pine Key (two populations). The separation of these populations may affect the ability of this species to persist. Evaluate habitat fragmentation and how it affects the survival of *P. robinii*.

H3.4.1. Investigate the historic distribution. Determine what geographic range is necessary to recover this species.

H3.4.2. Determine minimum habitat area required for a stable or increasing population. Populations of this species fluctuate from site to site depending upon the availability of suitable habitat. Investigate minimum habitat area requirements.

H3.4.3. Determine the amount and configuration of habitat necessary to support a stable or increasing population of *P. robinii.* Only two populations are believed to be self-sustaining. Investigate the configuration of occupied and unoccupied habitat and determine what is sufficient to recover this species.

H4. Monitor the status of *P. robinii* habitat. Conduct yearly monitoring evaluations of *P. robinii* habitat. Overlay habitat quality with GIS mapping of habitat locations, including what patches are being altered or lost each year. Monitor the availability of *P. robinii* habitat by updating the loss or change of habitat due to residential or commercial construction through GIS.

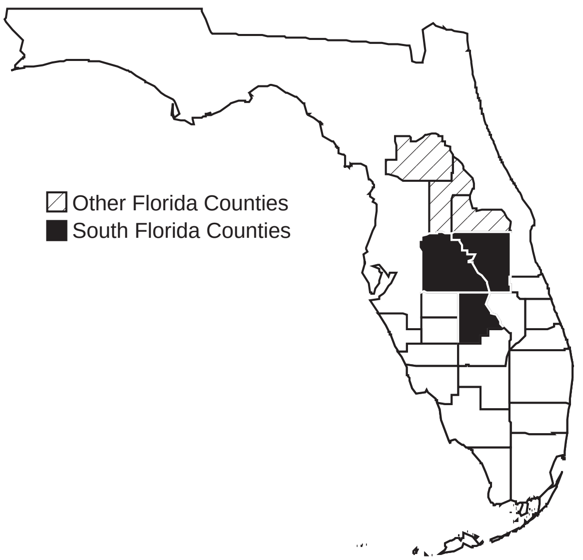
H5. **Increase public awareness of *P. robinii* habitat and instill stewardship.** Conduct workshops with the public to educate private landowners on appropriate management practices to preserve *P. robinii* habitat. Encourage private landowners to remove exotics, maintain natural hydrology, refrain from destroying habitat, and restore disturbed areas. Prepare literature to provide information regarding *P. robinii* habitat and ways to protect and conserve it.

Lewton's Polygala

Polygala lewtonii Small

Federal Status:	**Endangered (April 27, 1993)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of Lewton's polygala.



Lewton's polygala is a perennial herb that occurs in oak scrub and in high pine, but is more common in the transitional areas between these two community types. Oak scrub and high pine have been and continue to be destroyed for agriculture and residential housing construction. As with many other rare endemic plants, protection of this species must be achieved through habitat acquisition and implementation of appropriate land management measures to protect the structure and composition of oak scrub and high pine communities.

This account represents a revision of the existing recovery plan for Lewton's polygala (FWS 1996).

Description

Polygala lewtonii is a relatively short-lived (5 to 10 year) perennial herb. Each plant produces one to several annual stems, which are spreading, upward-curving or erect, and are often branched. The leaves are small, sessile, rather succulent, broader toward the tip, and are borne upright, tending to overlap along the stem, like shingles. The normally opening flowers are in erect, loosely flowered racemes about 1.5 cm (Wunderlin *et al.* 1981) or 3.3 cm (Weekley 1996) long. The flowers are about 0.5 cm long and bright pink (Wunderlin *et al.* 1981) or purplish-red (Ward and Godfrey 1979). Two of the five sepals are enlarged and wing-like, between which the largest of the three petals forms a keel that ends in a tuft of finger-like projections (Ward and Godfrey 1979). The plant also produces two types of small, cleistogamous (non-sexual) flowers (L. Miller, Ocala NF, personal communication 1996,Weekley 1996). This species is closely related to the widespread *P. polygama*, which forms larger clumps and has a longer root, narrower leaves, and differently shaped wing sepals. It also has short branches that hug the ground, bearing inconspicuous self-pollinating flowers.

Taxonomy

This small herb was first collected near Frostproof, Florida by F. L. Lewton in 1894, and was named by J.K. Small (1898). The status of *P. lewtonii* as a distinct species was affirmed by Blake (1924) and James (1957). There have been no other taxonomic treatments of this species.

Distribution

Polygala lewtonii occurs in oak scrub and high pine communities of Highlands, Polk, Osceola, Orange, Lake, and Marion counties (Figure 1), within the Lake Wales and Mount Dora ridges of central Florida.

Habitat

Polygala lewtonii is not strictly a scrub species and is found in widely scattered populations that frequently occur in transitional habitats between high pine and turkey oak barrens. *P. lewtonii* also occurs in both habitats (Wunderlin *et al.* 1981, Christman 1988). *P. lewtonii* depends on fire to maintain its habitat. It is found in sunny openings and often colonizes disturbed sites, such as roadsides and fire lanes. *P. lewtonii*'s preference for transitional habitats between high pine and turkey oak barrens suggests a preference for a burn frequency that is less frequent than high pine, but more frequent than turkey oak barrens.

Reproduction

Confusion has existed about whether *P. lewtonii* has cleistogamous flowers (James 1957, Wunderlin *et al.* 1981, Ward and Godfrey 1979, FWS 1996). More recently, Weekley (1996) and Miller (Ocala NF, personal communication 1996) confirmed the presence of two types of cleistogamous flowers. The first are solitary flowers in the axils of the lower leaves and the second are few-flowered racemes on underground rhizomes that are usually 5 to 15 cm long (Weekley 1996).

Polygala lewtonii blooms from February to May with chasmogamous flowers dominating from February to April. Chasmogamous flowers have an average of four to six racemes per plant, though one extreme individual had 30 racemes (Weekley 1996). Each raceme has 20 to 25 flowers 85 to 100 percent of these set fruit. This high percentage of fruit set suggests that flowers self-pollinate when insect pollinators are not present. A variety of insects have been observed visiting *P. lewtonii,* but insect pollinators of this plant are unknown (Weekley 1996).

Relationship to Other Species

Polygala lewtonii can be found with other federally listed plants: *Warea amplexifolia* in high pine in central Florida, *Ziziphus celata*, *Prunus geniculata*, and *Nolina brittoniana* in the scrub, and *Eriogonum longifolium* var. *gnaphalifolium* in scrub, high pine, and the ecotones between these

Lewton's polygala.
Original photographs by Steve Shirah.

habitats.

The pollinators for Lewton's polygala are unknown, though a variety of insects are frequent visitors, including butterflies (Lepidoptera), flies (Diptera), and wasps (Hymenoptera). Seeds of this species are probably dispersed by ants, but this relationship has not been confirmed (Weekley 1996).

Status and Trends

Polygala lewtonii was listed as an endangered species on April 27, 1993, due to land conversion and habitat destruction for agriculture and residential housing construction (58 FR 25754). It is estimated that Florida has lost 88 percent of its high pine habitat and 59 percent of its scrub communities since settlement by Europeans (Kautz *et al*. 1993). As habitat loss continues, the limited geographic distribution of the scrub plant species, the fragmentation of remaining habitat, and the small numbers of individuals in remaining habitat, exacerbate other threats faced by this species (58 FR 25754). For example, small tracts of scrub are degraded by trash dumping, recreational use of off-road vehicles, and disturbance caused by harvesting of rusty lyonia (*Lyonia ferruginea*) stems for the silk-plant industry. In publicly owned high pine habitat, all-terrain vehicles and motorcycles severely impact *P. lewtonii* and other listed species.

Polygala lewtonii is easily overlooked and often confused with *P. polygama.* Its identification requires scrutiny during surveys. With more survey work, *P. lewtonii* may prove to be somewhat less rare and spotty in occurrence than indicated by existing surveys. For example, intensive surveys identified 48 occurrences of *P. lewtonii* in Ocala NF (Clutts 1995). However, habitat loss has been severe throughout its range, especially in Lake County, where large areas of high pine once supported a number of endangered plants, including *Prunus geniculata, Nolina brittoniana* (Wunderlin *et al.* 1981), and *Warea amplexifolia* (Judd 1980). Today this habitat is nearly gone.

In South Florida, an aggressive land acquisition program is underway to conserve the remaining parcels of natural habitats along the central ridges. There are six protected sites in Polk and Highlands counties. The largest site in South Florida is Carter Creek, which has not been acquired yet. Acquisition of this site is crucial to the security of this plant.

Protected sites for *P. lewtonii* include: Ocala NF, Lake Wales Ridge SF, Arbuckle SP, Catfish Creek SP, Tiger Creek Preserve, Pine Ridge Preserve at Bok Tower Gardens, and Highlands Hammock SP. These sites represent only a small fraction of habitat that was once available.

Management

Polygala lewtonii occurs in the highly fire-dependent high pine community and the less-frequently burned oak scrub community. It seems to favor the ecotonal habitat where the burn frequency is highly variable. In general, this species responds favorably to fire, as it resprouts quickly and there is an increase in seedling recruitment. After an initial increase in recruitment, populations tend to fluctuate widely. However, large changes in population size coupled with its cryptic nature makes monitoring difficult in many situations. Though more research is needed on the species' response to different fire frequencies and intensities, it is clear that periodic fire is needed for the persistence of this species.

Polygala lewtonii may have experienced some degree of range expansion due to artificial fire regimes (Clutts 1995). The practice of winter burning may have allowed *P. lewtonii* to expand its distribution from scrub vegetation into high pine. Winter burns prohibit the sexual reproduction of wiregrasses in the high pine habitat and have resulted in an increase in the openings that would have naturally occurred in this habitat. More open areas favor establishment and persistence of *P. lewtonii*. Ocala NF personnel are studying this relationship.

Because of *P. lewtonii*'s presence in Ocala NF, prospects for conserving this species are probably quite good. In the Lake Wales Ridge, the south portion of Carter Creek has the largest known population and acquisition of this site is possible. Continued surveying for this species should include areas with large tracts of turkey oak barrens and the ancient dunefields on the east side of the Lake Wales Ridge in Polk and Highlands counties (K. DeLaney, Environmental Research Consultants, Inc., personal communication 1995).

Literature Cited

Blake, S.F. 1924. Polygalaceae in North American flora 25(4,5):305-374.

Christman, S. 1988. Endemism and Florida's interior sand pine scrub. Final project report, project number GFC-84-101. Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Clutts, J. L. 1995. Letter from National Forest Service to the U.S. Fish and Wildlife Service. 5 October 1995. On file at the U.S. Fish and Wildlife Service; Vero Beach, Florida.

DeLaney, K. 1995. FWS Multi-Species Recovery Team meeting. December 6-8, 1995.

James, C.W. 1957. Notes on the cleistogamous species of *Polygala* in southeastern United States. Rhodora 59:51-56.

Judd, W.S. 1980. Status report on *Warea amplexifolia*. U.S. Fish and Wildlife Service; Jacksonville, Florida.

Kautz, R.S., D.T. Gilbert, and G.M. Mauldin. 1993. Vegetative cover in Florida based on 1985-1989 Landsat thematic mapper imagery. Florida Scientist 56(3):135-154.

Miller, L. 1996. Letter. 1 April 1996.

Small, J.K. 1898. Studies in botany of the southern [southeastern] United States. Bulletin Torrey Botanical Club 25:134-181.

U.S. Fish and Wildlife Service. 1996. Recovery plan for nineteen central Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Ward, D.B. and R.K. Godfrey. 1979. Lewton's polygala. Pages 50-51 *in* D.B. Ward ed. Rare and endangered biota of Florida, volume V, Plants. University Presses of Florida; Gainesville, Florida.

Weekley, C. 1996. Some observations on the reproductive biology of *Polygala lewtonii*. Florida Plant Conservation Program/ Division of Forestry; Tallahassee, Florida.

Wunderlin, R.P., D. Richardson, and B. Hansen. 1981. Status report on *Polygala lewtonii*. Report to U.S. Fish and Wildlife Service; Jacksonville, Florida.

Recovery for the Lewton's Polygala

Polygala lewtonii Small

Recovery Objective: RECLASSIFY to threatened.

Recovery Criteria

Polygala lewtonii may be reclassified from endangered to threatened when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations and sites needed to assure 20 to 90 percent probability of persistence for 100 years; when these sites, within the historic range of *P. lewtonii*, are adequately protected from further habitat loss, degradation, and fragmentation; when these sites are managed to maintain the seral stages of high pine and xeric oak scrub to support *P. lewtonii*; and when monitoring programs demonstrate that these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution and status of *P. lewtonii.* This species' distribution is somewhat questionable since individuals are easily overlooked. A thorough survey is needed to determine the distribution for this species.

S1.1. Conduct surveys for populations of *P. lewtonii*.

S1.1.1. Survey scrub, high pine, and turkey oak habitats in Osceola and Hardee counties. Adequate survey work has not been performed off the Lake Wales Ridge. Sites on private property cannot be protected without survey knowledge.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. Maintain distribution of known populations and suitable habitat in GIS database. Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, has become isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. Protect populations on private land through acquisition, conservation easements, or agreements with landowners.

S2.2. Protect populations on public lands. Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. Develop *ex situ* collection. *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species.

S2.4. Enforce available protective measures. Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *P. lewtonii* lives.

S2.4.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.4.2. Enforce take prohibitions. This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. Conduct research on life history characteristics. Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species, more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *P. lewtonii*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring on the localities of *P. lewtonii* sites, will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S4. Monitor existing populations of *P. lewtonii*.

S4.1. Develop monitoring protocol to assess population trends for *P. lewtonii*.

S4.1.1. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival, and mortality. Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. Monitor the effects of various land management actions on *P. lewtonii*. Assess any changes in demographic characteristics of *P. lewtonii* in response to land management activities, such as prescribed fire, exotic plant control, *etc.*

S4.2. Develop a quantitative description of the population structure of *P. lewtonii*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for collect individual plants, data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors).

S5. Provide public information about *P. lewtonii*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. Care is needed, though, to avoid revealing specific locality information about *P. lewtonii.*

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *P. lewtonii* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there are six protected or acquisition sites for *P. lewtonii* in South Florida.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. Since little xeric scrub habitat is remaining for this species, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *P. lewtonii* populations by preventing damage from off-road vehicle use and overcollection, and by providing proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *P. lewtonii*.

H1.2.3. Control access to areas where listed plants are growing. Collection, trampling, and off-road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *P. lewtonii* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc*., on the habitats where *P. lewtonii* occurs.

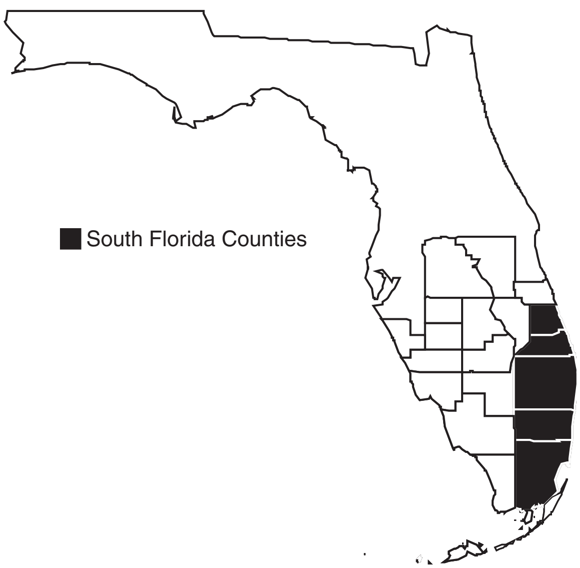
H5. Provide public information about scrub and its unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the SFWMD, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Tiny Polygala

Polygala smallii Smith and Ward

Federal Status:	**Endangered (July 18, 1985)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of the tiny polygala.



Polygala smallii is in the family Polygalaceae, commonly referred to as the milkworts. It was once thought to be endemic to Miami-Dade and Broward counties, but recent surveys have extended its range to southern St. Lucie County. All 11 known populations are found within 9.7 km of the Atlantic Coast. The tiny polygala or Small's milkwort is a short-lived herb. The only known populations occur in sand pockets of pine rocklands, open sand pine scrub, slash pine, high pine, and well-drained coastal spoil. Within these habitats, it requires high light levels and open sand with little to no organic litter accumulation. The survival and recovery of *Polygala smallii* is threatened by habitat loss from urban development, fire suppression, and exotic plant infestation.

This account represents a revision of the existing recovery plan for the tiny polygala (FWS 1988).

Description

Tiny polygala is an erect short-lived herbaceous species. Most plants germinate and die within one year. It forms a rosette and grows no more than 8 cm tall (Kennedy 1998). It has one to four, short, usually unbranched stems, and a well-developed, scented taproot. Its leaves are oblanceolate to lanceolate, from 1.5 to 5 cm long and 0.2 to 1.4 cm broad and occur in a basal rosette. The inflorescence is a cylindric raceme from 0.4 to 7 cm long and 0.5 to 1.8 cm thick and usually surpassed by the basal leaves (Kennedy 1998) The flowers have both functional stamens and pistils (perfect) and are not radially symmetrical (zygomorphic). The calyx has five sepals. The lateral pair is decurrent, large and petaloid. The corolla is a greenish-yellow color with three petals. The fruit is a thin-walled, two-celled capsule that splits down the center of the compartment. The seed is 1.2 to 1.4 mm long, with sparse rather short, stiff, appressed hairs (strigose). It also has a pair of aril-like outgrowths about half the length of the capsule (Gann and Bradley 1995, Smith and Ward 1976).

Taxonomy

J.K. Small first described tiny polygala as *Polygala arenicola* (Small 1905; type specimen at New York Botanical Garden, Small #1276). The specific epithet was later found to be invalid due to its prior use in 1903 by Gurke in describing another species of *Polygala* from southeast Africa (Smith and Ward 1976). In 1933, Small revived the segregate genus *Pilostaxis* Raf., and renamed tiny polygala *Pilostaxis arenicola* (Small) Small. The genus *Pilostaxis* has since fallen out of use, but represents the series *Decurrentes*, a natural group of seven species of *Polygala* found only in the southeastern U.S. (Smith and Ward 1976). Long and Lakela (1971) considered tiny polygala to be conspecific with *Polygala nana* (Michx.) DC., a species widely distributed in the southeastern U.S., but in 1976, Smith and Ward defended the specific status of tiny polygala, recognizing distinct characters of the seeds, lateral sepals, flower color, and leaves, and proposed *Polygala smallii* Smith and Ward as a nomen novum.

Synonyms: *Polygala arenicola* Small, non Gurke; *Pilostaxis arenicola* (Small) Small; *Polygala nana* auct., non (Michx.) DC.

Distribution

Prior to 1995 *P. smallii* was thought to be a local endemic of pine rocklands and scrub in Miami-Dade and Broward counties, Florida (Smith and Ward 1976, Austin, *et al*. 1980). Extensive surveys conducted in 1995 by Gann and Bradley expanded the known range of tiny polygala to the north. It is now known to occur on the Atlantic Coastal Ridge of southeast Florida, from the Perrine area of Miami-Dade County north to southeast St. Lucie County (Figure 1). In some populations in Palm Beach and Martin counties, *P. smallii* co-occurs with its closest congener, *P. nana*. *P*olygala *nana* does not occur south of Broward County (S. Kennedy, Florida International University 1999). The historic distribution of tiny polygala to the north is uncertain; it possibly ranged as far north as central Brevard County (derived from E. Palmer, s.n., 1874, labeled “Indian River,” New York Botanical Garden Herbarium).

Habitat

Tiny polygala occurs in four distinct habitats with similar characteristics: pine rockland, scrub, high pine, and open coastal spoil (Gann and Bradley 1995). All of these habitats are pyrogenic-extremely dry and prone to periodic natural fire. Pine rocklands historically burned every 2 to 15 years (Snyder *et al*. 1991). Sand pine scrub and sandhill burn less frequently, possibly every 10 to 50 years.

Miami-Dade County populations of tiny polygala occupy sand deposits within the pine rocklands that are primarily in the southern portion of the county. The depth of the sand deposits ranges from 2 mm to greater than 90 cm (Kennedy 1998). The sand deposits are interspersed throughout the pine rockland’s Opalocka Rock Outcrop soil complex. No plants were found in soil shallower than 2.0 cm. *Polygala smallii* occurs in areas with significantly shallower litter deposits than the surrounding pine rockland habitat. No plants

Tiny polygala.
Original photograph by Deborah Duval.

occurred in litter deeper than 2.5 cm (DERM 1996, Kennedy 1998).

The overstory canopy of the Miami-Dade County population is composed of South Florida slash pine (*Pinus elliottii* var. *densa*), several species of oaks, (*Quercus pumila*, *Q. minima*, *Q. virginiana)*, and tallow-wood (*Ximenia americana).*

The Broward County population occurs in sand pine scrub which regenerated following clearing in the late 1970s. The soils are St. Lucie fine sand, at an elevation of 2.8 m, and have little to no slope. The tree canopy is composed of sand pine (*Pinus clausa*) with a shrub understory of rosemary, scrub live oak (*Quercus geminata*), myrtle oak (*Quercus myrtifolia*), Chapman oak (*Quercus chapmanii*), and dwarf cabbage palm (*Sabal etonia*). Commonly associated herbs and graminoids include: *Paspalum graminifolia, Selaginella arenicola, Rhynchosopora megalocarpa,* and *Licanis michauxii.* Deer moss and soldier moss (*Cladonia* spp. and *Cladina* spp.) are also common groundcover components (Gann and Bradley 1995).

The Palm Beach County population occurs in a scrubby flatwoods association that became established on spoil dredged from the intracoastal waterway prior to 1940. The spoil is relatively well-drained Quartzipsamments, with an elevation of 1.2 m and little to no slope. The tree canopy is dominated by sand live oak (*Quercus geminata*), tallow wood (*Ximenia americana*), sand pine, and slash pine. Other common species include myrtle oak, cocoaplum, saw palmetto, silk grass (*Paspalum graminifolia*), partridge pea (*Chamaecrista fasciculata*), and *Dichanthelium portoricense* (Gann and Bradley 1995).

One Martin County population occurs in turkey oak sandhill with Pomello sand, at an elevation of 1.2 m. The tree canopy is composed of South Florida slash pine and turkey oak with a shrub understory of dwarf live oak, Chapman oak, and myrtle oak. Some of the associated herbs and graminoids are: *P. nana*, *Rhynchospora plumosa, Aristida beyrichiana, Eriocaulon ravenelii, Liatris chapmanii,* and *Satureja rigida.* The second Martin County population is on a disturbed north-facing slope of Paola Sand between a sand pine scrub association and a lake. The canopy is composed of a mix of South Florida slash pine and sand pine with no shrub layer. The herb layer is depauperate, composed mostly of silk grass.

The St. Lucie County population occurs on a scrubby flatwoods knoll in Hobe Sand soils. Site elevation is 2.0 to 3.0 m and gently slopes to a mesic flatwoods and marsh area. Canopy trees include sand pine, slash pine, and scrub live oak. Other members of this vegetative community include: saw palmetto, staggerbush, myrtle oak, wiregrass (*Aristida beyrichiana*), silk grass, and wireweed (*Polygonella gracilis*) (Gann and Bradley 1995).

Reproduction

Tiny polygala seedlings can be observed from late October through April, but are most typically seen from December to February (DERM 1996). Populations in Miami-Dade County appear to have two germination periods, a short one in June and a longer one between September and January (Kennedy 1998). Thus, seedlings can be germinating for 6 months out of the year, resulting in plants maturing at different times of the year, and overlapping generations within years. In populations, flowers appear throughour the year with a peak during summer. Also, seeds are produced year-round.

Approximately one year following appearance of seedlings, plants show a marked reduction in condition, apparently allocating resources to flowering instead of growth or self-maintenance. By July, approximately 18 months after the first seedlings are observed, remaining plants senesce and die (DERM 1994).

Pollination in tiny polygala has not been observed in 2.5 years of monitoring (Kennedy 1998), or in 3 years of monthly life history monitoring (DERM 1994). Zomlefer (1991) reports that self-pollination may occur in species of *Polygala* which have a tuft of hairs on the sterile apical lobe of the stigma. These hairs catch pollen when the anthers dehisce, and, as the flower develops, these hairs may touch the receptive lobes of the stigma, transferring pollen. Tiny polygala has these hairs (Smith and Ward 1976) and may be self-pollinating.

Tiny polygala seeds have paired, fleshy outgrowths, a typical adaptation to ant dispersal. Oostermeijer (1989) reports that a similar species *Polygala vulgaris* L. is a specialist in ant dispersal. Also, ants have been observed carrying tiny polygala seeds to their nests on several occasions in Miami-Dade County (K. Bradley, Institute for Regional Conservation, personal communication 1996). The seeds have a bilobed aril attached to the caruncle. This bilobed aril was suggested by some to be an elaisome, a structure that contains lipids that are attractive to ants. Kennedy (1998) reports observing ants going into the flowers and removing and transporting seeds by the arils. After applying Sudan IV stain to the arils, she determined that they do not contain lipids; rather the arils appear to be hollow sacs. It is unclear why the ants are moving the seeds, *Polygala smallii* seeds are able to float in water for extended periods (over three weeks) (Kennedy 1998). The hairs on the seed coat appear to provide most of the buoyancy by trapping air. Since many of the sites where tiny polygala occurs are riparian or riverine and the seeds are buoyant, water may be the primary means of dispersal.

After Hurricane Andrew, tiny polygala was found growing in areas where the soil was turned over or disturbed (*ie.* around uprooted fallen trees). A response to soil turnover may indicate a good seed bank. The seed banks probably occur in more habitat types than previously thought.

Relationship to Other Species

Tiny polygala likely has specific relationships to many species. Research on this species has not identified pollinators, or seed dispersers. Although ants have been observed to take seeds of this species back to their hills, the exact nature of the relationship between ants and this small herb is unknown. Hopefully, research needs outlined in this recovery plan will identify the interspecific relationships of this species and other members of this community.

Status and Trends

Until recently, tiny polygala was thought to be endemic to the pine rocklands and scrub of Miami-Dade and Broward counties, Florida (Smith and Ward 1976). However, new populations have been found in recent surveys by Gann and Bradley (1995) that have extended the range to the north about 21 km, and suggest this plant may occur in other vegetative communities.

The first known collection of *P. smallii* was made by Edward Palmer in 1874 (Herbarium of the New York Botanical Garden). The herbarium label reads "East Florida. Indian River." The Indian River extends from central Brevard County south to central Martin County. This collection was originally determined to be *P. nana* and later identified as *P. smallii* by C. Nauman. The next collections of *P. smallii* were made by A.P. Garber from "Miami" in 1877 (New York Botanical Garden and University of Florida herbaria). Additional collections in the Miami area were not made until 1903 (J.K. Small in Miami-Dade County "Between Coconut Grove and Cutler"). In November of 1903, Small collected tiny polygala in Broward County (New York Botanical Garden). Small made one more collection, from Miami-Dade County (New York Botanical Garden).

These collections show that Miami-Dade County populations once occurred from at least Arch Creek to the Cutler Ridge area. Assessment of the historical status of tiny polygala outside of Miami-Dade County is very difficult, since it was collected only two times before 1973, once in Fort Lauderdale and once at "Indian River." Upland habitats throughout its range along the Atlantic coast of peninsular Florida have been destroyed over such a large area, only a few scattered populations of this species remain.

Tiny polygala is currently known from 11 populations. Seven of these populations are on public land and are protected. Population sizes of tiny polygala can exhibit annual fluctuations as much as several hundred percent (season to season) (Gann and Bradley 1995, DERM 1994). Miami-Dade County DERM has been monitoring six populations in Miami-Dade County for 3 years and has not found any clear population trends.

Although effects of burning on *P. smallii* have not been thoroughly investigated, pine rockland habitat must be burned periodically to maintain an open, sunlit environment and to reduce organic litter accumulations. Fire suppression allows hardwood succession and litter accumulation that will eventually overshade and eliminate shade-intolerant herbaceous species. Exotic plant invasion will also out-compete scrub community species, and will eventually eliminate the tiny polygala. In Miami-Dade County pine rocklands, Burma reed (*Neyraudia reynaudiana*) is the greatest threat. This grass is now present in almost every pine rockland fragment and is expanding rapidly. Burma reed is seriously threatening at least two of the Miami-Dade County populations. Other species, including Brazilian-pepper (*Schinus terebinthifolius*), earleaf acacia (*Acacia auriculaeformis*), and natal grass (*Rhynchelytrum repens*) are problems in upland habitats throughout the range of tiny polygala.

The publicly owned populations seem to be significantly threatened by direct human impacts, primarily due to heavy foot and bicycle traffic.

Management

Of the 11 tiny polygala populations, seven occur on public sites with active management. The four other populations occur on private property. Two of these four populations are being managed as preserves; one is designated for acquisition and development by the DOT, and one is designated for acquisition by the St. Lucie County land acquisition program.

The Palm Beach County population of the tiny polygala is protected in the 108 ha Jupiter Ridge Natural Area. This site is owned by the State of Florida (former CARL project) and leased to Palm Beach County for management. The management plan addresses the needs of the tiny polygala.

The Miami-Dade County Parks and Recreation Department is managing exotic plant infestations at two tiny polygala sites, including the removal of Burma reed and Brazilian pepper; however, a fire management program has not been fully implemented. A management plan is currently being developed for the third publicly-owned Miami-Dade County site. This management plan will include provisions for fire management and exotic plant removal.

One of the Martin County sandhill populations is being burned regularly and exotic plants are not threatening this population. The second Martin County population is not being managed, although the Florida Park Service is developing a management plan for this site.

The fire ecology of *P. smallii* is not well understood. Since it is a short-lived plant with a shallow root system, fire kills it, and it must return from the seed bank. Field observations at a site in Martin County found *P. smallii* seedlings germinating a few months after a wildfire. The storm surge of Hurricane Andrew in August 1992 washed over one population of tiny polygala in Miami-Dade County on the eastern edge of the Miami Rock Ridge very close to Biscayne Bay. This population increased from about three plants before the storm to a dozen the next year (DERM 1994).

The seed bank of *P. smalii* may be the key to survival for this species. It has a very long-lived seed band; persistent seeds take over 1 year to germinate. Kennedy (1998) discovered that seeds buried in the soil within a natural population had an average viability rate of 80 percent after 2 years. Thus, the viability rate was nearly the same as the mean viability of fresh seeds. Because viability declined little in 2 years, *P. smallii* may remain viable for decades if buried under the soil surface.

P. smallii exhibits two kinds of dormancy in seeds: innate dormancy and conditional dormancy. Innate dormancy is the inability of fresh seeds to germinate within a few days. In *P. smallii*, it takes freshly produced seeds at least 2 to 3 weeks to overcome innate dormancy and then germinate, regardless of temperature. Seeds that become buried 1 cm or deeper become nondormant when primary dormancy is overcome after rippening. Then, during the winter, some of the buried seeds become conditionally dormant, meaning that they are viable, but will not germinate. In other species that have cycles of conditional dormancy/nondormancy, conditional dormancy prevents germination during unfavorable periods, and allows germination throughout the growing season. Seeds on the soil surface never express conditional dormancy; most germinate during September through January. Those surface seeds that fail to germinate during that period subsequently become inviable. Hopefully, the findings of Kennedy (1998) will encourage more research on seed biology studies and studies on how to stimulate seed bank recruitment in extirpated populations.

Because of the limited amount of habitat remaining for tiny polygala, continued management of the populations in public ownership will be necessary. Monitoring of all populations of tiny polygala is a necessary part of recovery and will tell us the effectiveness of the management practices. However, the natural fluctuations in population size from season to season will make it difficult to interpret the effect of management actions. Monitoring for tiny polygala should focus on the habitat, including the responses of other species to management actions, and the structural and compositional characteristics of other scrub-dependent species. Information collected from ongoing studies on the life history of tiny polygala will refine monitoring and management techniques.

Literature Cited

Austin, D.F., P. Krauss, J. Jones, B.E. Tatje and C.E. Nauman. 1980. Endangered and threatened plant species survey in southern Florida. U.S. Fish & Wildlife Service; Jacksonville, Florida.

Bradley, K. 1996. FWS Multi-Species Recovery Team meeting. 11-12 March, 1996.

Gann, G. and K. Bradley. 1995. Endangered species status survey: *Polygala smallii* Smith & Ward. Tiny Polygala. U.S. Fish & Wildlife Service; Jacksonville, Florida.

Farnsworth, S. 1998. Comments on technical agency draft multi-species recovery plan for South Florida. September 30. 1998.

Kennedy, S. 1998. Seed bank and seedling dynamics of *P. smallii.* Master's Thesis. Florida International University. Miami, Florida.

Kennedy, S. 1999. Comments on technical/agency draft multi-species recovery plan. March 24, 1999.

Long, R.W., and O. Lakela. 1971. A flora of tropical Florida. Banyan Books; Miami, Florida.

Miami-Dade County Department of Environmental Resource Management [DERM]. 1994. Annual Report. Endangered pine rockland plant species recovery project. Unpublished report prepared for the U.S. Fish and Wildlife Service; Jacksonville, Florida.

Miami-Dade County Department of Environmental Resource Management [DERM]. 1996. Endangered Plants of Miami-Dade County's Pine Rocklands, Habitat Characterization for *Amorpha crenulata*, *Euphorbia deltoidea*, and *Polygala smallii*. U.S. Fish and Wildlife Service; Jacksonville, Florida.

Oostermeijer, J.G.B. 1989. Myrmechochory in *Polygala vulgaris* L., *Luzula campestris* (L.) DC., and *Viola curtisii* Forster in a Dutch dune area. Oecologia 78:302-311.

Small, J.K. 1905. Additions to the flora of Subtropical Florida. Bulletin of the New York Botanical Garden 3:419-440.

Small, J.K. 1933. Manual of the southeastern flora. University of North Carolina Press; Chapel Hill, North Carolina.

Smith, R.R., and D.B. Ward. 1976. Taxonomy of the genus *Polygala* series Decurrentes (Polygalaceae). Sida 6(4):284-310.

Snyder, J.R., A. Herndon, and W.B. Robertson, Jr. 1990. South Florida rockland. Pages 230-274 *in* R.L. Myers and J.J. Ewel, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

U.S. Fish and Wildlife Service [FWS]. 1988. Recovery plan for five Florida pine rockland plant species. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Zomlefer, W. 1991. Flower plants of Florida, a guide to common families. Biological Illustration, Inc. Gainesville, Florida.

Recovery for the Tiny Polygala

Polygala smallii Smith and Ward

Recovery Objective: **PREVENT** extinction, then stabilize.

Recovery Criteria

Polygala smallii will, most likely, never reach a level at which reclassification could be possible. The objective of this recovery plan should be to increase existing populations and prevent extinction. *Polygala smallii* may be considered stabilized when existing populations, within the historic range, are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression. These sites must also be managed to maintain pine rocklands and scrub flatwoods to support *P. smallii*. Monitoring programs should demonstrate that populations of *P. smallii* on these sites support sufficient population sizes, are distributed throughout the historic range, and are sexually or vegetatively reproducing at sufficient rates to maintain the population.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Genetic information is of particular importance to the recovery of *P. smallii*, especially considering the recently identified populations in Martin and St. Lucie counties. Reclassification criteria may be developed if new information identifies ways of re-establishing populations of this species to expand its distribution within its historic range.

Species-level Recovery Actions

S1. **Conduct surveys to determine distribution and status of *Polygala smallii*.** Pine rocklands have been thoroughly surveyed in Miami-Dade County. Additional surveys in the historic range of this plant should be performed in the scrub, sandhill, and open coastal spoil of Broward, Palm Beach, Martin, and St. Lucie counties. Fire eliminates litter concealing species, it may kill seeds in the litter or soil surface, or it may enable seeds in the seed bank to germinate. For that reason, suitable habitats which did not contain listed species when unmanaged should be resurveyed after fire events.

S2. **Protect and enhance existing populations.** It is imperative for the recovery of this species that populations not be lost.

S2.1. **Augment natural populations of *P. smallii*, where appropriate.** The known populations of *P. smallii* are in a precarious situation; therefore, *ex situ* collections of *P. smallii* should be established, if possible. These collections should be used to cultivate plants and augment sparse populations in protected areas. These experiments with reintroductions will be useful in the future, and could be essential for the recovery of this species. Kennedy (1998) was able to germinate *P. smallii* seeds with high germination rates, and grow them through their entire life cycle *ex situ* at Fairchild Tropical Garden.

S2.1.1. **Continue work with *ex situ* propagation and seed banks.** Seeds should be banked for tiny polygala and should be identified precisely as to collection location.

S2.1.2. **Continue to identify potential reintroduction sites and reintroduce plants, where appropriate.** Sites identified as suitable for reintroduction, within the known historic range of this species should be surveyed and prepared to receive plants. Federal lands under proper management regimes may be good recipient sites. These sites should receive reintroduction stock.

S2.2. **Enforce available protective legislation.** State, Federal, and local regulations should be used to protect the pine rockland ecosystem and listed plants.

S2.2.1. **Initiate section 7 consultation when applicable.** Section 7 of the ESA applies to Federal activities which might impact listed species, especially on Federal lands.

S2.2.2. **Encourage implementation of management plans.** Federal agencies are obligated under section 7(a)(1) of the ESA to perform positive conservation programs for the benefit of listed species. Implementation of the Miami-Dade County's Richmond Pine Rocklands Management Plan (DERM 1994) constitutes such a positive conservation program. The Jupiter Ridge Natural Area Management Plan, prepared by Palm Beach County DERM, is another positive conservation program for this species (S. Farnsworth, Palm Beach County DERM, personal communication 1998). The FWS is available to meet with these agencies to discuss and assist in developing management plans for areas not under current management programs.

S2.2.3. **Continue to enforce take prohibitions.** *P. smallii* is protected by take and trade restrictions of the ESA and the Preservation of Native Flora Act.

S3. **Collect biological information important to species recovery.** Additional information on the ecology and life history of *P. smallii* plants needs to be collected.

S3.1. **Determine population size and viability of all populations.** Known populations of *P. smallii* should continue to be evaluated. Population viability needs to be investigated and determined for this species. This work has been initiated by Fairchild Tropical Garden for 2 populations in Miami-Dade County.

S3.2. **Investigate the genetic relationship of distinct Polygala populations.** Populations of *P. smallii* have been identified outside of Miami-Dade County. However, some researchers question the genetic relationship between these populations, since morphological characters alone were used to identify the populations. It is essential to identify their relationship since the plants appear to occur under somewhat similar habitat (dry, well-drained sites), although with different soil types.

S4. Develop standardized monitoring. Standardized monitoring needs to be developed for scrub species in order to determine the effect of management actions on these species.

S4.1. Collect existing and historical data, and place in a central location. Contact former researchers for historical data, gather information from herbaria and museums, and contact all present researchers to compile data and place in GIS database in the South Florida Ecosystem Office. This location will allow all researchers access to both historic and current data and provide the FWS with a means to monitor the success of recovery tasks.

S4.2. Convene a meeting of all researchers. A meeting of current researchers and land managers would enable the FWS to locate information sources and begin the process of compiling those data. The meeting would also afford cooperators an opportunity to discuss monitoring and management procedures and set realistic species-level goals.

S4.3. Monitor status and success of all populations; **change management practices if so indicated.** Because of the varying vegetation conditions and fire histories, different management may be required at different scrub sites. Different prescribed burn intervals may be necessary for best results. Intervals should be adjusted over the years to promote pine re-establishment and hardwood reduction.

S4.4. Monitor reintroduction success and modify procedures as necessary. Plant reintroductions should be monitored to determine the success of the procedure. The goal of reintroduction should be to establish a viable population. Management of the reintroduction sites should be modified as necessary to improve results.

S5. Continue to provide public information about scrub, sandhill, and open coastal spoil habitat and its unique flora. Public support will increase the chances of recovery for these species. Informational and educational materials have been produced. DERM and Miami-Dade County Parks and Recreation Department's Natural Areas Management have developed flyers, displays, newsletters, and press releases for pine rockland habitats, and have held workshops with the general public. Organizations best able to carry out information and education programs include: Metropolitan Miami-Dade County Parks and Recreation Department, the Florida Native Plant Society, Everglades National Park, Miami-Dade County DERM, and Palm Beach County DERM Support of local press coverage should continue.

Habitat-level Recovery Actions

H1. Continue to protect existing pine rockland, scrub, sandhill, and open coastal spoil plant habitats. The decline of the five federally listed pine rockland plants in Miami-Dade County is due to the almost complete elimination or alteration of pine rocklands in South Florida. The coastal scrub, sandhill and open spoil habitats in Palm Beach, Martin, and St. Lucie counties are also undergoing extensive development. Without protection and proper management, the remaining scrub habitat will be developed or will deteriorate.

H1.1. Protect pine rockland habitat. Acquisition of remaining private sites may be the only effective way to protect or conserve pine rockland habitat. Miami-Dade County's Environmentally Endangered Lands program and the State of Florida's CARL program have acquired over 180 ha of pine rocklands in Miami-Dade County since 1990. The State of Florida's CARL program has also purchased sensitive scrub habitat in Palm Beach, Martin, and St. Lucie counties. It should be noted that public lands may still be subject to development for recreational, maintenance, or other purposes. Such disturbances, unless carefully planned, may directly destroy preserved habitats and may secondarily result in exotic plant infestations as well as destructive human uses.

H1.2. Protect or acquire privately owned sites. Less-than-fee-simple acquisition should be used, where appropriate, as an alternative means of protecting scrub, sandhill, and open coastal spoil habitat. Covenants, as provided for under Miami-Dade County regulations, provide tax incentives for private landowners to protect pine rockland sites. A site owned by Florida Power and Light Company may be maintained through cooperation with that utility. Similar programs are being developed for Broward, Palm Beach, Martin, and St. Lucie counties.

H2. Restore areas to suitable habitat.

H2.1. Eliminate physical degradation of habitat and restore to optimal conditions. Physical degradation of scrub, sandhill, and open coastal spoil continues to occur. Hurricane Andrew in 1992 killed most of the adult pines in southern Miami-Dade County, excluding pine stands at Long Pine Key in Everglades NP. The continued degradation of these areas should be curtailed and restoration of uneven-aged pine stands undertaken. Tubelings, or direct seeding experiments may be used to accomplish this task. In order to use direct seeding techniques, collection of local pine seeds must continue.

H2.2. Develop best management practices for scrub, sandhill, and open coastal spoil. This would include development of fire management strategies that would benefit scrub, sandhill, and open coastal spoil species.

H2.2.1. Implement necessary management. Without active fire and exotic plant management, scrub, sandhill, and open coastal spoil will continue to disappear or degrade. Because of the highly fragmented and restricted nature of the remaining scrub, sandhill, and open coastal spoil, intensive management may be necessary at many of the remaining sites.

H2.2.2. Continue to conduct prescribed burns. Fire should be conducted at appropriate times of year to lower fuel loads, although growing season burns should be employed most often after fuel levels are under control. Due to the highly urbanized lands surrounding many of the remaining scrub, sandhill, and open coastal spoil sites, burning involves risks of smoke damage and annoyance, or worse, losing control of the fire. The Florida Division of Forestry has expertise in carrying out controlled burns in these habitats and can assist with burns. Fire management is necessary for all Federal and County scrub lands. Burning sites with *P. smallii* will take extra preparation and monitoring.

H.2.3. Implement additional management to meet habitat needs.

H2.3.1. Eliminate human-caused degradation. Preventing trash dumping or other destructive human activities in scrub, sandhill, and open coastal spoil habitats is important. In order to accomplish this task, fencing and access restrictions may be necessary.

H2.3.2. **Control invasive plant species, particularly exotics.** Burma reed, Cogon grass (*Imperata cylindrica*) and persistent hardwoods need to be controlled and may require special techniques, including herbicide, fire, mechanical, and hand clearing at most sites. Other management needs indicated by ongoing research should also be implemented.

H3. Research additional habitat relationships.

H3.1. Continue to investigate and refine the habitat needs of P. smallii. The habitat needs of scrub species have been studied, but are still not completely understood. The pollination, germination, or other requirements of *P. smallii* have not been fully investigated. Research should address how light levels affect survival and how fire management affects light levels, reproduction, and regeneration of these species.

H3.2. Investigate fire history and incorporate into management strategies. Look at fire history for pine rocklands and scrub, sandhill, and open coastal spoil sites in Miami-Dade, Broward, Palm Beach, Martin, and St.Lucie counties, incorporate into GIS database and analyze relative to healthy populations. This exercise will provide adequate information on fire history and intervals in urbanized and non-urbanized settings and enable assessment of the appropriateness of proposed management regimes in each of the counties.

H4. Monitor sites with pine restoration programs to determine success. A monitoring protocol should be developed and implemented at these sites.

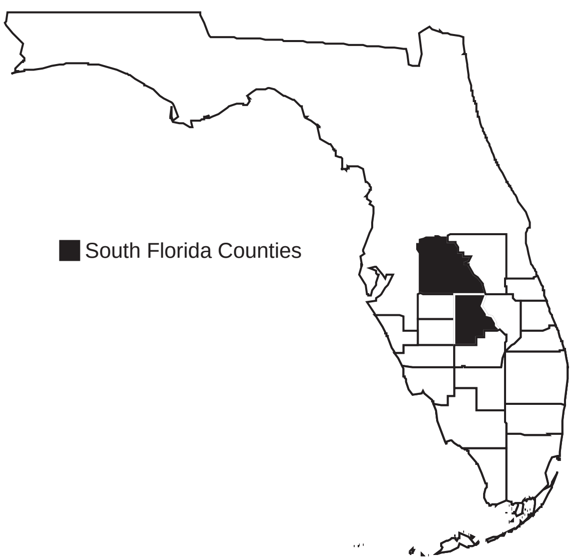
H5. Continue implementation of the fire education program and modify as necessary, any fire management education program that has been developed. Future modifications to this program may include tri-lingual distribution (Spanish, English, and Haitian Creole).

Wireweed

Polygonella basiramia (= ciliata var. *b.)* (Small) Nesom and Bates

Federal Status:	**Endangered (January 21, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of wireweed.



Polygonella basiramia is an herbaceous perennial endemic to the central ridges of the Florida peninsula. One of a suite of herbs found primarily in the rosemary phase of sand pine scrub, *P. basiramia* requires periodic disturbance, such as fire, to maintain habitat suitable for its survival and persistence. Today, the primary threats to this plant are the destruction of scrub vegetation and the lack of large-scale disturbance events.

This account represents a revision of the existing recovery plan for the wireweed (FWS 1996).

Description

The Lake Wales Ridge in central Florida is the center of diversity for the genus *Polygonella*, whose species have remarkably diverse growth habits ranging from tall and leafy, to upright and virtually leafless (wireweeds), to prostrate (Horton 1960). Though it was incorrectly reported as an annual by Lewis and Crawford (1995), *P. basiramia* is a short-lived, perennial herb (Hawkes, University of Pennsylvania, personal communication 1995). When vegetative, the plant consists entirely of basal, compressed stems with narrow, alternate leaves. Ocreae, the sheaths formed at stem nodes, are ciliate. Stems and leaves range in color from green to dark red; red coloration in the stems and leaves appears to be associated with individuals more exposed to sunlight and with older vegetative parts (although even seedlings are often red). As basal stems elongate, plants develop 1 to 46 slender, flowering, spike-like panicles as tall as 0.8 m (Hawkes and Menges 1995). This species is gynodioecious and plants have either only female flowers or hermaphroditic flowers. Individual flowers are small, white to slightly pink with 5 sepals (no petals), pink pistils, and black anthers. The gynoecium consists of 3 united carpels, 1-ovuled, ovary superior. Flowering occurs from the top spikelet downward on each stem. The fruit is a three-sided achene 1 to 3 mm in length.

Polygonella basiramia can be distinguished from *P. ciliata* based on growth form and filaments of the stamens (Nesom and Bates 1984). Whereas *P. basiramia* branches at ground level, *P. ciliata* does not do so until 10 to 50 cm above ground. Both species have basally dilated filaments with an additional basal, bilateral flange. In *P. basiramia*, the short, interwoven trichomes of the flange on each filament together surround the ovary in an undefined mass. In *P. ciliata*, the flanges are sharply defined and appear as flat sheets of tissue (Nesom and Bates 1984).

Taxonomy

Originally named *Delopyrum basiramia* by Small in 1924 (Nesom and Bates 1984), this species was later thought to be a variety of *Polygonella ciliata* by Horton (1963). In 1984 Nesom and Bates recognized *P. basiramia* as a separate species. This species is commonly known as hairy or tufted wireweed.

Polygonella basiramia is most closely related to *P. ciliata* and *P. gracilis* (Lewis and Crawford 1995). *P. basiramia* and *P. ciliata* are believed to have originated from *P. gracilis*, but whether they did so independently or from a single intermediate ancestral species is unknown.

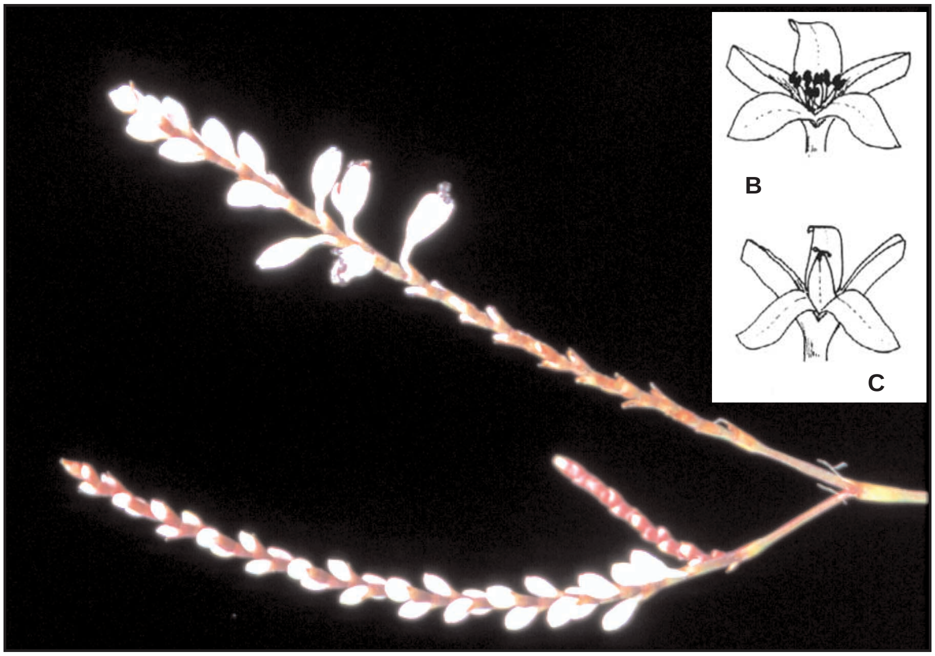
Distribution

Polygonella basiramia is endemic to the Lake Wales, Winter Haven, and Bombing Range ridges in central peninsular Florida. It ranges from Lake Pierce in Polk County southward to Venus near the southern tip of the Lake Wales Ridge in Highlands County (Christman and Judd 1990) (Figure 1). Christman (1988) found *P. basiramia* at 123 scrub sites.

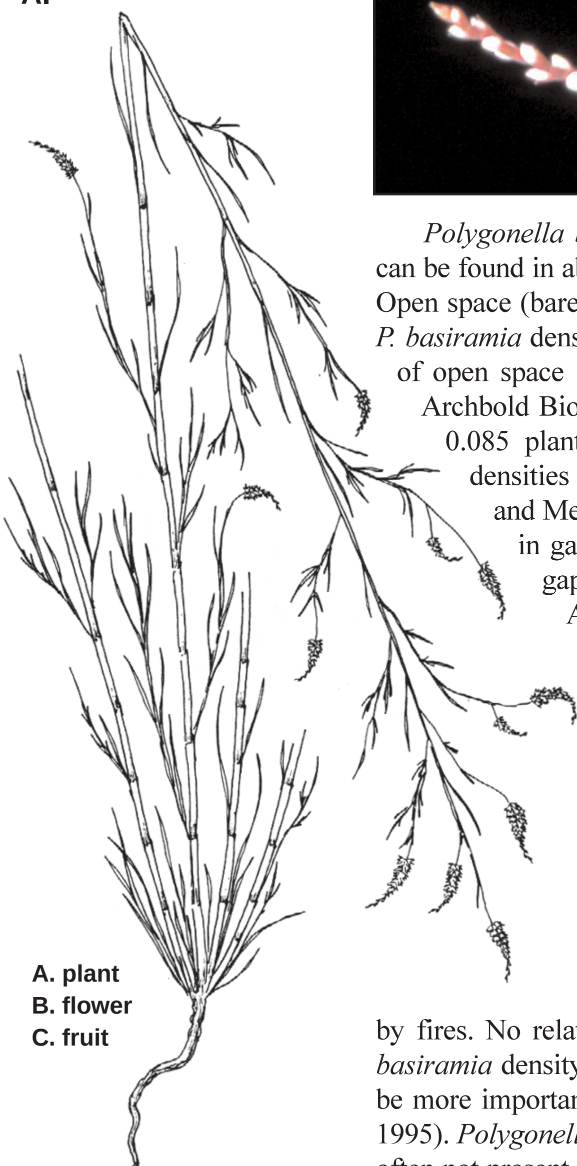
Habitat

Polygonella basiramia is most commonly found in rosemary scrub, also known as rosemary phase of sand pine scrub (Abrahamson *et al.* 1984, Menges and Kohfeldt 1995). At Archbold Biological Station, rosemary scrubs are found only on the higher ridges and knolls at 40 to 50 m in elevation, and are largely restricted to St. Lucie and Archbold soil types (Abrahamson *et al.* 1984), both well drained white sands (Carter *et al.* 1989). Outside Archbold Biological Station, rosemary scrubs are generally found on white sands and higher elevations (Hawkes, University of Pennsylvania, personal communication 1998). The fire cycle in rosemary scrub can range from 10 to as long as 100 years (Johnson 1982, Myers 1990). Rosemary scrub is dominated by Florida rosemary (*Ceratiola ericoides*) and oak species (*Quercus chapmannii*, *Q. geminata*, *Q. inopina*) with occasional sand pine *(Pinus clausa*). Abrahamson *et al.* (1984) provide a full description of the rosemary scrub habitat. The shrub matrix is interspersed with open sandy areas that contain a cover of herbs and lichens (Abrahamson *et al.* 1984, Hawkes and Menges 1996); these gaps are more persistent in rosemary scrubs than in scrubby flatwoods (Menges and Hawkes 1997).

Wireweed.
Original drawings by Anna-Lisa King.; original photograph by Steve Shirah.



A.



A. plant
B. flower
C. fruit

Polygonella basiramia occupies open spaces or gaps between shrubs and can be found in abundance along sandy fire lanes, which provide similar habitat. Open space (bare sand) in rosemary scrub was found to be a good indicator of *P. basiramia* density: higher plant densities are associated with greater amounts of open space (Hawkes and Menges 1995). Within rosemary scrub sites at Archbold Biological Station, density of *P. basiramia* ranged from 0.000 to 0.085 plants per m^2. Along fire lanes where open sand is abundant, densities were much higher, with a mean of 8.1 plants per m^2 (Hawkes and Menges 1995). Compared to other herbs, *P. basiramia* can persist in gaps of smaller size and is often found in the small, ephemeral gaps of scrubby flatwoods which border rosemary scrub (Hawkes, Archbold Biological Station, personal communication 1995). As gaps begin to close, there may be a shift in species composition among *Eryngium cuneifolium*, *Hypericum cumulicola,* and *P. basiramia;* with the bare sand specialist *E. cuneifolium* being lost first, followed by *H. cumulicola*, then *P. basiramia* (Quintana-Ascensio, Archbold Biological Station, personal communication 1995).

In rosemary scrub, open space decreases from nearly 100 percent immediately after fire to approximately 30 percent 4 years after fire when a great deal of habitat variation exists (Hawkes and Menges 1996). Gaps are affected by the fire cycle, because they are originally created by fires. No relationship, however, was found between time-since-fire and *P. basiramia* density (Hawkes and Menges 1995). Small-scale gap dynamics may be more important than the fire regime for *P. basiramia* (Hawkes and Menges 1995). *Polygonella basiramia* is an obligate seeder (Menges and Kohfeldt 1995) often not present in the first few years after fire, but whether it recovers through delayed post fire germination from a soil seed bank or disperses into sites remains unknown.

Reproduction

Polygonella basiramia is gynodioecious, with individual plants producing either pistillate (female) or perfect flowers (both sexes in a single flower). The ratio of female to hermaphroditic plants is 1:1 at Archbold Biological Station (Hawkes and Menges 1995). Pollinators of *P. basiramia* include small halictid bees, *Perdita polygonellae* (a bee specific to the genus *Polygonella*), Eumenidae wasps, and potentially *Glabellula* spp. (Bombyliidae) (M. Deyrup, Archbold Biological Station, personal communication 1995).

Seed production by female plants greatly exceeds that of perfect plants, with an average of 217.8 seeds per stem for females, but only 32.1 for perfect plants. *P. basiramia* is an obligate seeder which means that no adult plants survive a fire event and all new growth is from seedlings. On a population level, the number of seeds produced by *P. basiramia* in one reproductive season is more than 30 times the average plant density, sufficient to replace existing populations if only 3 percent of seeds were able to germinate and survive.

Density and seed production of *P. basiramia*, in relation to open sand and time post fire was studied by Hawkes and Menges (1995). Their analysis showed that *P. basiramia* densities and burn interval were not related, so it appears that *P. basiramia* can persist for many years without fire in the long-lasting sandy areas of rosemary balds. However, this species may require small-scale disruptions of the soil crust for populations to persist. Density and seed production of *P. basiramia* both increased with the area of open sand and were highest along firelanes where the soil crust had been disturbed by chopping (C. Hawkes, University of Pennsylvania, personal communication 1998). Large areas of open sand have especially dense populations of the plant, and seed production is greater on high-density than it is on low-density sites. They suggest that *P. basiramia* plants are sensitive to competition from shrubs, and only slightly sensitive to competition from each other. The lack of intraspecific competition probably is due to *P. basiramia* plants having shallow root systems bearing their leaves at ground level. Dense *P. basiramia* populations may also be especially attractive to pollinators that may also account for the high seed production.

Seedlings of *P. basiramia* at Archbold Biological Station and Lake Wales Ridge SF have been observed in highest numbers between late November and January. Flowering begins in September and achenes are produced in late November and early December. Because flowering is sequential, beginning at the top of each spike-like panicle and moving downwards, flowers and achenes are present at the same time mid-autumn. Achenes drop readily from the plant and most fall by mid-January.

Relationship to Other Species

A wide variety of herbs, grasses, small shrubs, and lichens (*Cladonia* spp.) utilize the same gap habitats as *P. basiramia*, but relationships among these species have not been studied extensively. These species include: *Calamintha ashei*, *Cnidosculus stimulosus*, *Eryngium cuneifolium*, *Euphorbia floridana*, *Hypericum cumulicola*, *Lechea cernua*, *L. deckertii*, *Licania michauxii, Paronychia chartacea, Polanisia tenuifolia, Polygonella polygama, P. robusta, Selaginella arenicola*, and *Stipulicida setacea*.

Christman (1988) reports that populations intermediate between *P. basiramia* and *P. ciliata* occur in scrubs near Lake Pierce and Lake Weohyakapka in Polk County, populations of *P. ciliata* occur in the same area, and that specimens from a Highlands County site have been tentatively assigned to *Polygonella ciliata*. However K. DeLaney (Environmental Research Consultants, Inc., personal communication 1995) cautions that in his experience, *P. basiramia* is a very distinctive species whose habitat does not overlap with that of *P. ciliata*, and that *P. gracilis* is easily misidentified as *P. ciliata* during its leafless phase.

In addition to the associations already described, soil crust organisms may provide a sealed surface layer for seed germination and a source of nitrogen for adult vascular plants like *P. basiramia* (C. Hawkes, University of Pennsylvania, personal communication 1998).

Status and Trends

Polygonella basiramia was federally listed January 21, 1987 (52 FR 2234), because of habitat loss and modification. It is restricted in distribution with a small number of remaining sites and is faced with continued and dramatic habitat loss. In addition, modification by trampling and off-road vehicles impacts some of the remaining habitat. Scrub habitat continues to diminish in the wake of land clearing for residential housing construction, citrus groves, and cattle ranches. Only if a sufficient amount of suitable habitat is conserved and properly managed will *P. basiramia* remain locally abundant.

The persistence of appropriate habitat for *P. basiramia* is dependent on disturbance processes which periodically create gaps. Historically, fire has been a large-scale disturbance which maintained open patches of different ages across the landscape. Today, wildfires no longer sweep through central Florida. Although *P. basiramia* also appears to be able to take advantage of smaller-scale disturbances which disrupt soil crust and create space (such as animal paths and burrow mounds), this has not been studied and such disturbances may only be suitable for colonization if created at the right place and time. In unmanaged areas, lack of disturbance, especially in less xeric sites where open space is fleeting, will be a major threat to *P. basiramia*.

Stratigraphic cores from Lake Annie (Archbold Biological Station, Highlands County) contained pollen from what was thought to be *P. ciliata* 37,000 ± 3,200 years ago. Watts (1975, 1980) reported that the flora from before 44,300 years ago to after 33,000 years ago was a dry, rosemary-dominated scrub habitat, much like what exists today. Because pollen from *P. basiramia* and *P. ciliata* are indistinguishable, the Lake Annie record is more than likely attributable to *P. basiramia* or a recent ancestor of both species. *Polygonella basiramia* may have been present on the central ridges as early as the mid-to late Pleistocene when its habitat, sand pine scrub, is thought to have originated (Laessle 1958).

The protected sites for *P. basiramia* include Catfish Creek, Lake Arbuckle State Preserve, and Saddle Blanket Lakes, Highlands Hammock SP, Flamingo Villas, Placid Lakes, Archbold Biological Station, Lake Apthorpe, and the west side of Lake June in Winter, Florida. It is present at targeted acquisition sites including Holmes Avenue (East), Avon Park Lakes, Carter Creek, Eagle Lake, Flaming Arrow, Polk #52, and Sun Ray.

Management

Florida scrub is a fire-adapted community experiencing shifting fire intensity and frequency (Myers 1990). The fire cycle in rosemary scrub can range from 10 to as long as 100 years (Johnson 1982, Myers 1990). This species is an obligate seeder that does not mature for 10 to 15 years and is adapted for a 10-40 year fire interval (Johnson 1982). Unlike oak-dominated scrubs, rosemary scrubs recover slowly from burns (Johnson *et al.* 1986) and openings persist longer. These openings are used by a number of rosemary scrub endemics, such as *Cladonia* spp., *Calamintha ashei*, *Cnidosculus stimulosus*, *Eryngium cuneifolium*, *Euphorbia floridana*, *Hypericum cumulicola*, *Lechea cernua*, *L. deckertii*, *Licania michauxii, Paronychia chartacea, Polanisia tenuifolia, Polygonella polygama, P. robusta, Selaginella arenicola*, and *Stipulicida setacea*. In designing fire management for rosemary scrubs, responses of the particular species present must be taken into account when planning fire return intervals (Hawkes and Menges 1995). Menges and Kohfeldt (1995) suggest a 15 to 40 year burn interval with mosaic burns on large pieces of property.

Using fire to manage the habitat is the preferred option for *P. basiramia*. In rosemary scrub, open space decreases from nearly 100 percent immediately after fire to approximately 30 percent at 4 years post fire, after which a great deal of variation exists (Hawkes and Menges 1996). Gaps are affected by the fire cycle, as they are originally created by fires. There is no relationship, however, between fire intervals and *P. basiramia* density. Small-scale gap dynamics may be more important than the fire regime for *P. basiramia* (Hawkes and Menges 1995). *Polygonella basiramia* is an obligate seeder (Menges and Kohfeldt 1995) often not present in the first few years after fire, but whether it recovers through delayed post fire germination from a soil seed bank or disperses into sites remains unknown. *Polygonella basiramia* seedlings require about 1 year to mature and set seed, so populations would not recover if fires occur at intervals insufficient for sprouting and maturity (Hawkes and Menges 1995). Long fire-return intervals may not negatively affect *P. basiramia* if openings persist, but it may be harmful to other species that share the habitat (Hawkes and Menges 1995)

In cases where fire is not an option, mechanical disturbance can have some benefits by providing openings.

Literature Cited

Abrahamson, W.G., A.E. Johnson, J.N. Layne, and P.A. Peroni. 1984. Vegetation of the Archbold Biological Station, Florida: an example of the southern Lake Wales Ridge. Florida Scientist 47:209-250.

Carter, L.J., D. Lewis, L. Crockett, and J. Vega. 1989. Soil survey of Highlands County, Florida. U.S. Department of Agriculture, Soil Conservation Service.

Christman, S.P. 1988. Endemism in Florida's scrub interior. Project No. GFC-84-101, Florida Game and Freshwater Fish Commission; Tallahassee, Florida.

Christman, S.P. and W.S. Judd. 1990. Notes on plants endemic to Florida scrub. Florida Scientist 53:52-73.

Delaney, K. 1995. FWS Multi-Species Recovery Team Meeting. December 6-8, 1995.

Hawkes, C.V. and E.S. Menges. 1996. The relationship between open space and fire for species in a xeric Florida shrubland. Bulletin Torrey Botany Club 123(2):81-92.

Hawkes, C.V. and E.S. Menges. 1995. Density and seed production of a Florida endemic, *Polygonella basiramia*, in relation to time since fire and open sand. American Midland Naturalist 133:138-148.

Hawkes, C. 1995. Comments on draft account. July 1995.

Hawkes, C. 1998. Comments on draft species account. January 21.

Horton, J.H. 1960. A monograph of *Delopyrum* Small, *Dentoceras* Small, *Polygonella* Michx., and *Thysanella* Gray (Polygonaceae). Unpublished PhD dissertation, University of North Carolina, Chapel Hill, North Carolina.

Johnson, A. 1982. Some demographic characteristics of the Florida rosemary *Ceratiola ericoides* Michx. American Midland Naturalist 10:170-174.

Johnson, A. F., W.G. Abrahamson, and K.D. McCrea. 1986. Comparison of biomass recovery after fire of a seeder (*Ceratiola ericides*) and a sprouter (*Quercus inopina*) species from south-central Florida. American Midland Naturalist 116:423-428.

Laessle, A.M. 1958. The origin and successional relationships of sandhill vegetation and sand-pine scrub. Ecological Monographs 28:361-387.

Lewis, P.O. and D.J. Crawford. 1995. Pleistocene refugium endemics exhibit greater allozymic diversity than widespread congeners in the genus *Polygonella* (Polygonaceae). American Journal of Botany 82:141-149.

Menges, E.S. and N. Kohfeldt. 1995. Life history strategies of Florida scrub plants in relation to fire. Bulletin Torrey Botanical Club 122:282-297.

Myers, R.L. 1990. Scrub and high pine. Pages 150-193 *in* R.L. Myers and J.J. Ewel (eds.). Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

Nesom, G.L. and V.M. Bates. 1984. Reevaluations of intraspecific taxonomy in *Polygonella* (Polygonaceae). Brittonia 36:3744.

Quintana-Ascensio, P. 1995. FWS Multi-Species Recovery Team Meeting. December 6-8, 1995.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery plan for nineteen central Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Watts, W.A. 1975. A late Quaternary record of vegetation from Lake Annie, south-central Florida. Geology 3:344-346.

Watts, W.A. 1980. The late Quaternary vegetation history of the southeastern United States. Annual Review Ecological Systems 11:387-409.

Recovery for the Wireweed

Polygonella basiramia (= ciliata var. b.*)* (Small) Nesom and Bates

Recovery Objective: RECLASSIFY to threatened.

Recovery Criteria

Polygonella basiramia may be reclassified from endangered to threatened when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations and sites needed to assure 20 to 90 percent probability of persistence for 100 years; when these sites, within the historic range of *P. basiramia*, are adequately protected from further habitat loss, degradation, and fragmentation; when these sites are managed to maintain the rosemary phase of xeric oak scrub communities to support *P. basiramia*; and when monitoring programs demonstrate that populations of *P. basiramia* on these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species. Individuals growing opportunistically in unnatural areas, for example fire lanes, should be excluded from consideration when determining the status of this species.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution status of *Polygonella basiramia*. This species' distribution is somewhat questionable for taxonomic reasons. A thorough survey is needed to determine the distribution for this species.

S1.1. Conduct surveys for populations of *P. basiramia*.

S1.1.1. Continue surveys in Polk and Highlands counties. The Lake Wales Ridge has been well surveyed, but because it is quite common within this region, new sites may still be found. Polk County should be the focus of survey work.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. *Polygonella basiramia* identification. Some uncertainty remains over the identification of this plant (versus *Polygonella ciliata* and *P. gracilis*), and therefore its geographic range is somewhat unclear. Herbarium specimens from as many protected sites as possible (especially Avon Park AFR) should be evaluated by a systematist to assure that they have been identified correctly. If they are not already available, voucher specimens must be collected from protected sites, especially in Polk County where the distributions of the two species might overlap. The systematics of these species was reviewed by Nesom and Bates (1984), and there is no apparent need for further systematic investigations.

S1.3. Maintain distribution of known populations and suitable habitat in GIS database. Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. Protect populations on private land through acquisition, conservation easements, or agreements with landowners.

S2.2. Protect populations on public lands. Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. Continue *ex situ* conservation. *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *P. basiramia*.

S2.3.1. Conserve germ plasm. The seed of this species is not presently in long-term storage.

S2.3.2. Maintain *ex situ* collection. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *P. basiramia* as part of the National Collection.

S2.4. Enforce available protective measures. Use local, State and Federal regulations to protect this species. Regulations should also be used to protect xeric vegetative communities where *P. basiramia* lives.

S2.4.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.4.2. Enforce take prohibitions. This species is protected by take provisions of the Endangered Species Act (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. Conduct research on life history characteristics. Though much of the basic biology and ecology of this species is understood, to effectively recover this species additional biological information is needed.

S3.1. Conduct research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, survival, microhabitat requirements, and mortality. Dispersal is an important issue for this species.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *P. basiramia*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring information on the localities of *P. basiramia* sites will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S4. Monitor existing populations of *Polygonella basiramia*.

S4.1. Develop monitoring protocol to assess population trends for *P. basiramia*.

S4.1.1. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival, and mortality. Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. Monitor the effects of various land management actions on *P. basiramia*. Assess any changes in demographic characteristics of *P. basiramia* in response to land management activities, such as prescribed fire, exotic plant control, *etc*.

S4.2. Develop a quantitative description of the population structure of *P. basiramia*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. It should also include data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors).

S5. Provide public information about *P. basiramia*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degredation, and fragmentation have already occurred throughout the range of this species. Both development and fire suppression have decreased the available habitat. To date, there are 13 protected or planned acquisition sites for *P. basiramia*.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. Since little xeric scrub habitat remains for this species, any method of securing unprotected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain P. basiramia populations by providing proper management of habitat, including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. A 15 to 40 year cycle is recommended for *Polygonella basiramia.* In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *P. basiramia*.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire.

H2.2. Ensure natural populations. This species grows readily in fire lanes and old road beds. These should not be considered natural populations and should not be counted toward the recovery of this species.

H3. Conduct habitat-level research projects. Study the response of *P. basiramia* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation. More information is needed on the response to management activities for this species.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc.,* on the habitats where *P. basiramia* occurs.

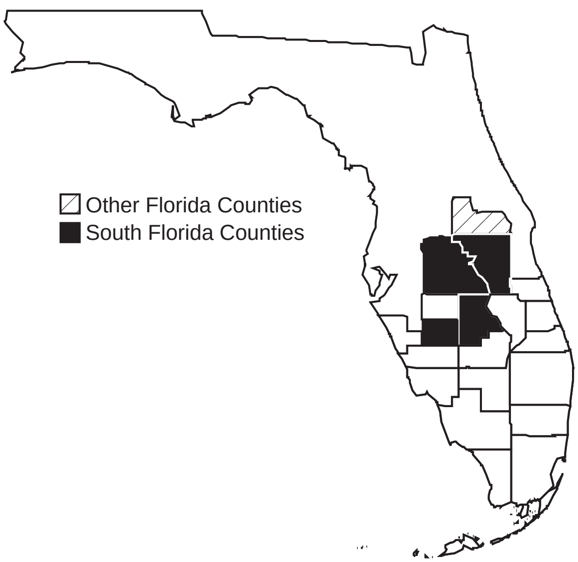
H5. Provide public information about scrub and its unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the SFWMD, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Sandlace

Polygonella myriophylla (Small) Horton

Federal Status:	**Endangered (April 27, 1993)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of sandlace.



The sandlace is one of many plants endemic to central Florida's upland ridge that have been listed as endangered because of increasing threats from agricultural, commercial, residential, and recreational conversion of natural habitat. This species is found in moderately disturbed scrub. It probably requires regular fires to persist, although competition may also be limited by allelopathy. Even though the number of individuals and range of this species has been substantially reduced, the prognosis for its survival is better than for most other endemic scrub plants. The sandlace occurs on many sites that are currently protected or on sites that are proposed for acquisition and management of scrub habitat.

This account represents a revision of the existing recovery plan for the sandlace (FWS 1996).

Description

Polygonella myriophylla is a sprawling shrub that looks somewhat like the ornamental creeping juniper (*Juniperus horizontalis*). Its many branches zigzag along the ground and root at the nodes, forming low mats. The lower parts of the creeping branches have bark that cracks and partly separates in long, flat, interlacing strips. The short lateral branches end in flowering racemes. *P. myriophylla* has the sheathing leaf stipules (ocreae and ocreolae) typical of the jointweed family. The leaves are needle-like and are from 0.3 to 10.0 mm long. The small, white or cream colored flowers have white petal-like sepals up to 3.4 mm long (Kral 1983).

Taxonomy

Sandlace is one of 11 species of North American *Polygonella* and one of three species of *Polygonella* that occur in scrub habitat in south Florida (Lewis and Crawford 1995). The sandlace was first collected in the early 1920s and was subsequently identified and named by Small (1924) as *Dentoceras myriophylla*. Horton (1963) combined two of Small's genera with the genus

Polygonella. *P. myriophylla* has been commonly called sandlace (Christman 1988), Small's jointweed and woody wireweed (Wunderlin 1982).

Distribution

Polygonella myriophylla occurs within scrub habitats that covered about 10,000 ha when inventoried by Christman (1988) (Figure 1). It is found in three sites in western Orange County where it occurs with the endangered scrub lupine (*Lupinus aridorum)* (Wunderlin 1984) and at one site in Osceola County near Interstate 4. In Polk County, *P. myriophylla* is found on the Lake Wales Ridge from the Davenport-Poinciana area. It is also found well west of the Lake Wales Ridge in a highly altered area just southeast of Bartow. In Highlands County, *P. myriophylla* is found on the Lake Wales Ridge south to Archbold Biological Station. Kral's (1983) distribution map places this plant in DeSoto County, based on a specimen collected by J. K. Small and J. B. DeWinkler in 1919, before Highlands County was created in 1921.

Habitat

This low, spreading shrub thrives in areas of bare white or yellow sand created by moderate disturbance.

It is not known whether regular fires are needed to maintain bare sand habitat for this species. *Polygonella myriophylla* is believed to be an allelopathic species (Richardson 1985). This allelopathic nature may create suitable conditions to maintain sufficient bare sand for the species to persist. Where found, *P. myriophylla* is a dominant part of the ground cover vegetation in young scrubs. In many localities, however, the herbaceous layer is poorly developed because of the xeric conditions. The shrub layer of this habitat is dominated by oaks (*Quercus* spp.) and ericaceous plants. Any overstory trees are usually widely spaced, forming an open canopy (Wunderlin *et al.* 1980).

Reproduction

This species reproduces sexually and asexually. Pollinators of *P. myriophylla* include small halictid bees (*Perdita polygonellae*), a genus-specific pollinator. Pollinators of another *Polygonella* include Eumenidae wasps and *Glagellula* spp. which may also be responsible for pollination of *P. myriophylla* (FWS 1996). The species also reproduces by suckering and/or adventitious rooting of decumbent stems. Information on seed production and germination is not available for this species. However, we do know that due to the allelopathic effects of this species, seedlings do not survive in the vicinity of mature plants.

Relationship to Other Species

Polygonella myriophylla become established in bare spots within scrub that are created by intense fires within sand pine (*Pinus clausa*) scrub. Once established, the allelopathic tendencies of *P. myriophylla* may limit growth and survival of other herbs and shrubs.

Sandlace.
Original photograph by Harold Malde; original flower photograph by Steve Shirah.

Status and Trends

Sandlace was known from about 119 scrubs as of the late 1980s (Christman and Judd 1990). These habitats covered about 10,000 ha along the Central Florida Ridge. Like most other endemic plants, habitat for this species is being acquired for conservation purposes. Unfortunately, only a small fraction of remaining habitat will be preserved with the limited conservation funds available. About 15 sites are protected or will be protected through acquisition, conservation, and management. These sites represent a small fraction of the historic numbers and range of this species. Estimates of remaining scrub range from 60 (Southeast Environmental Research Program and Center for Plant Conservation 1995) to 75 percent (Christman 1988). Using these values, we estimate that *P. myriophylla* probably occupied 300 to 475 scrub sites. Protection of 15 sites, therefore, represents conservation of only four percent of the sites that historically contained sandlace.

Management

Polygonella myriophylla persists in scrub habitats with substantial bare ground. These patchy habitats are commonly found after intense fires in sandpine scrub. This habitat condition is also common within rosemary scrub due to extreme xeric conditions and the allelopathic nature of several species that limits vegetative growth. Persistent, patchy, open sands are not prevalent in oak dominated scrubs, since fires are more frequent and less devastating.

The importance of open, patchy, sand to the persistence of *P. myriophylla* has not been studied. Though specific life-history information for *P. myriophylla* is unavailable, many of the factors that influence *P. basiramia* (wireweed) distribution, abundance, and recruitment may also affect *P. myriophylla.*

Management for *P. myriophylla* will probably require development of long-term burning regimes that mimic the 50 to 100 year natural fire cycles of sandpine/rosemary scrub and rosemary balds (Wunderlin *et al.* 1980). The interaction of allelopathic effects and fire frequency needs to be investigated. If allelopathic effects are sufficient to maintain open sand patches in some areas, fire may not be necessary as a management tool. However, the effects of fire timing and intensity on other scrub endemics should be considered before excluding fire.

The species' tendency to colonize disturbed areas along easily accessible road cuts and right-of-ways can result in overestimations of the species' abundance and health. On publicly managed lands, we caution against using species presence or abundance in altered habitats as the benchmark from which management decisions are made. Instead, management decisions should be made to maintain and enhance the dynamic diversity of Florida's scrub vegetation.

Literature Cited

Christman, S. 1988. Endemism and Florida's interior sand pine scrub. Final project report, project no. GFC-84-101. Submitted to Florida Game and Fresh Water Fish Commission; Tallahassee, Florida.

Christman, S. and W.S. Judd. 1990. Notes on plants endemic to Florida scrub. Florida Scientist 53:52-73.

Horton, J.H. 1963. A taxonomic revision of *Polygonella* Polygonaceae. Brittonia 15:177-203.

Kral, R. 1983. A report on some rare, threatened, or endangered forest-related vascular plants of the South. Technical publication R8-TP 2, U.S. Forest Service, Atlanta, Georgia.

Lewis, P.O. and D.J. Crawford. 1995. Pleistocene refugium endemics exhibit greater allozymic diversity than widespread congeners in the genus *Polygonella* (Polygonaceae). American Journal of Botany 82:141-149.

Richardson, D. 1985. Evidence for allelopathy in sand pine scrub. Oral presentation to: Florida Native Plant Society, May 3, 1985. Based on unpublished thesis, University of South Florida; Tampa, Florida.

Small, J.K. 1924. Plant novelties from Florida. Bulletin of the Torrey Botantical Club 51:379-393.

Southeast Environmental Research Program and Center for Plant Conservation. 1995. An action plan to conserve the native plants of Florida, Missouri Botanical Gardens; St. Louis, Missouri.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery plan for nineteen central Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Wunderlin, R.P., D. Richardson, and B. Hansen. 1980. Status report on *Polygonella myriophylla*. U.S. Fish and Wildlife Service; Jacksonville, Florida.

Wunderlin, R. 1982. Guide to the vascular plants of central Florida. University Presses of Florida; Gainesville, Florida.

Wunderlin, R.P. 1984. Endangered and threatened plant status survey, *Lupinus aridorum*. McFarlin ex Beckner. Unpublished report prepared under contract with U.S. Fish and Wildlife Service; Jacksonville, Florida.

Recovery for the Sandlace

Polygonella myriophylla (Small) Horton

Recovery Objective: RECLASSIFY to threatened, then delist.

Recovery Criteria

Polygonella myriophylla may be reclassified from endangered to threatened when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations and sites needed to assure 20 to 90 percent probability of persistence for 100 years; when these sites, within the historic range of *P. myriophylla*, are adequately protected from further habitat loss, degradation, and fragmentation; when these sites are managed to maintain the seral stage of xeric oak scrub communities to support *P. myriophylla*; and when monitoring programs demonstrate that populations of *P. myriophylla* on these sites support the appropriate numbers of self-sustaining populations, and those populations are stable throughout the historic range of the species.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *P. myriophylla.* A thorough survey is needed to determine the distribution for this species.

S1.1. Conduct surveys for populations of *P. myriophylla*.

S1.1.1. Continue surveys in Polk, Osceola, and Highlands counties. The Lake Wales Ridge has been well surveyed, though sites may still be found.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. Maintain distribution of known populations and suitable habitat in GIS database. Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database.

Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties have been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. Protect populations on private land through acquisition, conservation easements or agreements with landowners. Carter Creek and Flamingo Villas on the Lake Wales Ridge are crucial to the recovery of this species. Flamingo Villas is currently being acquired by the FWS, but Carter Creek acquisition will be difficult due to a number of factors.

S2.2. Protect populations on public lands. Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. Develop *ex situ* and germ plasm collections of *P. myriophylla*. *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *P. myriophylla*.

S2.4. Enforce available protective measures. Use local, State and Federal regulations to protect this species. Regulations should also be used to protect xeric vegetative communities where *P. myriophylla* lives.

S2.4.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.4.2. Enforce take prohibitions. This species is protected by take provisions of the Endangered Species Act (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. Conduct research on life history characteristics. Though much of the basic biology and ecology of this species is understood, to recover this species more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *P. myriophylla*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential to develop adaptive management techniques.

S4. Monitor existing populations of *P. myriophylla*.

S4.1. Develop monitoring protocol to assess population trends for *P. myriophylla*.

S4.1.1. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival and mortality. Also monitor for pollinators, herbivory, disease and injury.

S4.1.2. Monitor the effects of various land management actions on *P. myriophylla*. Assess any changes in demographic characteristics of *P. myriophylla* in response to land management activities, such as prescribed fire, exotic plant control, *etc*.

S4.2. Develop a quantitative description of the population structure of *P. myriophylla*. This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data should also be gathered about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors).

S5. Provide public information about *P. myriophylla*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. Care is needed, though, to avoid revealing specific locality information about where *P. myriophylla* is found.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *P. myriophylla* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there are 15 protected or acquisition sites for *P. myriophylla.*

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. Little xeric scrub habitat is remaining for this species. Any method of securing unprotected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *P. myriophylla* populations by preventing damage from off-road vehicle use and overcollection, and by providing proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible.

H1.2.2. **Control and eliminate exotic and invasive plants and animals.** Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *P. myriophylla*.

H2. **Restore areas to suitable habitat.** Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. **Restore natural fire regime.** Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.2. **Enhance sites with native plant species.** Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. **Conduct habitat-level research projects.** Study the response of *P. myriophylla* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. **Monitor habitat/ecological processes.** Monitor the effects of land management actions, such as prescribed fire, exotic plant control, on the habitats where *P. myriophylla* occurs.

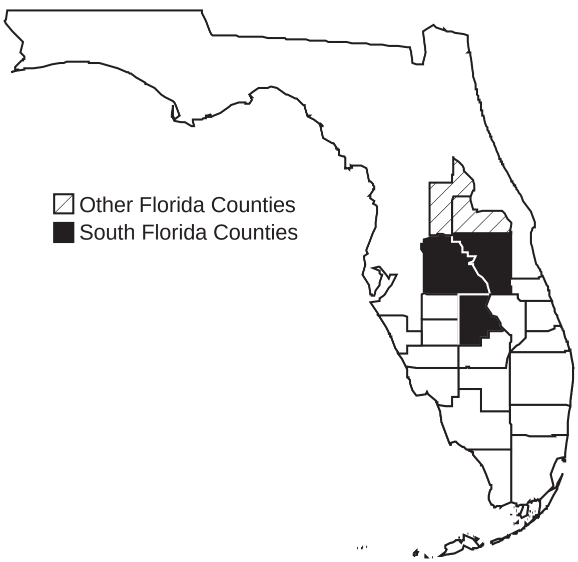
H5. **Provide public information about scrub and its unique biota**. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the SFWMD, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Scrub Plum

Prunus geniculata

Federal Status:	**Endangered (January 21, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. County distribution of scrub plum.



The scrub plum is a small shrub endemic to the oak scrub and high pine communities of the Lake Wales Ridge. The scrub plum has declined with the destruction and fragmentation of its scrub habitat for agriculture and residential housing. The scrub plum is also collected by ornamentalists because of its small, fragrant flowers. Recovery of this species will require additional surveys, land protection, and prescribed burns.

This account represents South Florida's contribution to the existing recovery plan for the scrub plum (FWS 1996).

Description

The scrub plum is a heavily branched, broad-crowned shrub that can reach 2 m in height, although 0.5 m may be more typical at sites with frequent fires. It grows from gnarled, half-buried trunks and spreads by sucker shoots. Its young twigs are strongly geniculate (zig-zag shaped), while its lateral branches are either short, stubby, spur shoots bearing leaves and flowers, or are strongly tapering and spine-like. The bark of old stems is thin, gray, usually lichen-encrusted, and forms small rectangular or square plates. The bark of new shoots is lustrous reddish-brown or purplish and smooth.

The scrub plum's leaves are crowded on the spur shoots (an arrangement typical of the Rosaceae family) and are widely spaced on the normal shoots. The stipules are linear-subulate, roughly 5 mm long, green, and pectinately fringed at the margins with reddish glands. The leaf blades are ovate to obovate or elliptic, 1 to 3 cm long, short-acuminate, and serrulate with gland-tipped teeth. The leaf base is rounded or broadly cuneate. The leaf stalk is a third to half as long as the blade.

The scrub plum has small, fragrant flowers that are 11 to 13 mm across when open. Like the leaves, flowers found on the spur shoots are rather crowded, while those found on the regular shoots or the spine bases are spaced further apart. The pedicels extend only slightly beyond the bud scales, so the flowers give the appearance of being sessile. The flowers are radially symmetrical with a 3 mm long hypanthium (the cup-shaped structure formed by the united portions of the bases of the sepals, petals, and stamens). The 5 calyx lobes are radially symmetrical, spreading to ascending triangular with acute apices, sparsely ciliate on the margins, reddish or green, with the bottom surfaces smooth and the upper surfaces white-tomentose. The 5 petals are white, spreading, and about 5 mm long. The petal blades are ovate to obovate with rounded tips and attenuated bases ending in short, ciliate-margined claws. The stamens are numerous, roughly 0.5 mm long, and borne on the rim of the hypanthium.

The fruit of the scrub plum is an ovoid or ellipsoidal drupe, 12 to 25 mm long, and dull reddish in color. It has a thin, bitter flesh and a slightly flattened seed.

Prunus geniculata is similar to other Florida plums, but it is the only one that has flowers which appear to be sessile. It most resembles the Chickasaw plum (*Prunus angustifolia*), which also has glands on the teeth of the leaves. However, Chickasaw plum has the leaves folded along the midrib and forms thickets by sprouting from sucker shoots. Scrub plum's fruit resembles that of the sloe or hog plum (*Prunus umbellata*) (Kral 1983).

Prunus geniculata is also similar to other scrub plants. It is one of several characteristic scrub plants with a geniculate (zig-zag stem), thorny habit of growth. Others are *Bumelia tenax*, *Ximenia americana*, *Ziziphus celata*, and a distinctive local variant of *Crataegus lepida beadle* (Judd and Hall 1984).

Taxonomy

Prunus geniculata was first described by Roland M. Harper in 1911 (Harper 1911). There has been no additional treatment of this species. The common name "scrub plum" was first used by Small (Small 1933).

Distribution

Prunus geniculata is a scrub endemic that is known to occur in three areas along the ridges of central Florida (Figure 1): Lake County, west and southwest of Lake Apopka; the southwest and northwest corners of Orange and Osceola counties, respectively; and Polk and Highlands counties, from the City of Lake Wales south to the Highlands County/Glades County border (FNAI 1996). In these areas, *P. geniculata* occurs in both high pine and in oak scrub communities (FNAI 1985, Johnson 1981, Stout 1982). The development of scrub and sandhill vegetation has left only remnants of scrub plum habitat available in these areas.

The historic distribution of *P. geniculata* has been described using only information from a few herbarium specimens that were collected after its discovery in 1909 (FNAI 1985, Harper 1911). Thus, the historic range may have been more extensive than originally believed. Floristic surveys (FNAI 1985, 1996; Johnson 1981; Stout 1982) and work underway at the Florida State Museum indicate that the general boundaries of the plant's present geographic distribution are accurately represented.

Scrub plum.
Original photograph by J.N. Layne; original flower photograph by Steve Shirah.

Habitat

The scrub plum prefers dry, sunny, nutrient-poor sites (Harper 1911). It has been found on soils of the St. Lucie series and on other fine sands or fine sand Entisols that are excessively drained. These soils are acidic, are subject to rapid drying, and have little silt, clay, or organic matter.

Prunus geniculata is native to the high pine and oak scrub community types. The high pine community has a grassy understory and is subject to frequent fires (every one to five years) of low intensity. The oak scrub community has shrubby vegetation and is subject to infrequent fires of greater intensity. Fires are important for the maintenance of both habitats. In the absence of frequent fires, high pine vegetation is typically invaded by sand pines and evergreen oaks, eventually succeeding to upland hardwood forest if fires do not occur for long periods (Myers 1985). Similarly, scrub is likely to succeed toward upland hardwood forest if fire is absent from the habitat for long periods (Myers 1985). This succession of scrub to upland hardwood forest is likely to result in the shading out of scrub plum.

Reproduction

In *P. geniculata*, both male and perfect flowers occur on the same plant, however, the male to perfect ratio is unknown (C. Weekley, Lake Wales Ridge SF, personal communication 1997). Insects (mainly bees) may disseminate the pollen of the scrub plum; its seeds are disseminated by birds, and possibly mammals.

Few seedlings have been found in the wild and there is concern that the scrub plum is not successfully reproducing. The low reproductive rate may be caused by a large proportion of male to perfect flowers, low fruit set due to the nutrient-poor condition of scrub habitat, and heavy predation (C. Weekley, Lake Wales Ridge SF, personal communication 1997). An experiment examined germination rates under various conditions. Seeds on bare ground, unshaded and open were removed from the plot within a few days. One seedling was located in an enclosed area of unshaded, bare ground. Seeds covered in litter and shaded had not been disturbed, and showed a germination rate of 18.75 percent as of January 1998 (C. Weekley, Lake Wales Ridge SF, personal communication 1998).

The phenology of *P. geniculata* appears to be similar to *P. angustifolia* (Ward 1979). Flowering occurs in January to February, leafing occurs from late February to March, fruit begins to develop in late February and may continue to early May, seed dispersal is in early May, but germination dates are unknown (Harper 1911, Ward 1979, C. Weekley, Lake Wales Ridge SF, personal communication 1998). Flowers may or may not open all at the same time, before the leaves expand (Harper 1911, C. Weekley, Lake Wales Ridge SF, personal communication 1998). Most of the published information on the phenology of this species is from R. Harper's account of his discovery of the plant.

Relationship to Other Species

Heavy predation has been observed on scrub plum fruit. Insects, such as the plum curculio (*Conotrachelus sp.*) appear to be responsible for most of the damage (C. Weekley, Lake Wales Ridge SF, personal communication 1997). The plum curculio is believed to feed on the fruit and another insect (not yet identified) eats the seeds. In addition to insects, rodents and armadillos are known to eat scrub plum fruits. This heavy predation may be part of the reason few seedlings have been found in the wild.

Shade from trees and taller shrubs is likely to affect *P. geniculata*. However, the response of scrub plum to different degrees of shading is uncertain. High pine plants that can be found in the vicinity of scrub plum include wide-leaf warea (*Warea amplexifolia),* Chickasaw plum (*Prunus angustifolia*), tallowwood (*Ximenia americana*), wiregrasses (*Aristida* spp.), broomsedges (*Andropogon* spp.), *Polanisia tenuifolia*, *Polygonella robusta*, and *Prunus gracilis.* Turkey oak (*Quercus laevis*), the dominant tree, and longleaf pine (*Pinus palustris*) are common trees in scrub plum habitat.

Status and Trends

Prunus geniculata was federally listed as endangered on January 21, 1987 (52 FR 2234) because of habitat loss due to conversion to agriculture (primarily citrus) and residential development. Removal by ornamental and rare plant collectors is an additional threat to the survival of this species.

High pine was once extensive on the Lake Wales Ridge (Myers 1990). Although many people involved in conservation of natural areas associate the Lake Wales Ridge with the scrub community, the public is much less aware that the scrub was originally surrounded by a larger matrix of high pine. Scrub certainly has been reduced to a small percentage of its historic range, but high pine, which was more suitable for conversion to citrus, has been reduced to a much smaller percentage of its original range (DEP 1996).

The loss of scrub habitat on the Lake Wales Ridge has been severe. In Lake County, most of the xeric habitats occupied by scrub plum have been converted to citrus groves (52 FR 2234). In Highlands County, 64 percent of the xeric habitat (scrub, scrubby flatwoods, and high pine) present before settlement was destroyed by 1981. An additional 10 percent of the xeric vegetation was moderately disturbed, primarily by building roads to create residential subdivisions (Peroni and Abrahamson 1985). The situation is similar in Polk County.

Despite the destruction of suitable habitat, the scrub plum still occurs within most of its historic range. Historically, this plant was found in Lake, Polk, Highlands and Osceola counties. Presently, it is found in these four counties and a small portion of Orange County as well (FNAI 1996, Johnson 1981, Stout 1982). Although it still occurs in the same range, the distribution of scrub plum within this range has decreased.

In addition to habitat loss, two other factors pose threats to *P. geniculata.* One threat is fire suppression, which has degraded the quality of scrub and high pine habitats of the species. The other is the low number of seedlings that have been found in the wild (FWS 1996), suggesting that scrub plum may not be sufficiently reproducing.

In an attempt to preserve this and other Lake Wales Ridge species, sites at several locations in south-central Florida have been protected. In Polk County, protected sites containing scrub plum exist at the Arbuckle and the Lake Walk-in-the-Water tracts of Lake Wales Ridge SF, at the Pine Ridge Nature Preserve of Bok Tower Gardens, at Catfish Creek, and at Tiger Creek. Scrub plum may also exist at Saddle Blanket Lakes, although its occurrence there has not been confirmed. In Highlands County, the scrub plum is protected at Silver Lake, Carter Creek, Flamingo Villas, kake Apthorpe Preserve, Holmes Avenue, Gould Road, Archbold Biological Station and at Lake June in Winter, Florida.

Management

Fire, or equivalent artificial disturbance, appears to be necessary for perpetuation of *P. geniculata* (Kral 1983, Myers 1985). This species readily resprouts after fires or mechanical disturbances (FWS 1996). In addition, fires may benefit scrub plum by regulating the numbers or sizes of plants that shade or otherwise compete with it (Kral 1983). Though the optimum frequency of disturbance is unknown, the fire frequencies typical of high pine (2 to 5 years) and scrub (15 to 20 years) are understood. Developing a prescribed burning program that mimics these typical frequencies and monitoring the response of scrub plum may be a prudent way to manage for this species.

Although *P. geniculata* does not persist in citrus groves or other agricultural areas, it may be capable of establishing itself and persisting in a variety of human-modified areas such as: road rights-of-way, abandoned agricultural land, and vacant lots. *Prunus angustifolia* and *P. umbellata* are widespread on such sites. Unfortunately, no information is available on the extent to which *P. geniculata* occurs at such sites.

Literature Cited

Florida Natural Areas Inventory [FNAI]. 1985. Element occurrence data for: *Prunus geniculata*. Tallahassee, Florida.

Florida Natural Areas Inventory [FNAI]. 1996. Element occurrence data for: *Prunus geniculata*. Tallahassee, Florida.

Harper, R. 1911. A new plum from the Lake Region of Florida. Torreya 11:64-67.

Judd, W. 1980. Status report on *Hypericum cumulicola*. Unpublished report prepared for U.S. Fish and Wildlife Service; Jacksonville, Florida.

Judd, W.S., and D.W. Hall. 1984. A new species of *Ziziphus* (Rhamnaceae) from Florida. Rhodora 86:38l-387.

Kral, R. 1983. A report on some rare, threatened, or endangered forest-related vascular plants of the South. USDA Forest Service Technical Publication R8-TP2.

Myers, R. 1985. Fire and the dynamic relation between Florida sandhill and sand pine scrub vegetation. Bulletin of the Torrey Botanical Club 112:241-252.

Peroni, P.A., and W.G. Abrahamson. 1985. A rapid method for determining losses of native vegetation. Natural Areas Journal 5:20-24.

Small, J.K. 1933. Manual of the southeastern flora. J.K. Small; New York, New York.

Stout, I.J. 1982. Descriptions of 84 stands of Florida sand pine scrub vegetation. Unpublished report prepared for U.S. Fish and Wildlife Service; Jacksonville, Florida.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery plan for nineteen Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Ward, D.B. 1979. Scrub plum. Pages 53-54 *in* D.B. Ward, ed. Rare and endangered biota of Florida, volume 5, plants. University Presses of Florida, Gainesville, Florida.

Weekley, C. 1997. Letter communication. March 21, 1997.

Weekley, C. 1998. Comments on draft species accounts. January 28.

Recovery for the Scrub Plum

Prunus geniculata

Recovery Objective: RECLASSIFY to threatened, then delist.

South Florida Contribution: STABILIZE, and support reclassification.

Recovery Criteria

Prunus geniculata may be considered stabilized when existing populations, within the historic range of *P. geninculata*, are adequately protected from further habitat loss, degradation, and fire suppression. These sites must also be managed to maintain high pine and xeric oak scrub communities to support *P. geniculata*. Proper management for this species will include verification that this long-lived species is in fact reproducing. Currently, seedlings for this species are not being found. The status of *P. geniculata* cannot be determined until adequate reproduction is verified among all populations.

Once the existing populations are stabilized, *P. geniculata* may be considered for reclassification and, ultimately, delisting. Reclassification will be considered when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations required to ensure 20 to 90 percent probability of persistence for 100 years; when these populations, within the historic range of *P. geniculata* are adequately protected from further habitat loss, degradation, and fire suppression; when these sites are managed to maintain the high pine and xeric oak scrub communities to support *P. geniculata*; and when monitoring programs demonstrate that these sites support sufficient population sizes, are distributed throughout the historic range, and are sexually or vegetatively reproducing at sufficient rates to maintain the population.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information.

Species-level Recovery Actions

S1. Determine current distribution of *P. geniculata*.

S1.1. Conduct surveys for *P. geniculata*.

S1.1.1. Survey scrub habitat in Osceola County. Adequate survey work has not been onducted off the Lake Wales Ridge.

S1.1.2. Continue surveys in Polk and Highlands counties. The Lake Wales Ridge has probably been adequately surveyed, though new sites may still be found for *P. geniculata*.

S1.1.3. **Continue surveys on protected lands. New sites for listed species are still being found on protected lands.** This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. **Maintain distribution of known populations and suitable habitat in GIS database.** Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the FNAI database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This infor-mation would show potential habitat for scrub endemics based on their habitat needs.

S2. **Protect and enhance existing populations.** Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties has been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. **Protect privately owned habitat through acquisition, conservation easements, or agreements with landowners.**

S2.2. **Protect populations on public lands.** Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages.

S2.3. **Use local or regional planning to protect habitat.** Utilize available regional and county planning processes to encourage protection of suitable, unoccupied, and occupied habitat of *P. geniculata.*

S2.4. **Continue *ex situ* conservation.** *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *P. geniculata.*

S2.4.1. **Conserve germ plasm.** The seed for this species is not presently in long-term storage.

S2.4.2. **Maintain *ex situ* collection.** Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *P. geniculata* as part of the National Collection.

S2.5. **Enforce available protective measures.** Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *P. geniculata* lives.

S2.5.1. **Initiate section 7 consultation when applicable.** Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. **Enforce take and trade prohibitions.** This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the

Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. Conduct research on life history characteristics of *P. geniculata.* Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, dispersal, growth, survival, and mortality. Given that no seedlings have been confirmed in the wild, recruitment and survival are of primary concern for this species.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations/populations, and spatial distribution needed to ensure persistence of the species.

S3.2.1. Conduct research to assess management requirements of *P. geniculata.* Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring at *P*. *geniculata* sites will provide information about factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers and close coordination among land managers is essential in the development of management techniques. *Prunus geniculata* grows in both scrub and high pine communities. In each of these habitats, *P. geniculata* is exposed to a different fire regime and the species reacts differently to these burn cycles. More information on these reactions is needed to develop management recommendations.

S4. Monitor existing populations of *P. geniculata*.

S4.1. Develop monitoring protocol to assess population trends for *P. geniculata*.

S4.1.1. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, dispersal, survival and mortality. Also monitor for pollinators, herbivory, disease and injury.

S4.1.2. Monitor the effects of various land management actions on *P. geniculata*. Assess any changes in demographic characteristics of *P. geniculata* in response to land management activities, such as prescribed fire, exotic plant control, *etc*.

S4.2. Develop a quantitative description of the population structure of *P. geniculata.* This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) should also be included.

S5. Provide public information about *P. geniculata*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species.

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *P. geniculata* and other rare species requires a self sustaining, secure number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there are six protected sites for *P. geniculata* in Polk and Highlands counties.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *P. geniculata* populations by preventing damage from land off-road vehicle use, overcollection, and by providing proper management of habitat, including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic/invasive plants may become a threat to the survival and recovery of *P. geniculata.*

H1.2.3. Control access to areas where listed plants are growing. Collection, trampling, and off-road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites, a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were historic, may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. **Conduct habitat-level research projects.** Study the response of *P. geniculata* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. **Monitor habitat/ecological processes.** Monitor the effects of land management actions, such as prescribed fire, exotic plant control, etc., on the habitats where *P. geniculata* occurs.

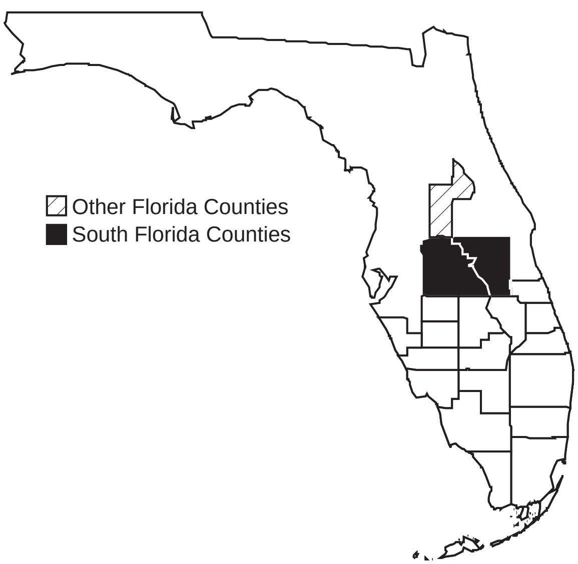
H5. **Provide public information about scrub and its unique biota.** Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the South Florida Water Management District, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful.

Wide-leaf Warea (or Clasping Warea)

Warea amplexifolia Nutall

Federal Status:	**Endangered (April 29, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. County distribution of wide-leaf warea.



Wide-leaf warea is an erect annual herb in the mustard family (Brassicaceae). The species has an extremely limited distribution, covering a north-south distance of about 80.5 km along the northern portion of the Lake Wales Ridge. In the South Florida Ecosystem, *Warea amplexifolia* is known to persist at only two sites in Polk County and one in Osceola County. *Warea amplexifolia* is endemic to high pine (sandhill) habitat, which has been greatly reduced by conversion of natural habitat to citrus groves, residential and commercial development, sand mining, and the lack of proper fire management in the remaining natural habitats.

This account represents South Florida's contribution to the existing recovery plan for the wide-leaf warea (FWS 1993).

Description

Warea amplexifolia is an annual herb in the mustard family (Brassicaceae). Plants may be 30 to 100 cm tall and the stalk may be unbranched or, more often, branching mid-way up the stem. Leaves are alternate, from 2 to 5 cm long, and 1 to 3 cm wide, smaller as they ascend the stalk, with a rounded apex and entire margin. On young plants, the leaves are slightly folded along the midrib, tipped upward, and the lobes at the base of leaves reach around the stem. This characteristic has led to one of the common names for the species, clasping warea. The heart-shaped clasping leaf bases and its pale green, slightly glaucous leaves readily distinguish *W. amplexifolia* from the three other species in its genus in Florida. The characteristic leaves can be used in field identification even if the plants are not flowering.

The pale lavender flowers of *W. amplexifolia* vary in individuals from almost white to almost purple. Flowers appear at the ends of the branches in spherical clusters about 5 to 6 cm across. Superficially, the flowers look like small versions of the garden cleome (*Cleome hasslerana*), a member of the family Capparaceae. The inflorescences are dainty, and in the field the flowering plants look almost fluffy. Individual flowers are about 1.5 cm across, with four petals and six long stamens.

Warea amplexifolia is also readily identifiable in seed, even as the stalk turns brown and the leaves wither, by the clusters of narrow down-curving seed pods, from 5 to 7 cm long. The pods split longitudinally, with small black seeds on either side of the center membrane.

Polonisia tenuifolia, an annual in the family Capparaceae, which grows about as tall as *W. amplexifolia*, might be mistaken for *W. amplexifolia* when the plants are brown and dry at the end of the season. However, *Polonisia* seed pods, which are about the same size as those of *Warea*, appear singly in the leaf axils and are erect and straight (FWS 1993).

Taxonomy

Warea amplexifolia was originally described by Thomas Nutall in 1822 from a specimen collected in central peninsular Florida by N.A. Ware. Nutall at first placed this plant in the genus *Stanleya*, but in 1834 transferred it to the genus *Warea* and provided an amplified description that accommodated specimens from the Florida panhandle. The panhandle specimens were later recognized as a distinct species, *Warea sessilifolia,* by Nash. Shinners (1962) proposed a new name for the peninsular species, *Warea auriculata*, but most authors consider *W. amplexifolia* the correct name (Payson 1922, Channel and James 1964, Judd 1980).

Distribution

Warea amplexifolia was collected infrequently between its initial discovery in the early 1800s and 1986, when it was listed as endangered. This is most likely due to its extremely limited range. By the time a status survey for *W. amplexifolia* was conducted (Judd 1980), much of the high pine habitat in the region had been destroyed or degraded. As a result, it is impossible to determine the species' original range.

Judd (1980) believed the former range of *W. amplexifolia* included Lake County, western Orange County, extreme northwestern Osceola County, and northern Polk County, but he wrote that the species' range had been reduced to three sites in Lake County and a single site in northern Polk County before his survey. Since then, additional sites have been discovered in Lake, Polk, and Osceola counties and several of the previously documented sites have been eliminated. The present distribution of *W. amplexifolia* includes Lake, Polk, and Osceola counties (Figure 1); the species has probably been extirpated from Orange County.

Habitat

Warea amplexifolia is endemic to the high pine (or sandhill) habitat (Myers 1990) that once covered the northern half of the Lake Wales Ridge in Lake and Polk counties. The high pine community has a relatively high diversity of herbaceous ground cover (Myers 1990), which was maintained, under natural conditions, by

Wide-leaf warea flower.
Original photograph by Steve Shirah.

patchy summer fires sparked by lightning. The FWS currently does not have a list of USDA soil series on which *W. amplexifolia* grows throughout its present range. However, comparing a map provided by Judd (1980) of a *W. amplexifolia* location in northern Polk County (Haines City site) with USDA soil maps (USDA 1990), the species was growing on Apopka fine sand. Plants at the other site in Polk County, at Bok Tower Gardens, are growing on Candler sand (T. Race, Bok Tower Gardens, personal communication 1997). Candler sand is also the dominant soil type on the higher elevations of the Lake Davenport site, Osceola County. Several of the FNAI records for this species report the species growing on Astatula Series soils (FNAI 1997).

Warea amplexifolia is limited to dry, open longleaf pine (*Pinus palustris*) woods, longleaf pine/turkey oak (*Quercus laevis*) woods, or live oak/bluejack oak (*Q. geminata*/*Q. incana*) woods that occur on well-drained, sterile, yellowish sands on the Lake Wales Ridge. *Warea amplexifolia* is limited to sunny openings in those woodlands. *Warea amplexifolia* seems unable to tolerate shading or intense competition; it may be favored by slight disturbance, but does not generally occur in weedy sites (roadsides, cleared fields, citrus groves, or pastures) (Judd 1980). Under a natural fire periodicity, *W. amplexifolia* would be expected to grow in areas having a scattered overstory of *P. palustris*. Judd (1980), however, observed that xeric oaks (*Q. laevis*, *Q. incana*, and *Q. geminata*), which under natural fire frequency are present in the understory, were forming an overstory at several of the *W. amplexifolia* sites, due to lack of fire and the cutting of longleaf pine. Under a natural fire regime, a diverse assemblage of herbaceous vegetation grows in the sunny, open areas with exposed sand. Scattered individuals of *W. amplexifolia* are generally widely spaced in these openings, with much exposed sand among patches of reindeer moss (a lichen, *Cladonia* spp.).

Reproduction

Warea amplexifolia flowers from mid-August to early October, and fruiting occurs from late September to mid-November. Senescence occurs just before the fruit matures, and the population overwinters as seeds. The showy flowers are pollinated by various Hymenoptera (bees) and Lepidoptera (butterflies). Reproduction is exclusively sexual, with seeds probably released from the pods by wind action. The small seeds generally fall near the parent plant (FWS 1986). Experimental propagation to field plots at Bok Tower Gardens suggests that the number of flowering plants is related to the amount of rainfall during the December prior to the growing season. They also found that plants grew from seeds that had been sown into the experimental plots 2 to 4 years earlier, which indicates that seed banking in the soil is important in this species (Bok Tower Gardens 1994).

Relationship to Other Species

Like many herbaceous plants that grow in open, sandy patches, *W. amplexifolia* does not tolerate shading by dense shrubs or trees. The habitat structure of the surrounding forest around the open patches is controlled under natural conditions by fire. Other methods of controlling canopy closure and potential problems with exotic grasses are discussed below under Management.

Bok Tower Gardens (1994) believes that *W. amplexifolia* and wiregrass (*Aristida beyrichiana*), the dominant native grass in the high pine community, depend on similar fire regimes, but recommends further research to determine the relationship of these species to fire intervals and burn regimes.

Bard (1996) noted that four species of ants (*Camponotus socius*, *Pogonomyrmex badius*, *Formica pallidafulva*, and *F. archboldi*) occur around *W. amplexifolia* at Lake Griffin State Recreation Area, and believed these ants help disperse *Warea* seeds. No information is currently available on the relationship of *W. amplexifolia* to wildlife species, such as the gopher tortoise (*Gopherus polyphemus*), which could be important in generating minor soil disturbance in this habitat.

Status and Trends

Warea amplexifolia was included in the list of plant species the Smithsonian Institution believed warranted listing in its January 1975 report to Congress. *Warea amplexifolia* was listed as endangered under the ESA on April 29, 1987 (52 FR 15505); the listing cited the species' limited distribution and loss of its habitat, primarily to urban expansion and conversion to citrus groves, as the primary reason for listing it endangered.

High pine was once extensive on the Lake Wales Ridge (Myers 1990). Although many people involved in conservation of natural areas associate the Lake Wales Ridge with the scrub community, the public is much less aware that the scrub was originally surrounded by a larger matrix of high pine. Although scrub has certainly been reduced to a small percentage of its historic range, high pine, which was more suitable for conversion to citrus, has been reduced to a much smaller percentage of its original range (DEP 1996).

As mentioned earlier, it is impossible to determine the original range and abundance of *W. amplexifolia*, but the high pine community in which it lives has been greatly reduced by agricultural, commercial, and residential development. Judd (1980) determined that *W. amplexifolia* had likely been extirpated from the historic Apopka, Clarcona, Ocoee, and Windemere sites in Orange County and from the Wilson Lake Road site in northwestern Osceola County. Judd located only three extant populations in Lake County and one in northern Polk County and reported that all of these were in private ownership. Judd apparently was unaware that an approximately 8 ha wooded area, surrounded by development, which he called "Leesburg Site" is a small disjunct portion of the Lake Griffin SRA.. The recovery plan (FWS 1993) stated that 10 populations had been identified in Lake and Polk counties, including a population at Bok Tower Gardens, near Lake Wales in Polk County, which had been identified by Hall (1985). Judd's "Haines City" site, located west of U.S. Highway 27 and east of Lake St. Charles about 7 km north of Haines City, is most likely now eliminated by a residential housing development (N. Bissett, Natives Nursery, personal communication 1997).

The FNAI produced a land acquisition proposal, entitled the Warea Archipelago, for the (CARL) program, based on surveys conducted in 1991and 1992 (R. Hilsenbeck, The Nature Conservancy, Tallahassee, personal communication 1997). Six tracts of land containing *W. amplexifolia* were identified: Sugarloaf Mountain, Ferndale Ridge, Castle Hill, Flat Lake, Schofield Sandhill, and Lake Davenport. Five of these are in Lake County and one is in Osceola County.

The FNAI conducted another survey for *W. amplexifolia* in 1994 and 1995 in Lake County on behalf of the Lake County Water Authority and the SJWMD. This survey located a total of 17 sites (G. Race, Lake County Water Authority, personal communication 1997). Unfortunately, large portions of Lake County are being cleared for the suburban expansion of the Orlando metropolitan area. Two homes are being constructed on or near the Ferndale Ridge site; although this may not preclude acquisition of the remaining properties in the Ferndale Ridge area. Increasing density of homes in the area could increase land values and make fire management of the remaining properties more difficult (G. Race, Lake County Water Authority, personal communication 1997).

Warea amplexifolia is present in a remnant high pine habitat next to a golf course in the Mountain Lake Estates housing development, near Bok Tower Gardens, Polk County (T. Race, Bok Tower Gardens, personal communication 1997). *Warea amplexifolia* has been discovered on the site of a proposed nursery along Champaigne Road, between Haines City and Davenport, Polk County. The plan for the nursery on this 4 ha acre property calls for preservation of about half the site in native vegetation, which could be managed by controlled burning (N. Bissett, Natives Nursery, personal communication 1997).

Because individual plants die at the end of each growing season, and because the number of plants at a given site varies greatly from year to year (T. Race, Bok Tower Gardens, personal communication 1997), it is difficult to document trends in population numbers. The ecology of *W. amplexifolia* (a fall-blooming annual growing in a habitat which normally burns during the summer growing season) and anecdotal evidence of plants appearing at sites where they had not been seen for several years, suggests that the species banks seeds in the soil (FWS 1993, Bok Tower Gardens 1994). This complicates the identification of population trends, requiring long-term monitoring at several sites.

Management

The CARL program includes as a high priority the Lake Wales Ridge Ecosystems Project, which in turn includes a subset of parcels commonly known as the Warea Archipelago sites, targeted at remnant high pine habitats in the northern Lake Wales Ridge. *Warea amplexifolia* occurs on all six sites proposed for acquisition. The 49 ha Flat Lake property in Lake County is now under contract for acquisition by The Nature Conservancy. The Nature Conservancy is still attempting to negotiate a sale for the Lake Davenport property in Osceola County (R. Hilsenbeck, The Nature Conservancy, Tallahassee, personal communication 1997). Purchase of all six properties should be a high priority for recovery of the species.

Bok Tower Gardens has researched methods for propagating *W. amplexifolia*. Although propagation from seed in a greenhouse resulted in a high rate of germination and early survival, all of the seedlings planted outside in native yellow sand died before flowering from the action of leaf miners, lepidopteran larvae, fungus, and unknown causes (Bok Tower Gardens 1994). Direct sowing of *W. amplexifolia* seeds in the field was more effective. In 1990, 2,000 seeds were sown, resulting in 30 percent germination and 16 flowering plants (0.8 percent). In 1991, 5,000 seeds produced 280 (5.6 percent) seedlings, and 46 (0.92 percent of total seed) flowered.

At Lake Griffin SRA, *W. amplexifolia* covered about 0.08 ha on the 8 ha parcel in May 1994. Under a FWS recovery contract, DEP started clearing oaks (except bluejack oak), and treated the cut surfaces with Garlon 3A (triclopyr) or Roundup (glyphosate). After removal of the oaks, centipede grass (*Eremochloa ophiuroides*) increased around the colony of *W. amplexifolia*. The exotic centipede grass was treated with Poast (sethoxydim). Other exotic plants that were hand pulled or treated with herbicide included rosary pea (*Abrus precatorius*), Chinese tallow (*Sapium sebiferum*), mimosa *(Albizia julibrissin*) and Sprenger's asparagus (*Asparagus sprengeri*). As of 1997, about 2 ha had been cleared. By 1996, the area covered by Warea was estimated to be about 0.2 ha. The number of individual *W. amplexifolia* plants was 57 in 1994 and 118 in 1996. Approximately 26,000 wiregrass plants have also been planted in the restored area, and within a few years, DEP anticipates that the wiregrass should be established enough to perform a controlled burn (Bard 1996; A. Bard, DEP, personal communication 1997).

Bok Tower Gardens (1994) recommends field experiments to determine the influence of wiregrass on the fire ecology of *W. amplexifolia*. Because *W. amplexifolia* also grows in association with several other protected species, research is needed on the fire ecology of each component of the community to devise a compatible management plan.

The *W. amplexifolia* population at Mountain Lake Estates is apparently not under immediate threat of development, and a conservation committee has been formed among the residents (T. Race, Bok Tower Gardens, personal communication 1997). This may provide an opportunity to establish a cooperative agreement for management of this remnant high pine habitat on private property.

Literature Cited

Bard, A.M. 1996. Enhancement of resource management activities for *Warea amplexifolia* at Lake Griffin State Recreation Area. Division of Recreation and Parks, Florida Department of Environmental Protection; Apopka, Florida. Unpublished report prepared under contract with U.S. Fish and Wildlife Service; Jacksonville, Florida.

Bard, A.M. Telephone conversation. 30 January 1997.

Bok Tower Gardens. 1994. Experimental reintroduction project for *Warea amplexifolia*. Anonymous report, 1 March 1994. Files of the U.S. Fish and Wildlife Service; Jacksonville, Florida.

Channel, R.B., and C.W. James. 1964. Nomenclatural and taxonomic corrections in *Warea* (Cruciferae). Rhodora 66:18-26.

Florida Department of Environmental Protection. 1995. Conservation and Recreational Lands (CARL) annual report. Florida Department of Environmental Protection; Tallahassee, Florida.

Florida Natural Areas Inventory. 1997. Letter (with enclosed Element Occurrence Records) from Ann. F. Johnson to Robert Pace, U.S. Fish and Wildlife Service; Vero Beach, Florida.

Hall, D.W. 1985. Letter to Edward Wheeler; 14 November 1985. Institute of Food and Agricultural Sciences, University of Florida; Gainesville, Florida.

Hilsenbeck, R. Telephone conversation. 5 February 1997.

Judd, W.S. 1980. Status report on *Warea amplexifolia*. Unpublished report prepared under contract with U.S. Fish and Wildlife Service; Jacksonville, Florida.

Myers, R.L. 1990. Scrub and high pine. Pages 150-174 *in* R.L. Myers and J.J. Ewell, eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

Nutall, T. 1822. A catalogue of a collection of plants made in East-Florida, during the months of October and November, 1821 by A. Ware, Esq. American Journal of Science 5:297.

Payson, E.B. 1922. A monographic study of *Thelypodium* and its immediate allies. Annual Missouri Botanical Garden 9:233-324.

Race, G. Telephone conversation. 4 February 1997.

Race, T. Telephone conversation. 28 January 1997.

Shinners, L.H. 1962. *Warea auriculata* instead of *W. amplexifolia* of Small (Cruciferae). Rhodora 66:18-26.

Smithsonian Institution. 1975. Report on endangered and threatened plant species of the United States. House Document Number 94-51. U.S. Government Printng Office; Washington, D.C.

U.S. Department of Agriculture. 1990. Soil survey of Polk County, Florida. Soil Conservation Service.

U.S. Fish and Wildlife Service [FWS]. 1993. *Warea amplexifolia* (Clasping warea) recovery plan. U.S. Fish and Wildlife Service; Atlanta, Georgia.

Ward, D.B. (editor). 1979. Rare and endangered biota of Florida, volume five: Plants. University Presses of Florida; Gainesville, Florida.

Recovery for the Wide-leaf Warea (or Clasping Warea)

Warea amplexifolia Nutall

Recovery Objective: PROTECT EXISTING POPULATIONS; create new populations if feasible.

South Florida Contribution: PREVENT extinction, then stabilize.

Recovery Criteria

Recovery actions for *Warea amplexifolia* in South Florida are supportive of the overall recovery goal for the species. The objective of this recovery plan should be to increase existing populations and prevent extinction. *Warea amplexifolia* may be considered stabilized when existing populations, within the historic range, are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression. These sites must also be managed to maintain the high pine community to support *W. amplexifolia*.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *W. amplexifolia*.

S1.1. Conduct surveys of *W. amplexifolia*.

S1.1.1. Conduct surveys in Polk and Osceola counties. New locations for this species may be found.

S1.1.2. Continue surveys on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. Maintain distribution of known populations and suitable habitat in GIS database. Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the FNAI database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub and high pine endemics based on their habitat needs.

S2. **Protect and enhance existing populations.** Much of the native xeric uplands on the Lake Wales Ridge and surrounding areas has been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases is isolated.

S2.1. **Protect habitat** through acquisition, conservation easements, or agreements with landowners. The Warea Archipelago is a series of small properties that are being purchased through CARL that are designed to protect *W. amplexifolia* and the unique community in which it lives.

S2.2. **Protect populations on public lands.**

S2.3. **Use local or regional planning to protect habitat.** Utilize available regional and county planning processes to encourage protection of suitable habitat, both occupied unoccupied, and occupied habitat of *W. amplexifolia*.

S2.4. **Continue *ex situ* conservation.** *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *W. amplexifolia*.

S2.4.1. **Conserve germ plasm.** The seed for this species is not presently in long-term storage.

S2.4.2. **Maintain *ex situ* collection**. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *W. amplexifolia* as part of the National Collection.

S2.5. **Augment natural populations of *W. amplexifolia.***

S2.5.1. **Establish a protocol for reintroduction.** Records for source plants, techniques for establishing new populations, and protocols for monitoring are needed.

S2.5.2. **Locate potential (re)introduction sites.** Survey habitat within the historic range of *W. amplexifolia* and identify protected lands, both public and private, that would be suitable habitat.

S2.5.3. **(Re)introduce plants to protected sites.** Use plants under cultivation to (re)establish plants in suitable habitat.

S2.6. **Enforce available protective measures.** Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *W. amplexifolia* lives.

S2.6.1. **Initiate section 7 consultation when applicable.** Initiate section 7 consultations when Federal activities may affect this species.

S2.6.2. **Enforce take and trade prohibitions.** This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from State lands.

S3. Continue research on life history characteristics of *W. amplexifolia*. Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species more specific biological information is needed.

S3.1. Continue research to determine biology and demographic information, such as numbers of sites and populations, numbers of individuals in a population, morphology, reproduction, recruitment, dispersal, growth, survival, and mortality.

S3.2. Conduct research to assess management requirements of *W. amplexifolia*. Determine which natural populations can be stabilized or increased by habitat management. Surveys, research, and monitoring at *W. amplexifolia* will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers. Close coordination among land managers is essential to develop adaptive management techniques.

S4. Continue monitoring the existing populations of *W. amplexifolia*.

S4.1. Evaluate the effectiveness of the monitoring protocol used to assess population trends for *W. amplexifolia*. As more information is gained about *W. amplexifolia*, monitoring protocols may need to be altered to make use of new information.

S4.2. Monitor and detect changes in demographic characteristics, such as growth, survival, and mortality. Herbivory, pollinators, disease, and injury should also be monitored. Characteristics such as reproduction, recruitment, and dispersal cannot truly be monitored in the wild at this time, but should be included as introductions make reproduction possible.

S4.3. Monitor the effects of various land management actions on *W. amplexifolia*. Assess any changes in demographic characteristics of *W. amplexifolia* in response to land management activities, such as prescribed fire, exotic plant control, *etc.*

S4.4. Continue to work with private landowners. The successful recovery of this species will be influenced by the participation of private landowners. To date a varying amount of support has been gained among the individual landowners.

S4.5. Monitor introduced plants. Monitoring of reintroduced plants will be essential for assessing the status of new plants and their contribution to the population as a whole. Compare adult survival, seedling production, germination rates, seed survival, seedling survival, and growth rates between transplanted and natural plants. Where monitoring indicates that introduction has been unsuccessful, reevaluate protocol and methodology developed.

S5. Provide public information about *W. amplexifolia*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *W. amplexifolia* and other rare species require a self- sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss has already occurred throughout the range of this species. Both development and fire suppression have decreased the available habitat.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. Any method of securing protected high pine habitat should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *W. amplexifolia* populations by preventing damage from off-road vehicle use and collection, and by providing proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the high pine community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida high pine as compared to other communities in South Florida.

H1.2.3. Control access to areas where listed plants are growing. Collection, trampling, and off-road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H2.2. Enhance sites with native plant species. Because of logging or long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. These species can be reintroduced if natural colonization is not possible.

H3. Conduct habitat-level research projects. Study the response of *W. amplexifolia* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, etc., on the habitats where *W. amplexifolia* occurs.

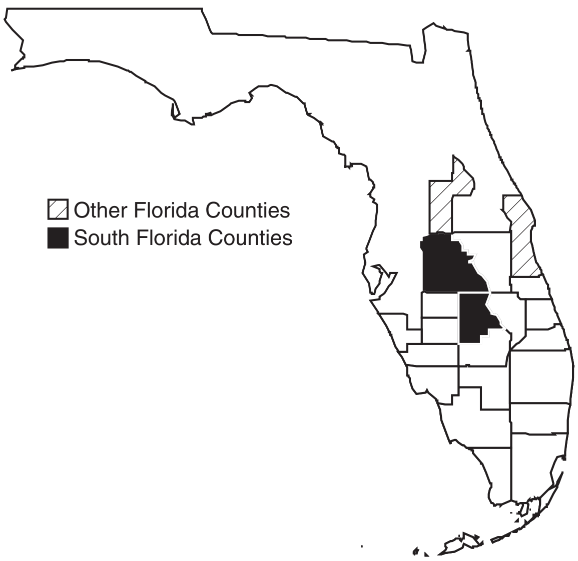
H5. Provide public information about scrub and high pine and their unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the South Florida Water Management District, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Carter's Mustard

Warea carteri Small

Federal Status:	**Endangered: (January 21, 1987)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of Carter's mustard.



Warea carteri is a fire-dependent annual herb occurring in xeric, shrub-dominated habitats on the Lake Wales Ridge of central Florida. One occurrence of *W. carteri* is also known from coastal scrub in Brevard County on Florida's Atlantic coast, but has not been relocated. The species occurred historically in the Miami metropolitan area, Miami-Dade County, and is extirpated from this county. The primary threats to *W. carteri* are habitat loss to citrus groves and residential developments, and long-term fire suppression, both of which cause local extirpations.

This account represents a revision of the existing recovery plan for Carter's mustard (FWS 1996).

Description

Warea carteri is an annual herb, 0.2 to 1.5 m tall with erect green stems. The plants usually have many slender, ascending branches forming an open, rounded crown. The leaves lack stipules and are arranged alternately on the stem. Lower leaves are lost by the time the plant flowers. Leaf size and shape varies with age and position on the plant. At the time of flowering, leaf petioles range from 0.8 to 3.9 mm with blades 1to 3 cm long. Towards the tips of stems, the leaves are smaller and narrowly elliptical to almost linear, while closer to the bases of stems and branches, the leaves are larger and oblanceolate or spatulate. All leaves are rounded at the tip, their margins entire, and their bases attenuate to cuneate. The lower leaves can also be undulate, margined or lobed.

The many inflorescences of *W. carteri* are dense, rounded racemes with many flowers (60 or more). The flowers are radially symmetric, with four white linear-oblanceolate sepals, about 4.5 mm long, and curved toward the center of the flower at the tip. The four petals are white, about 6.0 mm long, with more than half their length in the form of a slender claw. The petal's blade is nearly round with irregular margins. The six spreading stamens are irregularly subequal in length and arise from a nectar-producing floral disc. The ovary is superior, cylindric, about 2.3 mm long, and raised on a slender stalk (gynophore) about 2 mm long. The sessile stigma has two lobes. *W. carteri* is protandrous: the anthers begin to dehesce within an hour or two after the flower has opened. The stigmas are receptive until 2 to 4 days afterwards, by which time the stamens on that flower have dropped.

Warea carteri's fruit is a silique, long, slender pod divided lengthwise by a partition (septum). The pod is flattened, cylindrical in cross-section and gently curved along its length, which is 4 to 6 cm long and 1.5 mm wide. The pod is borne on a gynophore, which is a stalk-bearing pistil 5 to 6 mm long,above a spreading pedicel, which is around 8.5 mm long.The pod carries numerous oblong seeds, each 1.5 mm long (Kral 1983). Fruits split apart passively to shed the seeds.

Taxonomy

Warea carteri was named by Small in 1909. A review of the genus by Channel and James in 1964 retained Small's treatment of the species. There are no scientific synonyms (Nauman 1980). Common names for the species include Carter's mustard, Carter's warea, and Carter-warea.

Distribution

From what is known of the historic distribution of *W. carteri*, it occurred in scrubby flatwoods and sandhills of the Lake Wales Ridge in Highlands, Polk, and Lake counties, in South Florida slash pine forests of the Miami area in Miami-Dade County, and in coastal scrub in Brevard County. It has been found in yellow sand scrub at Lake Wales Ridge SF (C. Weekley, Lake Wales Ridge SF personal communication 1998).

The current known distribution of *W. carteri* includes Highlands, Polk, and Lake counties on the Lake Wales Ridge in central Florida. It may occur in Brevard County on Florida's Atlantic coast (Figure 1).

Habitat

The two largest populations of *W. carteri* on the Lake Wales Ridge occur at Archbold Biological Station and The Nature Conservancy's Tiger Creek Preserve. At Archbold Biological Station, *W. carteri* occurs in scrubby flatwoods and in turkey oak- and hickory-dominated sandhills, and is often found in the ecotone between these two vegetation types. Because sandhills occur on yellow sands, *W. carteri* is often found in or near yellow sands. Several populations of *W. carteri* at Archbold Biological Station are adjacent to roads, firelanes, or in areas with historic human disturbance. At Tiger Creek Preserve, *W. carteri* is found in degraded sandhill habitat where turkey oak is abundant, in scrubby flatwoods, and in xeric hammocks (E. Menges, Archbold Biological Station, personal communication 1995).

The collection of *W. carteri* made in Brevard County was in coastal scrub. In Miami-Dade County, *W. carteri* was found in South Florida slash pine

Carter's mustard.
Original photograph by Betty Wargo; original flower photograph by Steve Shirah.

(*Pinus elliotti* var. *densa*) flatwoods. Here it may have occupied some of the same sites as *Polygala smallii* (tiny polygala) and *Sabal miamiensis* (Miami palmetto), both of which occur in areas with a sandy surface rather than bare oolitic limestone.

Reproduction

Experiments have demonstrated that *Warea carteri* is self-pollinating, autogamous, and self-compatible (Evans *et al.*, in press). Autogamy and self-compatibility allow isolated or sparsely distributed individuals to reproduce. Natural levels of fruit- and seed-set are quite high, with a fruit-set of 62 percent, and seed-set of 50 percent (Evans *et al.* in press). Self-pollinated flowers showed significantly lower fruit- and seed-set, 41 percent fruit-set and 28 percent seed-set. This indicates that insect-mediated pollination is important in keeping fruit- and seed-set high, and individual fecundity high. Pollinators appear to be the limiting factor in fruit and seed production (Evans *et al.* in press). Because aboveground populations fluctuate wildly, autogamy helps ensure fecundity and may be a key life history trait (E. Menges, Archbold Biological Station, personal communication 1995).

Germination in W. carteri occurs in late winter through early spring (January-March). Flowering occurs in September and October. Fruiting occurs in October and November, and dispersal follows in November and early December (Kral 1983).

Preliminary observations of insect activity on *W. carteri* indicate it is a generalist with respect to pollination. A great diversity of insects visit the flowers, including native solitary bees, bumblebees, syrphids (known as hoverflies or bee-flies), wasps, flies, beetles, *etc*. Within-plant movements by insects appear to predominate over among-plant movements. Because of this, and in combination with the close proximity of male and female flowers in an inflorescence, self-pollination probably is a regular method of reproduction in this species (Evans *et al.* in press).

There are no obvious specialized forms of seed dispersal in *W. carteri*. The siliques do not open explosively; rather, the external walls of the fruit peel away from the central septum as the fruit slowly dries, exposing the mature seeds inside. The seeds drop passively to the ground or they may be flung a bit further if the plant is brushed. It's not likely that seeds are moved by wind once they reach the ground. Collection or movement of seeds of *W. carteri* by ants or other animals has not been studied, but there are no obvious specialized structures on the seed that would encourage such movement.

Large fluctuations observed in above ground population size suggest the possibility that seed banking plays a significant role in *W. carteri*'s biology. Environmental cues necessary for germination were explored experimentally at Archbold Biological Station (E. Menges, Archbold Biological Station, personal communication 1995). Moisture and light were found to be necessary for germination. The use of an oak leachate did not significantly affect germination. Some seeds stored in dry, dark conditions for 2 years germinated, demonstrating the potential of *W. carteri's* seeds to remain dormant at least that long. Fire-related cues such as heat do not stimulate germination, but germination does require light and seeds may remain dormant for more than 2 years (E. Menges, Archbold Biological Station, personal communication 1995).

Relationship to Other Species

Warea carteri typically occurs in dry oak sites where other scrub endemics are scarce (FWS 1996) and at the ecotone between scrub and high pineland with other plants: *Eriogonum longifolium* var. *gnaphalifolium* (scrub buckwheat) and *Prunus geniculata* (scrub plum) (K. DeLaney, Environmental Research Consultants, Inc., personal communication 1995). *W. carteri* does not seem to suffer badly from herbivory or predation by vertebrates or invertebrates, but a small percent of individuals do seem to suffer from the growth of a mold or fungus (M. Evans, Archbold Biological Station, personal communication 1995). There have not been any specific studies of *W. carteri*'s competitive relationships with other species. It is not clear whether the lack of above ground individuals in areas not recently burned is due to competition from other vegetation or if a direct effect of fire is necessary for germination (*i.e.* nutrient pulse, smoke, *etc*.). Although some persistent populations of *W. carteri* are found in openings in disturbed sites, populations in natural habitats following fire do not seem to be concentrated in openings between shrubs. In dense xeric hammocks though, they may prefer tree-canopy gaps (E. Menges, Archbold Biological Station, personal communication 1995).

Status and Trends

Warea carteri was listed as an endangered species in 1987 due to habitat loss (52 FR 2234). The primary threats to *W. carteri*'s persistence are habitat destruction and fire suppression. On the Lake Wales Ridge, *W. carteri* is threatened primarily by the conversion of its habitat to citrus groves or residential subdivisions. In Highlands County, 64.2 percent of the xeric vegetation (sand pine scrub, scrubby flatwoods, and southern ridge sandhills) present before settlement was converted to other land uses by 1981. An additional 10.3 percent of the xeric vegetation was moderately altered, primarily by building roads to create residential subdivisions (Peroni and Abrahamson 1985). The situation is similar in Polk and Lake counties. Fire suppression has been in practice throughout *W. carteri*'s range for many decades. Fire suppression is a threat to this species because its demography and reproduction seem to be closely tied to fire.

The historical distribution of *W. carteri* includes the sites of at least 14 herbarium collections made in what is now the Miami urban area in Miami-Dade County, from 1878 to 1934. Nearly all of the suitable habitat for the plant in this area has been altered by urban growth. The remaining tracts of native vegetation have been searched carefully in recent years (D. Austin, Florida Atlantic University, personal communication 1995). The plant is almost certainly extirpated from the county (Nauman 1980).

Warea carteri has probably been extirpated from Brevard County as well as no specimens have been observed in recent years.

The status of the two largest populations of *W. carteri* in central Florida (at Archbold Biological Station and Tiger Creek Preserve) has been monitored for 6 years (M. Evans, Archbold Biological Station, personal communication 1995). Extreme fluctuations of population size are observed year to year. The data accumulated on population sizes indicate a strong relationship with fire. *W. carteri* seems to respond quickly, strongly, and positively to fire. Major population increases and the discovery of new populations consistently occur 1 year after fire, while major population crashes, including the appearance of no above ground individuals, occur 2 years after fire (Menges 1995).

The demography of *W. carteri* is being studied at Archbold Biological Station, Tiger Creek Preserve, and the Lake Placid Scrub (E. Menges, Archbold Biological Station, personal communication 1995). Dozens of local patches are known from Archbold Biological Station and Tiger Creek Preserve, although not all patches have aboveground plants in any given year. At both Archbold Biological Station and Tiger Creek Preserve, many *W. carteri* populations have behaved fairly predictably in response to fire. Populations either appear or boom the year following fire (11 of 16 instances of population doubling at Tiger Creek Preserve occurred the year after a fire). Population crashes occur in the second year (18 of 26 populations at Tiger Creek Preserve lost more than 50 percent 2 years post fire) (Menges 1995, Menges and Gordon 1996). Populations in sites that have experienced prolonged fire suppression usually persist only in very low above ground densities.

Warea carteri is currently protected at Archbold Biological Station, Lake Placid Scrub, Tiger Creek Preserve, Lake Wales Ridge SF, Snell Creek and Horse Creek. Polk County. BLM is in contact with the SFWMD and FWS to determine the best course of action to pursue in order to protect and manage *W. carteri* at this site (S. Vogelpohl, BLM, personal communication 1998).

Management

The natural fire return interval in the various vegetation communities *W. carteri* inhabits ranges from every 2 to 6 years for turkey oak-dominated sandhill, to every 6 to 10 years in scrubby flatwoods, to every 10 to 20 years in hickory-dominated sandhill (Myers 1990). Through demographic monitoring of *W. carteri,* it is becoming clear that fire is an essential management tool to maintain large populations of this species. As with other rare species, habitat protection is a key element to preservation of *W. carteri*.

In the absence of fire, populations of *W. carteri* have survived in smaller numbers in areas of prior human disturbance, such as the margins of roads or firelanes. Several other Lake Wales Ridge endemics that are also federally listed appear to be favored by disturbance in this fashion including: *Eryngium cuneifolium* (snakeroot), *Polygonella myriophylla* (sand lace), *Prunus geniculata* (scrub plum), and *Conradina brevifolia* (short-leaved rosemary) (Johnson 1981), as well as *Polygonella basiramia* (wireweed) (Hawkes and Menges 1995) and *Dicerandra frutescens* (scrub mint) (Menges 1992).

Warea carteri is a locally abundant annual that may remain dormant as seed for several years, so a population may have a substantial number of growing, flowering plants only in the first year after a fire. Because this species is conspicuous only when in flower, monitoring and finding populations is difficult. As previously mentioned, fire management is a critical concern for this species. Long intervals between fires are likely to result in the real loss of viable seeds from the seed bank and declines in population sizes. The risk of extinction for this species is likely to be higher without proper fire management (E. Menges, Archbold Biological Station, personal communication 1995).

For management considerations, it is important to realize that at sites where *W. carteri* is known to occur, individual plants or all the plants at a site may not appear above ground in any given year. One year of searching is not enough to know whether a given site has *W. carteri*. This species is inconspicuous except during a brief flowering period lasting about a month. In addition, its remaining habitat on the Lake Wales Ridge has not been thoroughly surveyed. As a result, the present distributional records are likely incomplete (FWS 1996). The annual habit of *Warea carteri,* and its widely separated known localities, makes assessment of its status or planning its conservation more difficult than is the case for perennial herbs or shrubs.

Literature Cited

Abrahamson, W.G., A.E. Johnson, J.N. Layne, and P.A. Peroni. 1984. Vegetation of the Archbold Biological Station, Florida: an example of the southern Lake Wales Ridge. Florida Scientist 47:209-250.

Austin, D. 1995. FWS Multi-Species Recovery Team meeting. December 6-8, 1995.

Channel, R.B., and C.W. James. 1964. Nomenclature and taxonomic corrections in *Warea* (Cruciferae). Rhodora 66(765):18-26.

DeLaney, K. 1995. FWS Multi-Species Recovery Team meeting. December 6-8, 1995.

Evans, M.E.K., E.S. Menges, and D.R. Gordon. In press. Breeding system of *Warea carteri*: implications for conservation. Conservation Biology.

Evans, M. 1995. FWS Multi-Species Recovery Team meeting. December 6-8, 1995.

Hawkes, C., and E.S. Menges. 1995. Density and seed production of a Florida endemic, *Polygonella basiramia*, in relation to time since fire and open sand. American Midland Naturalist 133:138-148.

Johnson, A.F. 1981. Scrub endemics of the Central Ridge, Florida. Unpublished report to U.S. Fish and Wildlife Service; Jacksonville, Florida.

Kral, R. 1983. *Warea carteri* Small. A report on some rare, threatened, or endangered forest-related vascular plants of the South. U.S. Department of Agriculture, Forest Service technical publication R8-TP2; Atlanta, Georgia.

Menges, E.S. 1992. Habitat preferences and response to disturbance for *Dicerandra frutescens*, a Lake Wales Ridge (Florida) endemic plant. Bulletin of the Torrey Botanical Club 199(3):308-313.

Menges, E.S., and D.R. Gordon. 1996. Three levels of monitoring intensity for rare plant species. Natural Areas Journal 16:227-237.

Menges, E.S. 1995. Monitoring report for *Warea carteri*. Unpublished document. The Nature Conservancy, Florida Chapter. On file at the U.S. Fish and Wildlife Service; Vero Beach, Florida.

Menges, E. 1995. FWS Multi-Species Recovery Team meeting. December 6-8, 1995.

Myers, R. 1990. Scrub and high pine. Pages 150-193 *in* R. Meyers and J. Ewel eds. Ecosystems of Florida. University of Central Florida Press; Orlando, Florida.

Nauman, C.E. 1980. Status report on *Warea carteri* Small. Pages 743-756 *in* D. Austin. Flora and Fauna of South Florida. Unpublished report to U.S. Fish and Wildlife Service; Jacksonville, Florida.

Peroni, P.A., and W.G. Abrahamson. 1985. A rapid method for determining losses of native vegetation. Natural Areas Journal 5:20-24.

Small, J.K. 1909. Additions to the flora of peninsular Florida. Bulletin of the Torrey Botanical Club 36:159.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery plan for nineteen Florida scrub and high pineland species (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Vogelpohl, S. 1998. Comments on draft species accounts. January 16.

Weekley, C. 1998. Comments on draft species account. January 28.

Recovery for the Carter's Mustard

Warea carteri Small

Recovery Objective: STABILIZE, then reclassify to threatened.

Recovery Criteria

Warea carteri may be considered stabilized when existing populations, within the historic range of *W. carteri*, are adequately protected from further habitat loss, degradation, and fire suppression. These sites must also be managed to maintain scrubby flatwoods and turkey oak dominated high pine to support *W. carteri.*

Once the existing populations are stabilized, *W. carteri* may be considered for reclassification. Reclassification will be considered when: enough demographic data are available to determine the appropriate numbers of self-sustaining populations required to assure 95 percent probability of persistence for 100 years; when these populations, within the historic range of *W. carteri* are adequately protected from further habitat loss, degradation, and fire suppression; when these sites are managed to maintain the scrubby flatwoods and turkey oak dominated high pine to support *W. carteri*; and when monitoring programs demonstrate these sites support sufficient population sizes, are distributed throughout the historic range, and are sexually reproducing at sufficient rates to maintain the population.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. **Determine current distribution of *W. carteri.*** Some portions of *W. carteri*'s range have been well surveyed, yet a total distribution has not been ascertained for this species. A thorough survey is needed to determine the distribution for this species.

S1.1. **Conduct surveys for additional populations of *W. carteri.*** The distribution of this species may be among the hardest to ascertain. *Warea. carteri's* sparse and patchy occurrence make surveying very difficult. In addition, the seed bank must be considered for this species. Plants may occur for only a few years following a burn, not to return until another disturbance.

S1.1.1. **Survey scrub habitat in the coastal counties.** Adequate survey work has not been onducted off the Lake Wales Ridge. Given that this species has historically been found in both Miami-Dade and Brevard counties, more thorough survey work is warranted to determine its distribution.

S1.1.2. **Continue surveys in Polk and Highlands counties.** This species is found sparsely in scrub and high pine, as well as hammock. During surveys, this species could be overlooked. Many sites may still be unfound. September is the best month in which to conduct surveys.

S1.1.3. **Continue surveys on protected lands.** New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. **Maintain distribution of known populations and suitable habitat in GIS database.** Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the Florida Natural Areas Inventory database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. **Protect and enhance existing populations.** Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties has been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases, isolated. For this reason, existing populations are in need of protection from a variety of threats.

S2.1. **Protect privately-owned habitat through acquisition, conservation easements, or agreements with landowners.**

S2.2. **Protect populations on public lands.** Develop management guidelines that allow for a fire regime that includes a mosaic of successional stages. This species can probably survive with fire regimes in the 3 to 20 year range.

S2.3. **Use local or regional planning to protect habitat.** Utilize available regional and county planning processes to encourage protection of suitable habitat unoccupied and occupied both of *W. carteri*.

S2.4. **Conserve germ plasm.** The seed for this species is not presently in long-term storage.

S2.5. **Enforce available protective measures.** Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *W. carteri* lives.

S2.5.1. **Initiate section 7 consultation when applicable.** Initiate section 7 consultations when Federal activities may affect this species.

S2.5.2. **Enforce take and trade prohibitions.** This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under Federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida State Parkrules regarding removal of plants from State lands.

S3. Conduct research on life history characteristics of *W. carteri*. Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species' more specific biological information is needed.

S3.1. Continue research to determine demographic information, such as numbers of sites and populations, numbers of individuals in a population, recruitment, long-term seed bank, germination, seedling mortality, dispersal, growth, survival, and mortality.

S3.2. Once demographic data are known, conduct population viability and risk assessment analysis to determine the numbers of plants, sites, subpopulations and populations, and spatial distributions needed to ensure persistence of the species.

S3.3. Conduct research to assess management requirements of *W. carteri.* Determine which natural populations can be increased by habitat management. Monitoring information on the localities of *W. carteri* sites will identify factors contributing to any declines at these sites. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers .Close coordination among land managers is essential to develop adaptive management techniques.

S4. Monitor existing populations of *W. carteri.*

S4.1. Develop monitoring protocol to assess population trends for *W. carteri.*

S4.1.1. Monitor to detect changes in demographic characteristics, such as reproduction, recruitment, growth, long-term seed bank, germination, seedling mortality, dispersal, survival and mortality. Also monitor for pollinators, herbivory, disease, and injury.

S4.1.2. Monitor the effects of various land management actions on *W. carteri*. Assess any changes in demographic characteristics of *W. carteri* in response to land management activities, such as prescribed fire, exotic plant control, *etc.*

S4.2. Develop a quantitative description of the population structure of *W. carteri.* This description will provide a baseline for monitoring population dynamics in response to natural environmental changes and management treatments. Data recorded should include morphology, survivorship, mortality, and reproduction for individual plants. Data about each plant's microsite (vegetation cover, litter depth, substrate, and closest neighbors) should also be recorded. Data about survivorship and mortality should only be taken for a given year or for the seed bank since this species is a seed bank annual.

S5. Provide public information about *W. carteri.* It is important for the recovery of this species that governmental agencies, conservation organizations, and private landowners be appropriately informed about this species.

S5.1. Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *W. carteri* and other rare species requires a self-sustaining, secure, number of natural populations.

S5.2 Private land owners should also be made aware of the rarity of *W. carteri* and its specialized habitat needs. Conservation easements, habitat management plans, and other methods of protecting and enhancing scrub habitat should be developed with private land owners as a means of increasing the number of protected and managed populations of *W. carteri*.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss, degradation, and fragmentation have already occurred throughout the range of this species. Both urbanization and fire suppression have decreased the available habitat. To date, there are six protected sites for *W. carteri* in Polk and Highlands counties.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *W. carteri* populations by providing proper management of habitat, including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches is necessary to construct a natural fire landscape. Scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible to allow for variation. This species can live in a range of burn regimes with burn cycles from 3 to 20 years.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established. Without control, exotic and invasive plants may become a threat to the survival and recovery of *W. carteri.*

H1.2.3. Control access to areas where listed plants are growing. Collection, trampling, and off-road vehicles can severely threaten individual populations.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include *W. carteri.*

H2.2. Enhance sites with native plant species. Because of lack of habitat management and long periods without fire, certain native plant species that were present historically may now be absent from the natural composition of the community. *Warea carteri,* as well as other species of rare scrub plants should be reintroduced, if natural colonization is not possible. Wiregrass and longleaf pine should also be reintroduced to sandhill sites in locations where these species have been displaced by hardwood hammock species (C. Weekley, Lake Wales Ridge SF, personal communication 1998).

H3. **Conduct habitat-level research projects.** Study the response of *W. carteri* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic and invasive vegetation. More information is needed on the response to management activities for this species.

H4. **Monitor habitat and ecological processes.** Monitor the effects of land management actions, such as prescribed fire, exotic plant control, etc., on the habitats where *W. carteri* occurs.

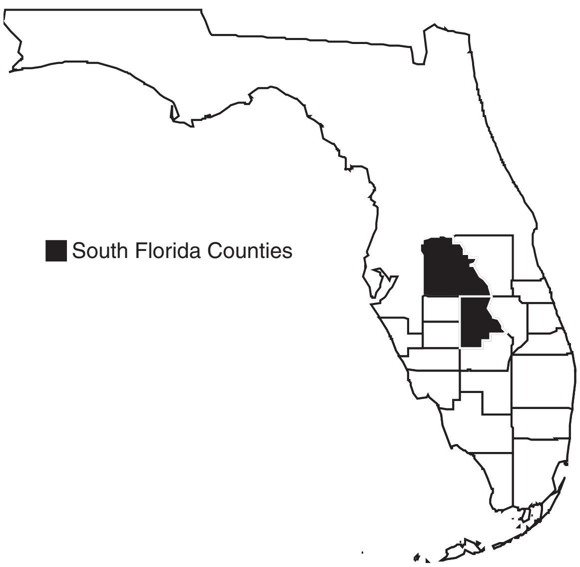
H5. **Provide public information about scrub and its unique biota.** Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge National Wildlife Refuge would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the South Florida Water Management District, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities, and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.

Florida Ziziphus

Ziziphus celata Judd and D. Hall

Federal Status:	**Endangered (July 27, 1989)**
Critical Habitat:	**None Designated**
Florida Status:	**Endangered**
Recovery Plan Status:	**Revision (May 18, 1999)**
Geographic Coverage:	**Rangewide**

Figure 1. County distribution of Florida ziziphus.



Florida ziziphus is a shrub that is endemic to the Lake Wales Ridge in central Florida. Florida ziziphus, which was believed extinct until 1987, occurs on the periphery of turkey oak sandhills or yellow sand oak-hickory scrub communities. The ziziphus is known to exist in only five remnant populations that are found in Polk and Highlands counties, but none of the plants on these sites appear to reproduce. These sites are threatened by continued land conversion for residential housing, agriculture, and road construction. Three of the five sites are pasture. Recovery efforts for the Florida ziziphus will include habitat protection, controlled propagation, reintroduction of this plant into unoccupied, suitable habitats, and land management of the scrubby flatwoods and high pine communities.

This account represents a revision of the existing recovery plan for the Florida ziziphus (FWS 1996).

Description

Ziziphus celata is a spiny shrub that averages between 0.5 to 1.5 m in height, but can grow to over 2 m. Plants occur in groups of stems, arising from what are assumed to be connected root systems. The primary branches are jointed and bent, and give rise to short, straight, spiny, branchlets. The oblong-elliptic to obovate leaves are alternate and deciduous. The leaves are characterized by rounded tips, cuneate bases, and entire margins. The upper leaf surface is dark glossy green, while the underside is a dull light green. Leaves vary from 4.5 to 21 mm in length, and from 3 to 13 mm in width. Fragrant *Z. celata* flowers are small, axillary, and solitary, but are tightly bundled on short shoots. Flowers are perfect, with five greenish-yellow sepals, and five white petals clasping five stamens; however, three-and four-merous flowers have been observed (Race and Weekley 1996). The bright yellow drupes range from 10 mm to 20 mm long, and 3 mm to 10 mm wide (Judd and Hall 1984, DeLaney *et al*. 1989, Race and Weekley 1996).

Taxonomy

Ziziphus celata was originally collected near Sebring in 1948. A second specimen was collected in 1954, perhaps from the same site as the original specimen, but the location of the latter collection is unknown. The plant remained unidentified and unnamed until 1984, when Judd and Hall (1984) named the original herbarium specimen *Ziziphus celata*. When it was named, the Florida ziziphus was thought to be extinct. However, it was rediscovered in 1987 at a site in Polk County (DeLaney *et al.* 1989).

Distribution

The original *Z. celata* herbarium specimen was collected from a scrub site near Sebring, Highlands County, Florida. Despite extensive searches, no specimens have been located in this area since 1955. *Z. celata* occurs at five known sites; four sites in Polk County and one in Highlands County, all on the Lake Wales Ridge of central Florida (Figure 1). Based on historic and existing locations, the north to south range of this species was approximately 56 km, and included much of the Lake Wales Ridge, from Highlands County north to at least central Polk County, and possibly further north (Burkhart *et al*. 1997).

Habitat

Ziziphus celata appears to prefer high pine habitat or the transition zone between scrubby flatwoods and high pine. K. DeLaney (Environmental Research Consultants, personal communication 1995) described the healthiest plants as growing on the lower slopes of turkey oak knolls with sparse cover. Based on Soil Conservation Service mapping, all of the sites where *Z. celata* occurs are characterized by excessively drained, nutrient poor soil types, including Tavares Fine Sand, Astatula, and Candler Sand (DeLaney *et al.* 1989, Soil Conservation Service 1990, Burkhart *et al*. 1997).

Three of the five sites where *Z. celata* occurs are improved pasture. The Lake Wales Ridge SF site is a degraded narrow ecotone between a high pine ridge and scrubby flatwoods. Other species in this ecotone include *Quercus* sp., *Bumelia tenax*, *Sabal etonia*, *Erigonium tomentosum*, *E. longifolium* var. *gnaphalifolium*, and *Serenoa repens* (DeLaney *et al.* 1989). The fifth site, referred to as the sandhill site, lies along the sloping edge of former sandhill. The site is surrounded by cherry laurel (*Prunus caroliniana*), oaks (*Quercus virginiana*, *Q. incanc*, and *Q. laevis*), and invading blackberry (*Rubus cuneifolius*). Within the site, *Z. celata* is associated with long leaf pine (*Pinus palustris)*, wire grass (*Aristida beyrichiana*), scrub buck wheat (*Eriogonum longifolium* var. *gnaphalifolium*), and *Serenoa repens* (Burkhart *et al*. 1997).

Habitat characterization for this species is difficult since many of the known sites are in pasture, with one site identified as a remnant sandhill and another an open oak-hickory, yellow sand scrub. This species does seem to prefer unshaded and uncrowded microsites within these communities (C. Weekley, Lake Wales Ridge SF, personal communication 1998).

Florida ziziphus.
Original drawing by Jean C. Putnam Hancock; original flower photograph by Steve Shirah.

Reproduction

Ziziphus celata is deciduous, losing its leaves in late fall. It begins blooming in late December or early January and blooming continues through late February (varying by site and year), while the branches are still bare (Burkhart *et al*. 1997). Fruits begin to develop in March, with new leaves forming at the same time or soon after. The fruits ripen in May or early June. No seedlings have been found in the wild, so it is not known whether the seeds germinate in the summer or later in the year. Common pollinators (bees and flies) have been observed visiting the flowers, although it is not known if these are pollinators of *Ziziphus*. No viable seeds have been observed in the wild. Natural fruit set has been observed twice in the wild, but few fruit were produced, and of those all aborted before maturity (K. DeLaney, Environmental Research Consultants, personal communication 1994; Burkhart *et al*. 1997). Lack of sexual reproduction may be due to the absence of compatible genotypes at a given site and/or the age of the above ground stems (Burkhart *et al*. 1997).

Ziziphus celata spreads asexually by sending shoots up from its roots. These additional stems give *Z. celata* a clump-like appearance, where individual plants in the clump are not distinguishable. Like other members of its genus, *Z. celata* is capable of parthenocarpic production of fruit, but it differs from others in its genus by not being dichogamous, having pistils and stamens that mature at different times to prevent self-fertilization (Burkhart *et al*. 1997).

Based on allozyme analysis, using five loci, it was found that the five remnant sites of *Z. celata* are composed of 11 distinct genotypes (Godt *et al*. 1996). Four of the sites consist of only one genotype. At least seven genotypes occur at the Highlands County site. More genotypes may exist since only a subsample of the population was analyzed. The genetic analyses are supported by observations in the field that plants at some sites seem to be reproductively incompatible and only reproduce vegetatively. However, plants in cultivation at Bok Tower Gardens from two different sites (eight genotypes) did produce fruits and viable seed in spring of 1994 and 1995. It is likely that the plants' proximity to one another in the Gardens allowed them to cross-pollinate between genotypes. In 1996 and 1997, only plants from the Highlands County site (seven genotypes) produced fruit, suggesting that plants at this site in the wild are capable of sexual reproduction. However, access to this site is restricted and these plants have not been included in annual population surveys. Based on a recent reproductive study (Burkhart *et al*. 1997), *Z. celata* plants are self-incompatible, and are not compatible within genotypes. The only successful pollinations occurred between different genotypes.

Relationship to Other Species

At the Lake Wales Ridge SF ecotone site, *Z. celata* occurs with a mixture of scrub and sandhill species such as *Quercus chapmanii*, *Q. geminata*, *Q. incana*, *Q. laevis*, *Q. myrtifolia*, *Bumelia tenax*, *Sabal etonia, Erigonum tomentosum*, *E. longifolium*, *Aristida* sp., and *Serenoa repens*. At the sandhill site in Polk County, it occurs with *Q. laevis, Q. virginiana,* and *Q. incana*, *Pinus palustris*, *Serenoa repens*, and *Aristida beyrichiana*. Also, blackberry bushes (*Rubus* spp.) are encroaching from the edges of the site.

Because of its rarity, little is known about animal interactions with *Z. celata*. Fruits of southwestern *Ziziphus* species are eaten by birds (MacMahon 1985). Herbivory on stems and leaves has been observed in the wild (K. DeLaney, Environmental Research Consultants, personal communication 1995). Rabbits have been observed eating the pulp from fruits which had fallen to the ground (T. Race, Bok Tower Gardens, personal communication 1995), and other animals such as rodents and gopher tortoises may also find the fruits palatable. The dense thorny branches provide protection for small animals; rabbits, lizards, and nesting mockingbirds have been observed using these plants as cover at Bok Tower Gardens.

Status and Trends

After almost 40 years of being presumed extinct, *Z. celata* was rediscovered in 1987. It was listed as an endangered species in July 1989 (54 FR 31190). The reasons for listing *Z. celata* are habitat loss, potential reproductive and genetic limitations, exotic species invasion, and the potential for overcollection and vandalism (54 FR 31190). Most *Z. celata* habitat was converted to pasture and citrus production before the species was rediscovered in 1987. Currently, *Z. celata* occurs at five locations; allozyme analysis indicates 11 different genotypes. Only the Lake Wales Ridge SF population occurs on protected public land. The remaining populations are on private property. Lack of protection and reproductive failures in the wild make this species more vulnerable to extinction.

Land conversion for agriculture and residential housing on the Lake Wales Ridge has greatly reduced the amount of *Z. celata* habitat and has caused much of the remaining habitat to become even more isolated. If cross-pollination is necessary between sites, increased isolation will decrease the chance of successful seed production. The further loss of any genetic material will weaken the possibilities of recovery for this species.

Management

Ziziphus celata plants at Lake Wales Ridge SF were heavily shaded, covered in lichens, and appeared stressed (Delaney et al. 1989, Wallace 1990), yet regenerated quickly after prescribed fire (Weekley 1996). Plants at the more open high pine site and open pasture sites appear to grow vigorously in full sun or light canopy. This combination of a need for open canopy and quick regeneration suggests that this species is adapted to the frequent fire regime which historically maintained the high pine ecosystem.

The Lake Wales Ridge SF is the only site on public lands where *Z. celata* occurs. Current management activities at this site include semi-annual monitoring and prescribed burning. An augmentation project is proposed for this site.

The Highlands County population occurs in improved pasture on private property. Access to this site has been restricted and these plants have not been included in the regular monitoring program. This population was sampled in 1989 and propagated for the National Rare and Endangered Plant Collection at Bok Tower Gardens. Management needs for this population include: developing contact with the landowners, including this group in the regular monitoring program, and propagating additional samples to ensure that a backup of all genetic variability is preserved.

The two populations of *Z. celata* that occur in improved pasture on private lands in Polk County have similar management needs. Both sites are open and the plants are fairly vigorous, flowering annually. However, plants at one site are impacted by livestock and many of the older stems are senescing due to old age and trampling. The landowner has fenced this site for protection. Plants at both sites are included in the regular monitoring program. Since the site has been fenced, prescribed burns are planned, which encourage new growth.

The population on the remnant sandhill site on private property in Polk County is currently protected. The owners have posted the property as a nature preserve. However, the main threat to this population is the invasion of exotics. Bok Tower Gardens and DACS' Division of Forestry have implemented some control of these species, but this control will need to be continued. Prescribed fire is recommended for portions of the site in order to limit the spread of exotics, encourage the growth of natural ground cover, and stimulate vigorous new growth of *Z. celata*. In addition, this population should be sampled and propagated for inclusion in the Bok Tower Gardens collection of endangered plants.

Management for *Z. celata* on private land depends on competing land uses and on the landowners' willingness to embrace land management techniques that will benefit this species. On the three pasture sites *Z. celata* has been exposed to mowing. Though currently not a problem, *Z. celata* only produces flowers on woody vegetation, so if mowing is done more frequently than every 2 to 3 years, the plant may be unable to reproduce (C. Weekley, Florida Department of Forestry, personal communication 1997). Other threats such as trampling and competition with invasive and exotic vegetation can only be eliminated if the private landowners support management recommendations.

To offset possible losses from private lands, plants have been propagated from three different sites (nine genotypes) and are maintained in the Center for Plant Conservation National Collection at Bok Tower Gardens. Plants representing two sites (eight genotypes) produced seed in 1994; plants from one site (seven genotypes) produced seed in 1995. Because the species is easily propagated, it appears feasible to establish new populations at the Lake Wales Ridge SF and other suitable sites.

Literature Cited

Burkhart, S., T. Race, and C. Weekley. 1997. Breeding system of the rare Florida endemic, *Ziziphus celata*. Report to U.S. Fish and Wildlife Service; Vero Beach, Florida.

DeLaney, K.R., R.P. Wunderlin, and B.F. Hansen. 1989. Rediscovery of *Ziziphus celata* (Rhamnaceae). Sida 13(3):325-330.

DeLaney, K. 1995. FWS Multi-Species Recovery Team meeting. 6-8 December 1995.

Judd, W.S., and D.W. Hall. 1984. A new species of *Ziziphus* (Rhamnaceae) from Florida. Rhodora 86:381-387.

Godt, M.W., T. Race, and J.L.Hamrick. 1996. A population genetic analysis of *Ziziphus celata*, an endangered Florida shrub. U.S. Fish and Wildlife Service; Jacksonville, Florida.

MacMahon, J.A. 1985. Deserts; The Audubon Society Nature Guides. Alfred A. Knopf; New York, New York.

Race, T. 1995. FWS Multi-Species Recovery Team meeting. 6-8 December 1995.

Race, T., and C. Weekley. 1996. Some observations on the flowering phenology of *Ziziphus celata* (Rhamnaceae). Report to Florida Department of Forestry; Tallahassee, Florida.

USDA Soil Conservation Service. 1990. Soil survey of Polk County Florida. National Cooperative Soil Survey.

U.S. Fish and Wildlife Service [FWS]. 1996. Recovery plan for nineteen central Florida scrub and high pineland plants (revised). U.S. Fish and Wildlife Service; Atlanta, Georgia.

Wallace, S.R. 1990. *Ziziphus celata*: Uphill climb for a rare Florida endemic. Botanic Gardens Conservation News. 1(7):45-47.

Weekley, C. 1996. Monitoring Report (July 1996). Florida Department of Forestry; Tallahassee, Florida.

Weekley, C., and T. Race. 1997. Monitoring Report (March 1997). Florida Department of Forestry; Tallahassee, Florida.

Weekley, C. 1997. Telephone communication. 24 January 1997.

Weekley, C. 1998. Comments on draft species account. 1998.

Recovery for the Florida Ziziphus

Ziziphus celata Judd and D. Hall

Recovery Objective: **PREVENT EXTINCTION,** then stabilize.

Recovery Criteria

Ziziphus celata may never reach a level at which reclassification could be possible. The objective of this recovery plan should be to increase existing populations and prevent extinction. Extinction is likely for this species due to low numbers of individuals and no known reproduction in the wild. *Ziziphus celata* may be considered stabilized when: existing populations, within the historic range, are adequately protected from further habitat loss, degradation, exotic plant invasion, and fire suppression and when this plant is successfully reproducing in the wild. These sites must also be managed to maintain the seral stage of high pine to support *Z. celata*.

This recovery objective is an interim goal because of the limited data on the biology, ecology, and management needs of this species. The recovery objective will be reassessed annually based on new research, management, and monitoring information. Reclassification criteria may be refined if new information identifies ways of re-establishing populations of this species to expand its current distribution within its historic range.

Species-level Recovery Actions

S1. Determine current distribution of *Z. celata.* It is possible that populations of this species have yet to be discovered. Currently, three of the sites for *Z. celata* are in pastures and the other two are in restricted remnant areas. A complete survey has not been made of the Lake Wales Ridge for this species, making defining a distribution difficult.

S1.1. Conduct surveys for additional populations of *Z. celata*.

S1.1.1. Conduct surveys in Polk and Highlands counties. The southern portion of this species' range has been well surveyed; the northern section needs further attention.

S1.1.2. Continue surveys for *Z. celata* on protected lands. New sites for listed species are still being found on protected lands. This survey work should be continued to catalog all existing protected sites and new sites as they are purchased.

S1.2. Maintain distribution of known populations and suitable habitat in GIS database. Use GIS to map existing populations and to assess the species' status and trends over time. The database should contain information on locations, population sizes, and status. This information should also be used for project review, in land acquisition activities, and to coordinate updates with the FNAI.

database. Currently, the Lake Wales Ridge Ecosystem Working Group and Archbold Biological Station are proposing to map the entire central ridge. This information would show potential habitat for scrub endemics based on their habitat needs.

S2. Protect and enhance existing populations. Much of the native xeric uplands on the Lake Wales Ridge and surrounding counties has been converted to agriculture or urban development. The remaining habitat is fragmented into small parcels and in many cases is isolated. Within the islands of xeric habitat, this species is found in only two remnant natural sites and three pastures sites, indicating how little habitat is left for *Z. celata*. For this reason, existing populations are in need of protection.

S2.1. Protect privately owned habitat through acquisition, conservation easements, or agreements with landowners.

S2.2. Protect populations of *Z. celata* on public lands. The only publicly-owned site for *Z. celata* is on the Lake Wales Ridge SF, where managers are developing a strategy for the benefit of *Z. celata.* Guidelines allow for a mosaic of successful habitat stages.

S2.3. Use local or regional planning to protect habitat. Utilize available regional and county planning processes to encourage protection of suitable unoccupied and occupied habitat of *Z. celata*.

S2.4. Continue *ex situ* conservation. *Ex situ* collections are important for preserving genetic diversity, preventing extirpation, and determining ecological characteristics and habitat management needs of species. These collections will be instrumental in the recovery of *Z. celata*.

S2.4.1. Conserve germ plasm. The seed for this species is not presently in long-term storage.

S2.4.2. Maintain *ex situ* collection. Currently, the Center for Plant Conservation coordinates conservation activities and maintains a database for the National Collection. Bok Tower Gardens, as a participating institution, maintains and propagates *Z. celata* as part of the National Collection.

S2.5. Augment natural populations of *Z. celata.* *A*ugmentation of known populations may be necessary to induce reproduction.

S2.5.1. Establish a protocol for reintroduction. Records for source plants, techniques for establishing new populations, and protocols for monitoring are needed.

S2.5.2. Locate potential (re)introduction sites. Survey habitat within the historic range of *Z. celata* and identify protected lands, both public and private, that would be suitable habitat.

S2.5.3. (Re)introduce plants to protected sites. Use plants under cultivation to (re)establish plants in suitable habitat.

S2.6. Enforce available protective measures. Use local, State and Federal regulations to protect this species from overcollecting and damage from off-road vehicle use. Regulations should also be used to protect xeric vegetative communities where *Z. celata* lives.

S2.6.1. Initiate section 7 consultation when applicable. Initiate section 7 consultations when Federal activities may affect this species.

S2.6.2. **Enforce take and trade prohibitions.** This species is protected by take provisions of the ESA (including its prohibition against removing and reducing to possession any endangered plant from areas under federal jurisdiction; maliciously damaging or destroying any such species on any such area; or removing, cutting, or digging up any such species), by the Preservation of Native Flora of Florida Act, and by the Florida rules regarding removal of plants from state lands.

S3. **Continue research on life history characteristics of *Z. celata*.** Much of the basic biology and ecology of this species remains poorly understood. To effectively recover this species more specific biological information is needed.

S3.1. **Continue research to determine biology and demographic information, such as numbers of sites and populations, numbers of individuals in a population, morphology, reproduction, recruitment, dispersal, growth, survival, and mortality.** Since this plant is not reproducing in the wild, the questions surrounding this issue are crucial to the recovery of *Z. celata.*

S3.2. **Continue research to assess the reproductive potential of *Z. celata* in the wild.** No mature fruit has been observed in the wild for this species. All recent growth in *Z. celata* has been vegetative. A pollination study is currently being conducted to ascertain the factors preventing natural reproduction.

S3.3. **Continue research to assess management requirements of *Z. celata*.** Determine which natural populations can be increased by habitat management. Surveys, research, and monitoring information will provide factors contributing to any declines at each site. Monitoring of populations should be in reference to various habitat management practices. Site-specific management guidelines should be provided to land managers. Close coordination among land managers is essential to develop adaptive management techniques.

S4. **Continue monitoring existing populations of *Z. celata*.**

S4.1. **Evaluate the effectiveness of the monitoring protocol used to assess population trends for *Z. celata*.** As more information is gained about *Z. celata*, monitoring protocols may need to be altered to make use of new information.

S4.2. **Monitor and detect changes in demographic characteristics, such as growth, survival, and mortality.** Herbivory, pollinators, disease, and injury should also be monitored. Characteristics such as reproduction, recruitment, and dispersal cannot be monitored in the wild at this time, but should be included as introductions make reproduction possible.

S4.3. **Monitor the effects of various land management actions on *Z. celata*.** Assess any changes in demographic characteristics of *Z. celata* in response to land management activities, such as prescribed fire, exotic plant control, *etc.*

S4.4. **Continue to work with private landowners.** The successful recovery of this species will be influenced by the participation of private land owners. To date a varying amount of support has been gained among the individual land owners.

S4.5. **Monitor introduced plants.** Monitoring of reintroduced plants will be essential for assessing the status of new plants and their contribution to the population as a whole.

Compare adult survival, seedling production, germination rates, seed survival, seedling survival, and growth rates between transplanted and natural plants. Where monitoring indicates that introduction has been unsuccessful, reevaluate protocol and methodology developed.

S5. Provide public information about *Z. celata*. It is important for the recovery of this species that governmental agencies, conservation organizations such as the Florida Native Plant Society, and private landowners be appropriately informed about this species. Care is needed, though, to avoid revealing specific locality information about *Z. celata.*

Public outreach efforts must also continue to address the increasing concern that horticultural demand for this and other rare species may not benefit conservation of threatened and endangered species. Public education should identify that commercial production and horticultural uses of endangered species provide little benefit to species, since the recovery of *Z. celata* and other rare species requires a self-sustaining, secure, number of natural populations.

Habitat-level Recovery Actions

H1. Prevent degradation of existing habitat. Extensive habitat loss has already occurred throughout the range of this species. Both development and fire suppression have decreased the available habitat. There is one protected site for *Z. celata* in Polk County and none in Highlands County.

H1.1. Secure habitat through acquisition, landowner agreements, and conservation easements. With so little xeric scrub habitat left, any method of securing protected populations should be sought.

H1.2. Manage and enhance habitat. Manage habitat to maintain *Z. celata* populations by preventing damage from off-road vehicle use and collection, and by providing proper management of habitat including prescribed fire.

H1.2.1. Conduct prescribed burns. Fire is a necessary and integral characteristic of the scrub community. A variable interval in fire return and in season is important to mimic the natural fire regime. In addition, spatial variation in fire intensity and unburned patches are necessary to construct a natural fire landscape. The scrub is naturally made up of islands of suitable and unsuitable habitat. To repeat this landscape pattern, sites should be burned as a mosaic when possible.

H1.2.2. Control and eliminate exotic and invasive plants and animals. Exotic plant and animal species are not yet a major threat in Florida scrub as compared to other communities in South Florida. However, in isolated areas, exotic species are becoming established, for example, camphor, wild cherry trees, and blackberry bushes have threatened one *Z. celata* site, but they have been removed and are no longer a threat. Without control, exotic/invasive plants may become a threat to the survival and recovery of *Z. celata*.

H1.2.3. Control access to areas where listed plants are growing. Collection, trampling, and off-road vehicles can severely threaten individual populations. *Ziziphus celata* is currently threatened at one site by cattle trampling and by the expansion of a county waste facility on another site.

Fencing is being installed at the first site, but the potential new facility may need future attention if an entire *Z. celata* site is not to be destroyed.

H2. Restore areas to suitable habitat. Native habitats that have been disturbed or that have experienced a long history of fire suppression may be good candidates for future reserves.

H2.1. Restore natural fire regime. Long periods without fire can change the species composition and the ability of the site to carry fire. Rehabilitation of a site may be a lengthy process, but with fewer and fewer sites remaining, these sites may become more valuable for future recovery. On these sites a seed bank may exist that could include rare endemic species.

H3. Conduct habitat-level research projects. Study the response of *Z. celata* to various land management practices, such as prescribed fire regimes, vegetative thinning, and control of exotic/invasive vegetation.

H4. Monitor habitat/ecological processes. Monitor the effects of land management actions, such as prescribed fire, exotic plant control, *etc*., on the habitats where *Z. celata* occurs.

H5. Provide public information about scrub and its unique biota. Educational efforts, especially those conducted by Archbold Biological Station, have been successful. Without these successful efforts, the Lake Wales Ridge NWR would not have been created. Florida's system of biological preserves depends on a broad base of public understanding and support for its funding and future success. In addition to past and ongoing educational efforts by The Nature Conservancy, Bok Tower Gardens, and Archbold Biological Station, future efforts by these organizations, and the Florida Park Service, the Florida Division of Forestry, the SFWMD, the Florida Native Plant Society, and local garden clubs are crucial in increasing public appreciation of scrub and high pine communities and their associated plant species. The Arbuckle Appreciation Day sponsored by the Florida Division of Forestry has been especially successful in disseminating knowledge about these unique communities.