DISTRIBUTION AND SEASONAL ABUNDANCE OF JUVENILE SALMON AND OTHER FISHES IN THE YUKON DELTA

by

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Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 660

July 1987

ACKNOWLEDGMENTS

The completion of this study could not have been accomplished without the aid of many individuals and organizations. We wish to thank all of the field team members including: Messrs. Richard Tyler, Dan Tyler, Clarke Beaudry, and Ms. Allison Reak. We also thank the ADF&G crew at Pilot Station for providing fish samples and Messrs. Larry Buklis and Jim Raymond (ADF&G) for providing supporting information concerning Yukon salmon. Special thanks to Mr. Calvin Van Zee, Envirosphere Company, for his assistance in obtaining and processing satellite images.

We are especially grateful to Mr. Jake Johnson and staff of the Emmonak Fisheries Cooperative for their generous assistance in repairs of field equipment. Logistical support was provided by the NOAA/OAD Helicopter Group, from Miami, Florida, and staff of the NOAA/Ocean Assessment Division, Anchorage. Special thanks to Messrs. Carl Anderson and Michael Meyer from NOAA for their concern and assistance in helping to make the job a little easier. We also thank Dr. David Carneggie and Mr. Michael Fleming, EROS Anchorage Field Office, U.S. Geological Survey, for providing the AVHRR digital tapes.

This study was funded in part by the Minerals Management Service, Department of the Interior, through an interagency agreement with the National Oceanic and Atmospheric Administration, Department of Commerce, as part of the Alaska Outer Continental Shelf Environmental Assessment Program.

ABSTRACT

The purpose of this study was to identify the importance of aquatic habitats in the Yukon River Delta for juvenile salmon and other fishes, and to determine the vulnerability of these fish to the potential impacts of an oil spill. An investigation was conducted of the distributary channels, nearshore, and shallow offshore habitats to determine the outmigration timing, distribution, and seasonal abundance of juvenile salmon and other fishes in the Yukon River Delta. Fisheries and oceanographic data were collected from three surveys that began immediately following ice breakup (i.e., early June) and ended in mid-August 1986.

Results indicated that outmigration of juvenile chinook salmon and chum salmon began before ice breakup. Chinook salmon smelts peaked on several dates during June and July with the largest catches occurring during late June. The peak timing of the juvenile chum salmon outmigration occurs during the mid to latter part of June. Low numbers of both species continued to outmigrate during the rest of the summer. The lengths of all outmigrant chinook salmon exceeded 69 mm, which suggests that most smolts were age 1+. Outmigrant chum fry were comprised of three different size groups with average lengths ranging from 36 mm to 60 mm.

Chinook and chum juveniles utilized the, outer delta front and delta platform habitats to a greater extent than the nearshore intertidal environment. Utilization of tidal slough and mudflat habitats were intermittent and restricted to regions near major distributary channels, whereas utilization of the offshore habitats was constant and relatively uniform along the delta front. There was no difference in the average size or size composition of juvenile salmon in lower river and other habitats which suggests that outmigrants were not residing in the shallow delta environment. The results indicate that the lower river, intertidal habitats, delta platform, and delta front are not utilized as a nursery area but rather as a migration corridor for juvenile salmon. Juvenile salmon that migrate through the delta front are most likely moving to deeper estuarine habitats in the prodelta.

The migratory routes through the delta and the utilization of delta habitats by juvenile salmon are thought to be influenced by the unique physiographic conditions. The network of sub-ice channels and the large river discharge carry juvenile salmon across the delta platform and distribute them along the delta front. Estuarine conditions that may be important rearing habitat exist only at the delta front and seaward as a result of the massive freshwater plume.

Peak outmigration of juvenile coregonid fishes occurred during July. Juvenile cisco were approximately three times more abundant than juvenile sheefish and juvenile whitefish. Intertidal mudflats and tidal sloughs are the most important habitats for these species.

Populations of juvenile salmon would be vulnerable to an oil spill in the offshore habitats and in the migration corridor. Outmigrants that may utilize the prodelta would be the most vulnerable to oil impacts because this habitat is located within the OCS lease area of Norton Sound . Sheefish, whitefish, and cisco populations would be highly vulnerable to an oil spill that reached the nearshore environment.

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1. INTRODUCTION

On March 15, 1983 the U. S. Department of the Interior accepted 59 bids for oil and gas exploration in Norton Sound (Sale No. 57). This lease sale area is located on the outer continental shelf just north of the Yukon River Delta (see map in Figure 2-1). Since this region supports a large subsistence and commercial fishery, baseline studies were needed to assess the potential impacts of oil and gas development. In response to this need for scientific information, the outer Continental Shelf Environmental Assessment Program (OCSEAP), the National Oceanic and Atmospheric Administration (NOAA) contracted with LGL Ecological Research Associates, Inc. to conduct a literature review which resulted in an ecological characterization of the Yukon River Delta (Truett et al. 1984). This characterization identified the estuarine environment (including the nearshore delta platform and the delta distributaries influenced by marine water) as most vulnerable to adverse effects of oil in the delta. However, site specific information concerning physical processes, fish distribution, and habitat utilization in the Yukon River Delta was very limited. This information is necessary to assess potential environmental impacts and to enable management decisions necessary to protect fishery resources. Consequently, OCSEAP initiated a field investigation of the physical processes and fishery resources of the Yukon River Delta during 1984.

During winter 1984 and summer 1985 Envirosphere Company conducted an investigation of the distribution, seasonal abundance, and feeding dependencies of juvenile salmon and other fishes in the Yukon River Delta (Martin et al, 1986). Fish were collected from an area extending over 150 km of the delta coastline and from 40 km upriver to 30 km offshore. The results of this investigation indicated that delta habitats support diverse and productive fish communities. Juvenile salmon occurred in most delta habitats during the period from ice breakup to early August and the peak abundance occurred during the latter part of June. Growth of juvenile salmon during the outmigration period suggested temporary residency in the delta. The diet of juvenile salmon was limited to a narrow spectrum of drift, plankton and epibenthic taxa, which suggested a trophic dependency on the delta environment. Sheefish, whitefish, and cisco accounted for 65 percent of the total catch during 1985 and were the most widely distributed of all species in the Yukon River Delta. Juveniles of all three groups exhibited a peak downstream migration during July and were most abundant in the coastal mudflats and sloughs. Based on the distribution and abundance of juvenile salmon and other important fishes, the inner delta platform, mudflat, and tidal slough habitats were identified as sites where the greatest potential impact could occur from an oil spill. Active distributary channels also received high potential impact ratings, whereas, the delta front and mid-delta platform received the lowest ratings (Martin et al. 1986).

The 1984-85 investigation provided the most comprehensive survey of fisheries resources ever conducted in the Yukon River Delta. However, data concerning run timing, distribution, residency and diet were only general because the sampling effort was spread over a large geographic area and most sites were sampled only a few times. In particular, sampling was limited in the outer delta platform and delta front habitats. Information concerning the distribution and abundance of salmon and other fish in these habitats is needed in order to determine the potential vulnerability to impacts. More information is needed on fish abundance and habitat utilization during early June, immediately following ice break-up, since sampling was limited at this time during 1985. Also, results from 1985 suggest "that the distribution of fish may he influenced by the dynamic physical processes (i.e., tidal flux, currents, and river flow) in the nearshore environment. Therefore more information concerning physical conditions and physical processes in the delta is needed in order to understand the distribution of fish in the Yukon delta. Envirosphere continued an investigation of the fisheries resources of the Yukon River Delta during 1986 in an effort to fill information needs and to address questions identified during the previous survey. Specific objectives addressed in this study include:

1. Identify the outmigration timing of juvenile salmon;

2. Determine the abundance, residence time and habitat utilization of juvenile salmon and other estuarine fishes; and,

3. Relate the distribution of juvenile salmon to the physical environmental conditions of the Yukon River delta.

Data obtained from this study and from the 1985 survey are used to address the three study objectives. Information concerning physical processes required for the third objective was limited because the primary focus of this study was biological,. Data on the physical processes is currently being developed by a companion study (OCSEAP, RU 670) hut the results were not available to incorporate into this report. Therefore, physical data collected during this study and information from Advanced Very High Resolution Radiometry (AVHRR) satellite imagery were used to provide a physical characterization of the Yukon Delta.

2. METHODS

2.1 DESCRIPTION OF STUDY AREA

The Yukon River Delta is located along the southwestern coast of Norton Sound, Alaska, which occupies the northeastern corner of the Bering Sea (Figure 2-1). The Yukon River is the 4th largest river in North America, has a maximum length of 3,185 km, drains an area of 855,000 km^2, and has an average annual discharge of 7,000 m^3/s (Czaya 1981). The modern delta is a relatively young geologic feature, beginning its development approximately 2,500 years ago when the river course shifted to where it currently enters Norton Sound (Dupre' 1978).

The geometry of the Yukon Delta is composed of a variety of depositional environments that are formed by a complex interaction of ice-, river-, and storm-dominated processes which affect sediment transport and deposition. A description of these environments is derived from Dupre' and Thompson (1979) and Dupre' (1980) as follows: The emergent portion of the delta (referred to as “delta plain,” Figure 2-2) is characterized as a gentle sloping plain containing a complex assemblage of active and abandoned distributaries, levees, interdistributary marshes, and lakes. The active distributaries have a radically bifurcating pattern consisting of two large channels (1-1.5 km wide and 10-15 m deep) and numerous smaller channels (some as small as 20 m wide and 2-5 m deep) typically spaced every 1-2 km along the coast. Point bars and mid-channel bars are common, particularly along the larger distributaries. Intermediate to the active distributaries are numerous small tidal sloughs which extend into and drain marsh areas along the coast. The width and length of these channels vary with tidal level and they may become dry at low tide. Surrounding the emergent portion of the delta is the delta margin which includes the prograding tidal flats, distributary mouth bars, sub-ice platform, and associated sub-ice channels. Tidal flats are typically 100-1,000 m wide where they occur along the fringe of the delta plain. Unlike deltas in temperate areas, the Yukon Delta has a broad sub-ice platform

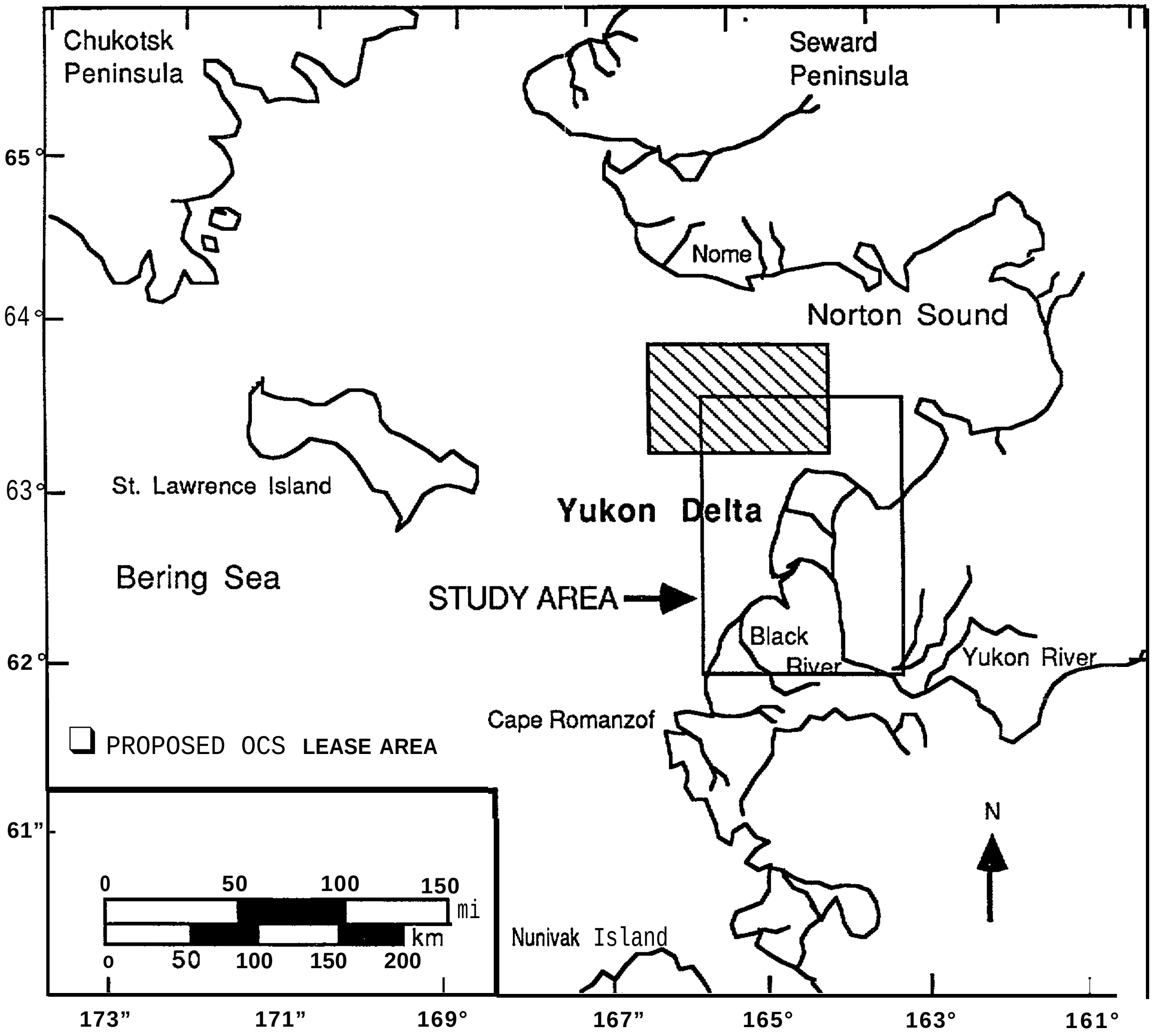

Fig. 2-1: Vicinity map of Norton Sound showing the location of the Yukon River Delta study area.

(here referred to as the delta platform) that extends 10-30 km offshore. The delta platform has an extremely gentle slope (1:1,000 or less) and typically shallow water (up to 3m). The sub-ice channels, which are unique among most deltas, are the offshore extensions of the major distributary channels. These subaqueous channels are most common on the western margin of the delta and are characteristically 0.5 to 1 km wide, 5-15 m deep, and extend up to 30 km across the delta platform. Adjacent to the delta platform is the steeper delta front (slope typically greater than 1:500) with water depth ranging 3 to 14 m. This zone is relatively narrow (approximately 10 km wide) except along the northwestern part of the delta where it includes a series of large (3-5 m high) shoals. The prodelta is the most distal edge of the deltaic sediments and extends up to 100 km offshore. The bottom in this zone has a gentle slope (typically 1:2,000) and water depths are relatively shallow (10-20 m).

2.2 SAMPLING PLAN

The primary emphasis of this study was to investigate the timing, distribution, and abundance of juvenile salmon in habitats that may be exposed to impacts from oil and gas development. Therefore, field survey timing and sampling locations were planned to provide these data and to extend the data base that was developed during 1985. During 1986 the sampling program was divided into three field surveys which occurred for 30 days, 7 days, and 8 days during June, July, and August, respectively. The June survey was scheduled to correspond with the timing of ice breakup in the Yukon Delta and the early phase of the juvenile salmon outmigration. The July and August surveys were scheduled to correspond With the postpeak and tail-end phases, respectively, of the outmigration period.

Samples were collected from 20 sites (Table 2-1) that were representative of the major and minor distributary, tidal slough, mudflat, delta platform and delta front habitats. '(he upper river stations (i.e., stations 14-16, Figure 2-3) were only sampled during early June prior to the time of ice breakup in the lower delta. Fish

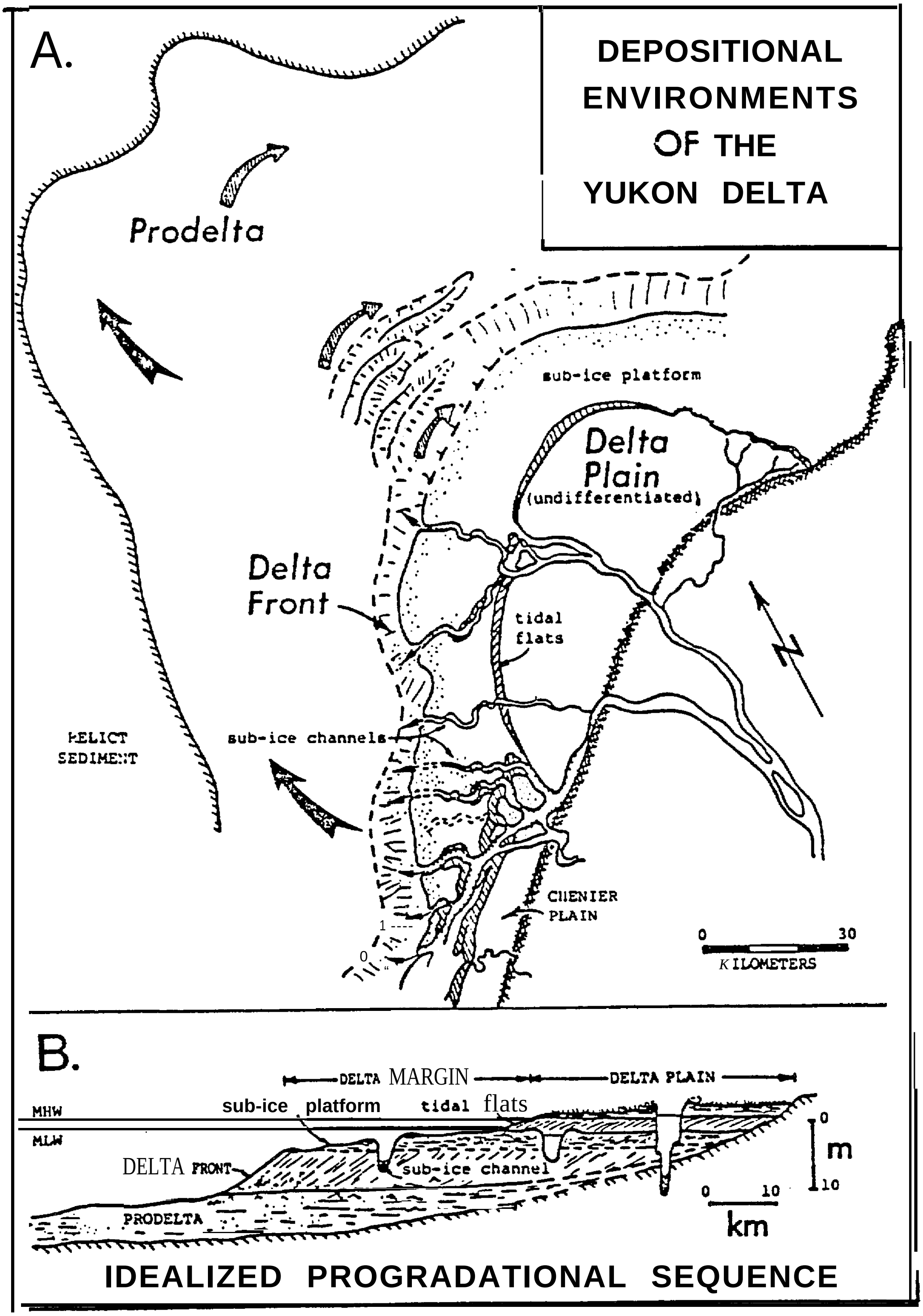

Fig. 2-2: Depositional environments of the modern lobe of the Yukon Delta (from Dupré and Thompson, 1979).

TABLE 2-1

Location and Description of Stations Sampled During the 1986 Field Season of the Yukon Delta Study

Station Number	Description	Latitude (N)	Longitude (W)
21	Delta front (sampled 6/6 only)	62° 40.61′	165° 37.53′
1	Delta front	62″ 29.85′	165° 33.70′
2	Delta front	62° 40.62′	165″ 28.62′
3	Delta front	62° 53.97′	165° 15.02′
41	Delta platform (sample 6/4 and 6/6 only)	62° 29.80′	165° 15.05′
51	Delta platform (sampled 6/6 only)	62° 38.85′	165° 23.69′
4	Delta platform	62° 30.06′	165″ 27.58′
5	Delta platform	62″ 40.69′	165″ 23.05′
6	Delta platform	62° 54.00′	165° 05.64′
8	Coastal mudflat	62° 40.79′	164° 52.61′
9	Coastal mudflat	62° 56.42′	164° 49.08′
10	Tidal slough	62° 26.50′	165° 16.90′
11	Tidal slough	62° 40.74′	164″ 51.72′
12	Tidal slough	62° 56.34′	164″ 48.73′
13	Active distributary, major	62° 40.82′	154° 36.62′
17	Active distributary, minor	62* 45.79′	164° 30.58′
14	Upper Yukon River, St. Mary's	62″ 00.95′	163° 13.87′
18	Upper Yukon River, Pilot Sta.	61°′ 56.75′	162″ 52.77′
15	Andreafsky River	62° 03.10′	163° 08.67′
16	Andreafsky River, North Fk.	62° 05.13′	163° 03.75′

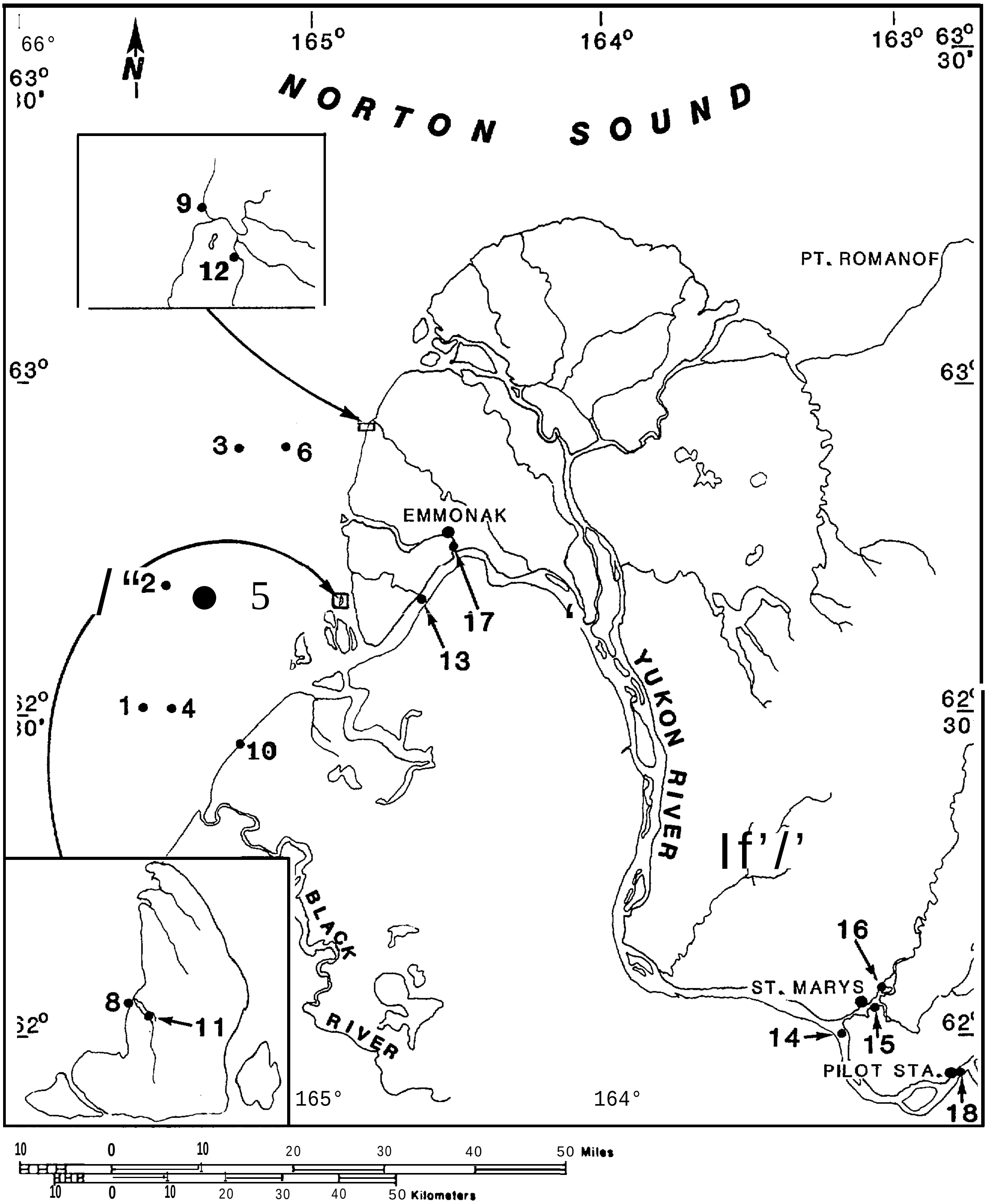

Fig. 2-3: Location of sample sites for the summer 1986 survey of the Yukon River Delta.

specimens collected from these stations were retained for the otolith study (see Section 2.5 for details). After ice breakup, all sampling was concentrated in the lower delta and offshore areas. Two stations were located in major and minor channels of the lower river in order to document the timing of' the outmigration and the size composition of the outmigrant population. These stations were located a short distance (i.e., less than 25 km) upriver from the coast under the assumption that fish residency was not occurring at this point. Therefore, catch statistics from these sites would be indicative of the population just prior to entering the estuary. The distribution, abundance, and residency of fish was determined from samples collected at 11 sites which were located along the coast and offshore. These sample stations extended from the coastal tidal sloughs out to the delta front and were distributed along three transects (Figure 2-3). The two southern transects were located within the turbid water plume from Kwikuak Pass and the northern transect was located along the outer edge of this plume. Stations 1, 2, and 3 were positioned at approximately the mid-slope point along the delta front and stations 4, 5, and b were positioned within several kilometers of the outer edge of the delta platform (Figure 2-2). Several other stations that are located in the vicinity of these sites (i.e., stations 21, 41, and 51, Tab-le 2-1) were also sampled during an initial reconnaissance survey. Stations 8 through 12 were located in tidal slough and intertidal mudflat areas.

2.3 SAMPLING TECHNIQUES

2.3.1 Water Quality and Physical Measurements

Discrete measurements of water temperature, conductivity, salinity, depth, and water transparency were measured at each fish sampling station. Surface and bottom measurements of temperature, conductivity, and salinity were measured *in situ* with a Beckman RS-5 conductivity/temperature instrument. A handheld thermometer and a YSI Model 31 conductivity meter were used as a backup and a 2 L Van Doren bottle was used to collect water samples. Water depths and water transparency were measured with an Echotec fathometer and a standard (200 mm diameter) secchi disc. Sea state was observed and recorded according to the World i'meteorological organization Sea State scale.

2.3.2 Fish Sampling

Fish were sampled with three types of active sampling gear. A 6.8 m wide surface tow net (Table 2-2) was used to sample the river channel, delta platform, and delta front habitats. A 45.7 m long beach seine and a 22.8 m long beach seine were used to sample the mudflat and tidal slough habitats, respectively (Table 2-2).

The tow net was selected as the primary sampling gear in place of the 136 m purse seine, which was used in 1985 (Martin et al. 1986), because the tow net was found to be more effective. Tests were performed during the first week of the survey to compare catches between the purse seine and tow net when both gears were deployed at the same site (Table 2-3). In three comparison tests the purse seine captured only juvenile chinook salmon in one test, whereas, the tow net caught both juvenile chum and chinook salmon from all three tests. The tow net also caught more juvenile salmon than the purse seine for an equal amount of effort as indicated from the results of the June 4th test. The purse seine was more effective, however, for catching larger fish and other fish species (e.g., cisco, whitefish, smelt, and sucker).

The tow net was deployed between two boats and towed against the direction of the current at an average speed of 0.8 m per second. The net was towed for a period of either 5 or 10 minutes and from 2 to 15 hauls were collected at a sample site. In most cases three 10-minutes hauls were collected from a site.

TABLE 2-2

Specifications for Fish Sampling Gear Used For the
Summer 1986 Survey of the Yukon River Delta

Gear	Specification	
Tow Net	Overall size:	6.8 mwide x 1.8 deep at mouth and tapered to a 0.3 m x 0.3 m bag at the cod end. Total length 11.0 m.
	Front panel:	2.4 m long, 50.8 mm (stretch) knotless mesh.
	2nd panel:	2.4 m long, 38.1 mm (stretch) knotless mesh.
	3rd panel:	2.4 m long, 19.1 mm (stretch) knotless mesh.
	Bag:	3.7 m long, 7.9 mm {stretch) knotless mesh.
Long Beach Seine	Overall size:	45.7 m long x 1.2 m deep with bag located at one end.
	Bag:	4.6 m wide x 1.2 m deep x 3.0 m long, 7.9 mm (stretch) knotless mesh.
	Inner wings:	3.0 m long x 1.2 m deep and 4.,6 m long x 1.2 m deep, 7.9 mm (stretch) knotless mesh.
	Outer wing:	33.5 m long x 1.2 m deep, 19.1 mm (stretch) knotless mesh.
Short Beach Seine	Overall size:	22.8 m long x 2.4 m deep at center and tapered to 1.8 m deep at end of wings, bag located in center.
	Bag:	7.7 m long x 2.4 m deep, 6.4 mm (stretch) knotless mesh.
	Wings:	two each, 7.7 m long x 2.4 m deep near center and tapered to 1.8 m deep at end, 12.7 mm (stretch) knotless mesh.

TABLE 2-3

Comparison of Species Composition and Catch Statistics for the Purse Seine and Tow Net

Station	Date	Gear	Number of hauls	Species	Catch	CPUE[a]	Mean Fork Length (mm)
14	6/1/86	Purse Seine		no fish	0	0	--
		Tow Net		chinook	3	0.43	105
				chum	12	1.71	38
				lamprey sp.	22	3.14	--
				burbot	8	1.14	--
13	6/4/86	Purse Seine		chinook	3	1.50	88
				whitefish sp.	1	0.50	112
				least cisco	8	4.00	222
				burbot	6	3.00	138
		Tow Net		chinook	7	2.33	90
				chum	16	5.33	39
				lamprey sp.	2	0.67	--
				burbot	1	0.33	--
13	6/5/86	Purse Seine		whitefish sp.	1	1.00	--
				least cisco	13	6.50	--
				boreal smelt	2	1.00	--
				longnose sucker	1	0.50	--
				burbot	1	0.50	--
		Tow Net		chinook	4	1.33	100
				chum	15	5.00	36
				lamprey	2	1.00	--
				burbot	1	0.33	--

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[a] Catch Per Unit Effort.

The 45.7 m beach seine was deployed by hand during the high tide period. Two round haul sets were collected from separate mudflat areas directly adjacent to the shore. The 22.8 m beach seine was set by hand and was pulled in the downstream direction in the tidal channels. Two 30 m long reaches were sampled during the high tide period.

2.3.3 Catch Processing

All fish were identified to species, when possible, and the total catch was enumerated. Juvenile whitefish (i.e., broad whitefish and humpback whitefish) and juvenile cisco (i.e., Bering cisco and least cisco) less than 75-100 mm cannot be readily distinguished in the field. Therefore, both species groupswere labeled as whitefish and cisco, respectively. Lengths were measured from a representative sample (i.e., minimum of 40 individuals per species) of all salmon from each sample site. Also, a minimum of five juvenile salmon specimens from each site were retained in 70 percent ethanol for otolith and stomach analysis.

2.4 ANALYTIC PROCEDURES

2.4.1 Hydrographic Conditions

Temperature and Salinity Data

The surface and bottom temperature and salinity samples collected (from stations 1-6 and 8-10) during this sample program lend themselves to the development of a qualitative description of the hydrographic conditions on the delta platform and delta front for each day of the fisheries study. Data from four complete survey days have been selected to discuss the physical processes of the Yukon Delta. These survey days are June 12, June 15, June 19, and August 6 of 1986. Wind conditions for these four surveys are dominated by the mean north-northeast (NNE) flow that characterizes the spring conditions in Norton Sound.

In keeping with the desire to develop a qualitative description of the distribution of hydrographic properties in the study area, a somewhat stylized rectangular model of the study area was developed incorporating the nine sampling stations (Figure 2-4). In this model the sampling positions were spaced evenly across a grid that defines the ends and midpoints of the rectangle's sides and center. The nearshore stations are assumed to be on the delta platform, the intermediate station at the delta front, and the offshore station at the outer edge of the delta front. Fresh water input enters the modeled study area at two locations along the coastline representing the middle and southern mouths of the Yukon River (Figure 2-4). Because only surface and bottom water samples were collected at each station, distributions of the hydrographic properties are highly interpretive and should be considered as qualitative descriptions of the conditions in existence during the surveys.

The spatial distribution of three distinct water classifications are investigated in this analysis: fresher water (<5 ppt), intermediate salinity water (5 - 15 ppt), and marine water (> 15 ppt).

Meteorological and Hydrological Data

Meteorological conditions were not available from the Yukon Delta study region and therefore data from Nome, Bethel, and Nunivak Island were obtained (from AEIDC) to approximate the wind conditions for each survey day. These wind data were important to determine the direction and rate of transport of coastal water masses in the study area. These three meteorological stations showed good agreement in both wind speed and direction for the June study period with standard deviations of ±2.0 kts wind speed and ±4.0 degrees for direction.

River discharge was not measured during this study, therefore data were obtained from the U.S. Geological Survey, Anchorage. These data are based on measurements of river stage which were recorded on a water level recorder located at Pilot Station (Figure 2-3).

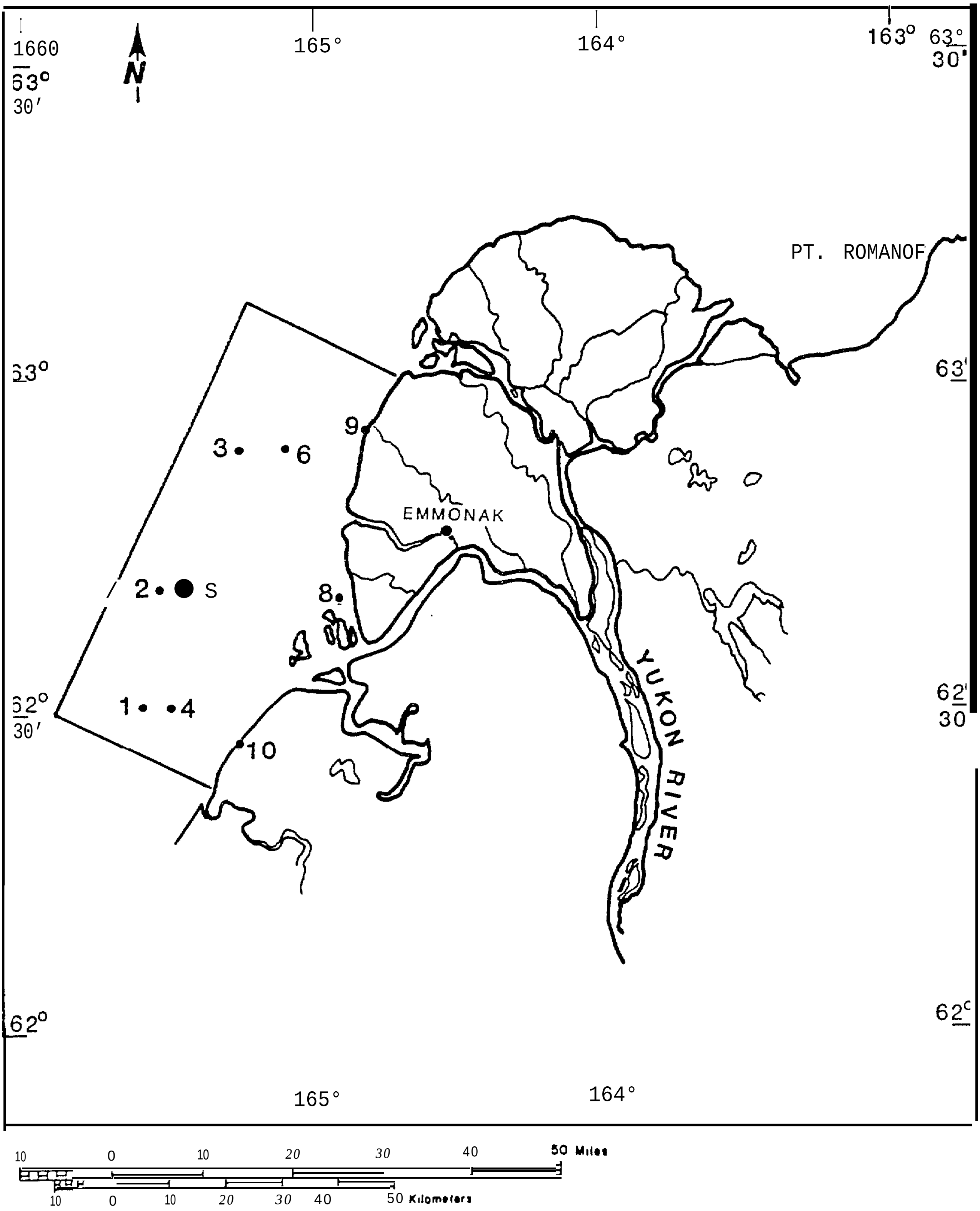


Fig. 2-4: Location of study area and sample stations included in the analysis of hydrographic properties of the Yukon River Delta.

Remote Sensing Data

NOAA AVHRR visible and thermal digital images were acquired for the 15 June 1986 fisheries survey date. These data were analyzed to determine the extent and behavior of the Yukon River sediment and thermal plumes. The digital images were acquired from the U.S. Geological Survey EROS field office (Anchorage) through the NOAA OCSEAP Anchorage office. Digital images were processed by Envirosphere's VAX-based image processing system using computer software originally developed by Scripps and the University of British Columbia. Processed images were displayed on a Raster Technologies Model One/25 Computer Color Graphics terminal. The general scheme of digital processing was as follows:

1) Read computer tape into Envirosphere VAX 11/71.

2) Reformat data as required depending on the satellite sensor system and the agency from which the computer tape was received.

3) Preprocess data including geometric and radiometric corrections to the digital data, apply the digital image mask to define the Yukon Delta study area, and navigate the image to essentially convert the image into a map.

4) Determine and apply a digital enhancement to the image to better define the physical characteristics of the study area.

5) Store the enhanced image on computer disk and video tape and take a color photograph of the enhanced image from the graphics terminal.

2.4.2 Data Recording and Archival

All field data were recorded on an electronic data logger known as a "Polycorder" from Omnidata International, Inc. An electronic data sheet was programmed specifically for this project and included error checking alarms which operated during the data entry process. Data stored in the Polycorder were downloaded daily and four data files were created with the aid of a portable microcomputer. One copyof the raw data file was recorded on a floppy disk and another copy was printed on paper. A third copy of the raw data file was edited for errors and stored on floppy disks. A backup copy of the edited data file was also created and archived.

After the field survey all the edited data files were combined to form one large data file. A hard copy of this file was created and visually checked for errors. Errors were also identified from a frequencies analysis. All the errors were corrected and a new edited version of the large data file was created.

2.4.3 Run Timing, Relative Abundance, and Density

Run timing and relative abundance was identified with histogram plots of catch per unit effort (CPUE) versus time for each sample station. The unit of effort was variable and depended upon gear. Catch in the tow net was standardized to a 10-minute haul; and, catch in the 45.7 m and 22.8 m beach seines was standardized to one round haul and one 30 m haul, respectively. Graphs for each species and station were compared in order to identify differences and similarities in the temporal utilization of habitat.

Density for juvenile salmon was expressed as the number of fish per square kilometer (no./km^2) of water surface area. Densities were calculated from a CPUE/density conversion factor which is based on the area sampled with one unit of effort for each gear type. Density equals:

$$\text{no./km}^2 = \text{CPUE} \times \text{conversion factor},$$

where the average area sampled and conversion factor for each gear are:

Gear	Area Sampled	Conversion Factor
Tow net	2,923 m^2	342
45.7 m Beach Seine	165 m^2	6,061
22.8 m Beach Seine	231 m^2	4,329

The average area sampled by the tow net was computed from measurements of the distance covered during typical 10-minute hauls (Table Z-4). Engine speed was held constant at 1,100 rpm for all tow net hauls. Thus., the water speed and distance covered by the tow net was constant regardless of differences in current velocity at each sample site. The area sampled by a round haul with the 45.7 m beach seine was assumed equal to the area of a circle with a circumference of 45.7 m. The area sampled by the 22.8 m beach seine was assumed equal to the product of a 30 m haul and the average width of a tidal slough (i.e., 7.7 m).

All estimates of fish density are considered to be conservative because no adjustments were made to compensate for gear efficiency. Gear efficiencies were not measured, but each type of gear is not 100 percent effective for catching all the fish within the area sampled. However, catch efficiencies were probably similar among the nets because each gear had small enough mesh to retain the target species and the turbid water conditions minimized the number of fish that could avoid and/or escape the nets.

2.4.4 Size Composition and Growth

Size composition was determined from length frequency analysis. Juvenile salmon were sorted by 3 mm size groups and length frequency distributions were computed for each habitat by sample period. Seven 4-5 day long sample periods were selected according to the clustering of sample dates which occurred during the survey.

Population growth rate during the survey period was computed by fitting a linear regression line to a plot of fish length with date. Population cohorts included in the regression were identified from the length frequency analysis.

TABLE 2-4

Estimates of Towing Speed, Area Sampled, and volume of Water Sampled During Typical 10-Minute Hauls With a 1.8 M X 6.8 M Tow Net

Station	Date	Replicate	Flow Meter Revolutions[a]	Distance (meters)	Speed (cm/sec)	Area Fished (m^2)	Volume Fished (m^3)
13	8/8	1	18,522	497.7	82.9	3,026	5,519
		4	15,651	420.6	70.1	2,557	4,664
		5	15,797	424.5	70.8	2,580	4,708
17	8/8	1	18,982	510.1	85.0	3,101	5,657
		2	16,629	446.9	74.5	2,717	4,956
		3	22,761	611.7	101.9	3,719	6,784
		4	16,917	454.6	75.8	2,764	5,041
Mean			17,894	480.9	80.1	2,923	5,333
S.D.			2,492	67.0	11.1	407.2	742.8

---

a/ General Oceanics model 2030 digital flowmeter.

2.4.5 Associated Environmental Conditions

The relationship between fish abundance and important environmental parameters (i.e., surface and bottom temperature, surface and bottom salinity, and visibility) was investigated. Fish catch associations with the above parameters were determined for all delta platform dnd delta front stations (i.e., stations 1 through 6). Environmental dissociations were made during the period of peak abundance for chum and chinook salmon (i.e., June 12, 15, and 19). Each of the continuous environmental parameters were categorized and fish catches that were associated with each category were summed. Since fishing effort was not equal for each environmental category fish catch was adjusted by effort (i.e., catch multiplied by the effort in the category divided by the maximum effort in any category). The adjusted catch for each category was expressed as a percentage of the total adjusted catch for all categories combined,

2.5 CHUM SALMON OTOLITH STUDY

2.5.1 Sample Collection

Chum salmon specimens were retained for otolith analysis from each sample site during each survey period. These samples were used for the determination of residency and growth rate of juveniles during the outmigration period. In order to determine otolith increment periodicity several fish holding experiments were conducted. During each experiment, approximately 100 juveniles tnat were collected from either stations 13 or 17, were placed in a net pen (1.2 m x 1.2 m x 1.2 m with 7.9 mm mesh netting) and held for a period of 6 days. A random sample of 30-50 juveniles were sacrificed at the beginning and at the end of each experiment. The hypothesis was that the difference in the average number of increments between the beginning and end of the experimental period divided by six was equal to the incremental periodicity.

2.5.2 Laboratory Procedures

Fork length was measured for each fish used in the study. The left sagitta was dissected from each fish and placed medial side down on a glass plate in an array so that individuals processed together could be recognized. The array was covered with a rubber mold and cast in polyester resin. Using thin section grinding and polishing equipment, the otoliths were ground on the medial surface until the primordia were apparent with transmitted light microscopy. This surface of the preparation was then polished and fixed to a glass slide. The lateral surface of the otoliths were then sectioned and polished in the same fashion until a preparation approximately 90 microns thick was obtained.

Otoliths were analyzed using transmitted light at a magnification of 300x. Data were collected using an Optical Pattern Recognition System which employs a microscope, video camera and monitor, digitizing pad and microcomputer. Data collected included total otolith radius, the radius from the point of hatching to the edge of the otolith, the number of otolith increments in this latter segment and the width of those increments. Measurements were taken along a radius line which passed through the center of the primordial core and was located at a 70 degree angle to the long axis of the otolith. The hatching check was defined as the point of transition from very dark and irregularly spaced increments to much more weakly expressed and regularly spaced increments. Results from our laboratory experiments suggest that this transition corresponds to the time of hatching and that the dark, irregular increments represent the prehatching life history of the fish.

3. RESULTS

3.1 WATER QUALITY AND PHYSICAL MEASUREMENTS

3.1.1 Discrete Physical Measurements

Water quality and physical environmental conditions for each sampling date and station are shown in Appendix Table A. Salinity and conductivity data for the July 1986 survey period are missing due to equipment failure. Only one measurement (either surface or bottom) of salinity, conductivity, and temperature was collected from the mudflat and tidal slough habitats because the water was shallow (<2m) and assumed to be uniformly mixed.

Water quality and physical conditions were variable among the different habitats and changed within habitats during the summer. Water depths ranged from very shallow (i.e., 0.3 - 2.0 m) in the tidal slough and mudflat habitats to relatively deep (i.e., 5.0 - 13.0 m) in the river channel and delta front habitats. Warmer fresh water was predominant in the lower river during the summer. Water temperature varied from 6.5° C in early June to 1.7.1° C in mid-July. The tidal slough and mudflat habitats were slightly more brackish (salinity range 0.6 - 2,7 ppt) and several degrees warmer (temperature range 8.4 - 19.1° C) than the river. The peak water temperature in these habitats occurred in mid-June which was several weeks earlier than the peak temperature measured in the river. Differences in surface and bottom salinity in the delta platform and delta front indicated that water in these habitats was stratified. Stratification was most evident at the delta front stations during early June. Bottom temperature and salinity was near 0° C and 26 - 29 pot, respectively, and surface temperature and salinity ranged 4 - 10° C and 7 - 14 ppt, respectively. By August the difference between surface and bottom conditions was less pronounced and the waters were more mixed.

Water clarity was low in most habitats throughout the summer and varied according to the distance from a distributary mouth. Secchi disc visibility was always less than or equal to 0.3 m in the river except on one occasion when 0.4 m was measured. Similarly, visibility in the mudflats was low, but visibility in the tidal channels was greater and ranged up to 0.9 m. Visibility generally increased with increasing distance from shore where measurements as great as 1.2 m were recorded at the delta front.

3.1.2 River Discharge

Discharge in the Yukon River during spring 1986 was substantially less than normal (Figure 3-1). The annual spring flood which normally precedes ice out in the lower river did not occur. Discharge peaked at approximately 580,000 cfs during the last week of May, but the river level did not exceed the banks. Discharge remained low throughout June and was substantially less than the more typical flows observed during 1985. Flows during the remainder of the summer were typical for this season.

3.1.3 Hydrographic Characterization

June 12, 1986

Winds ranged from 5 -- 15 kts from the NNE on this survey day. In response to these winds, surface water would be expected to move generally toward the south along the western face of the Yukon Delta front. Superimposed on this mean southerly flow of water, an offshore velocity component would be induced in the upper water layer by a near-surface Ekman flow. The distribution of water masses seen in the on/offshore vertical sections of salinity indicate that this offshore surface flow tended to spread the fresher upper layer of water in an offshore direction (Figure 3-2a - c). A compensating onshore flow of deeper water can be expected to accompany this offshore upper layer flow as indicated by the deeper, more saline layer, which occurred at. all three on/offshore transects {Figure 3-2a - c). The bulk of the

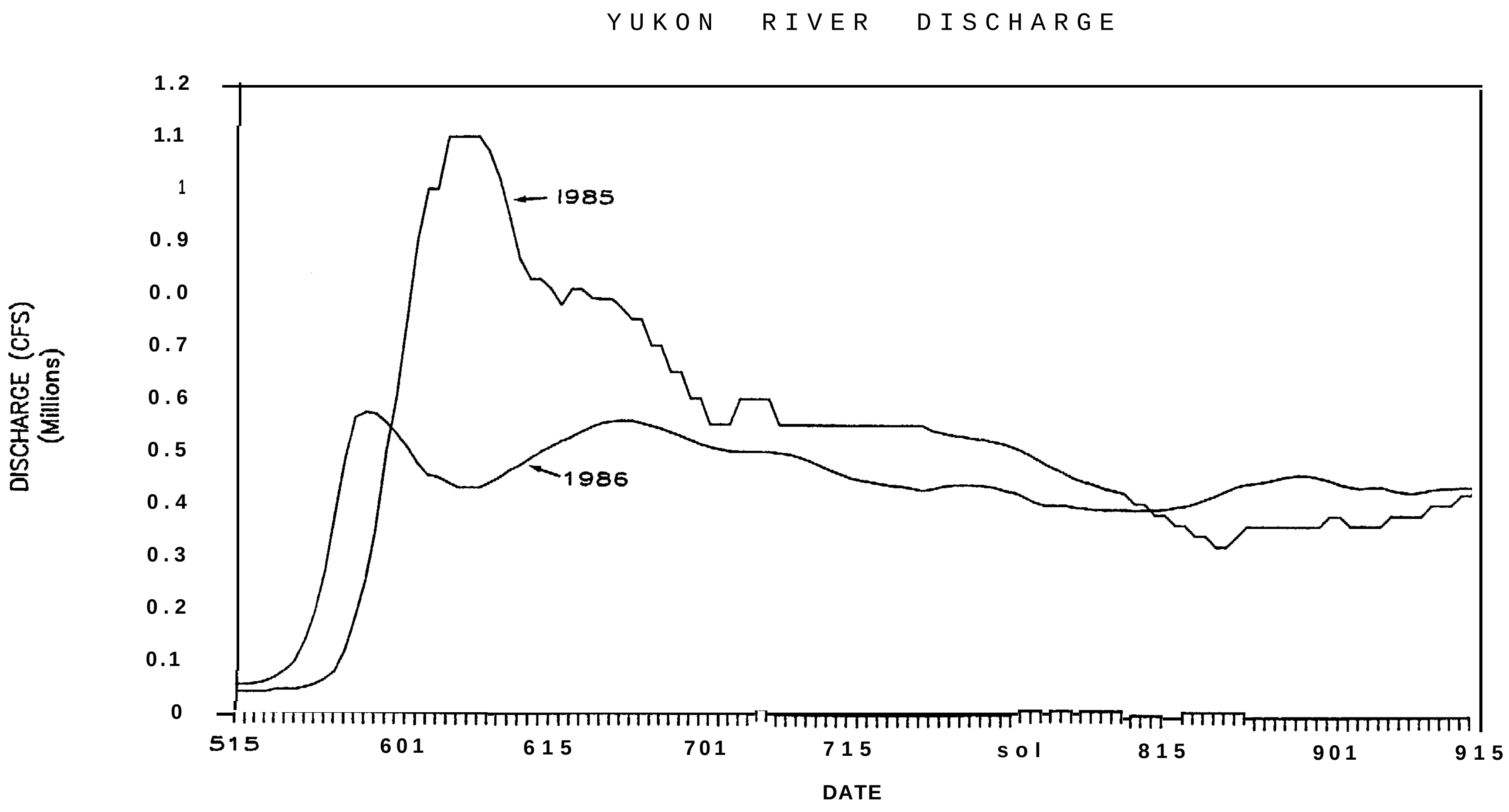


Fig. 3-1: Yukon River discharge at Pilot Station during summer 1985 and 1986. Based on provisional data from the U.S. Geological Survey, Anchorage, Alaska.

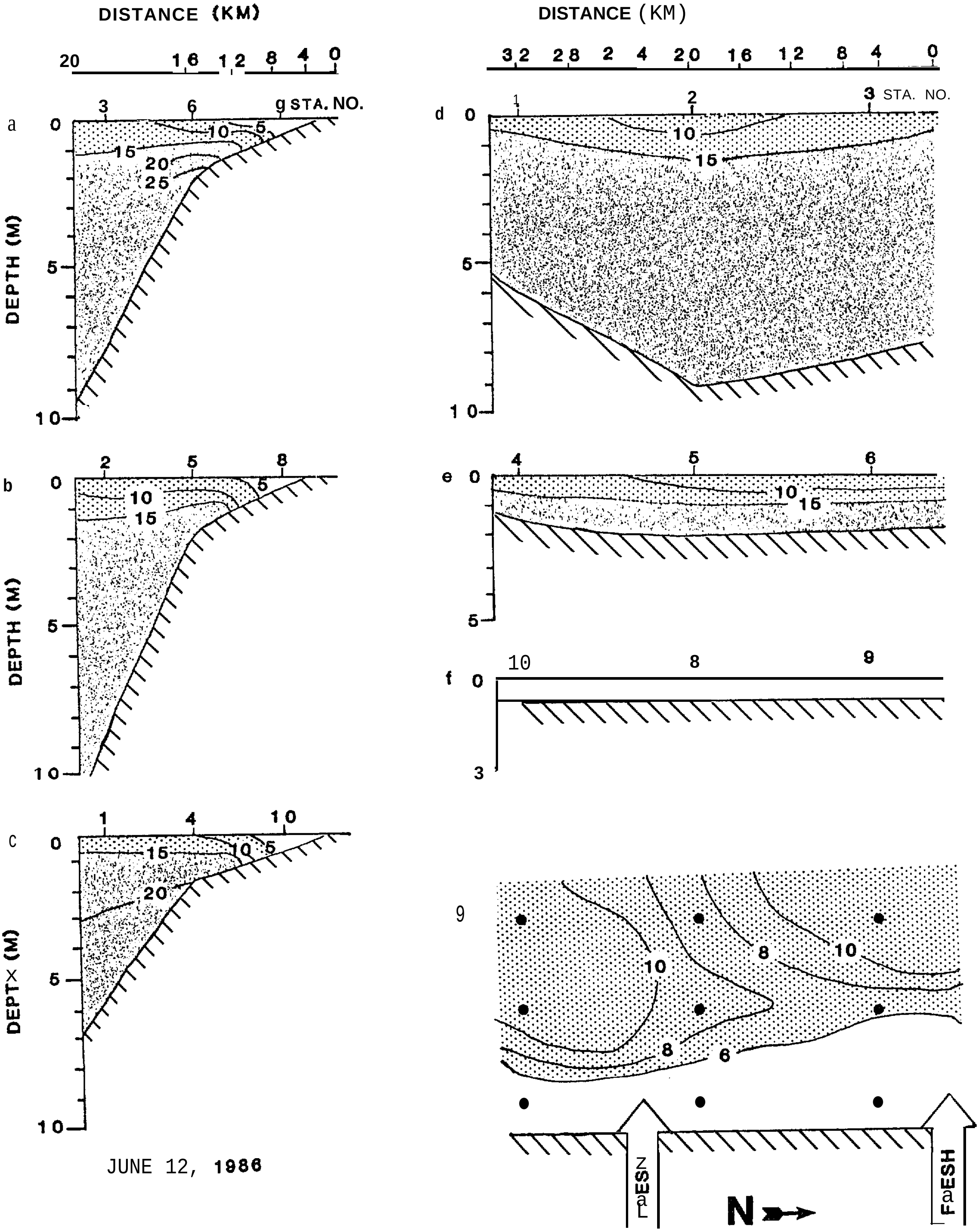


FIG. 3-2. Vertical sections of salinity for the on/offshore direction (a-c) and the along-shore direction (d-f). Graphical depiction of study area showing sample stations, horizontal contours of surface salinity, and sources of freshwater input to the area (g) for the June 12, 1986 survey of the Yukon River Delta.

fresher water (<5 ppt) was generally contained in a narrow near-shore region inside of the 1 m isobath. Intermediate salinity water (5 - 15 ppt) was generally distributed in the upper 1.0 - 1.5 m of the water column in the region extending from the fresher nearshore water to beyond the furthest offshore station (Figure 3-2a - f). This layer of water appears to have coupled effectively with the NNE wind field while maintaining its identity from the deeper water. More marine water (>15 ppt) lay below this intermediate salinity water and generally filled the entire lower portion of the water column. Hydrographic distributions suggest a very dynamic system with net southerly wind driven water movement and superimposed estuarine circulation patterns complete with upwelling.

June 15, 1986

Winds on this survey day ranged from 5 -10 kts from the NNE. As described in the discussion of the previous survey, the wind field would be expected to move coastal water southward along the delta front. The two northernmost transects (Figure 3-3a - b) contained fresher (≤ 5 pt), nearshore water than did the southerly section (Figure 3-3), suggesting that the source of the fresher water may be from the north (middle mouth of the Yukon River Figure 2-4). This hypothesis is consistent with the southerly, wind driven movement of the nearshore water. Both the fresher and the intermediate salinity water are confined to the delta platform in the northern section (Figure 3-7a). The middle section shows that the intermediate salinity water extended throughout the offshore region in a 2 m thick upper layer. The fresher water in this section is confined to the nearshore in water depths less than 1 m. At the southern section, the offshore upperlayer flow had decreased the upper layer thickness to 1 m and allowed the marine water (> 15 ppt) to move more onshore under the upper layer to the 1.5 meter isobath. Wind mixing again was insufficient to mix the water column below 1 - 2 m.

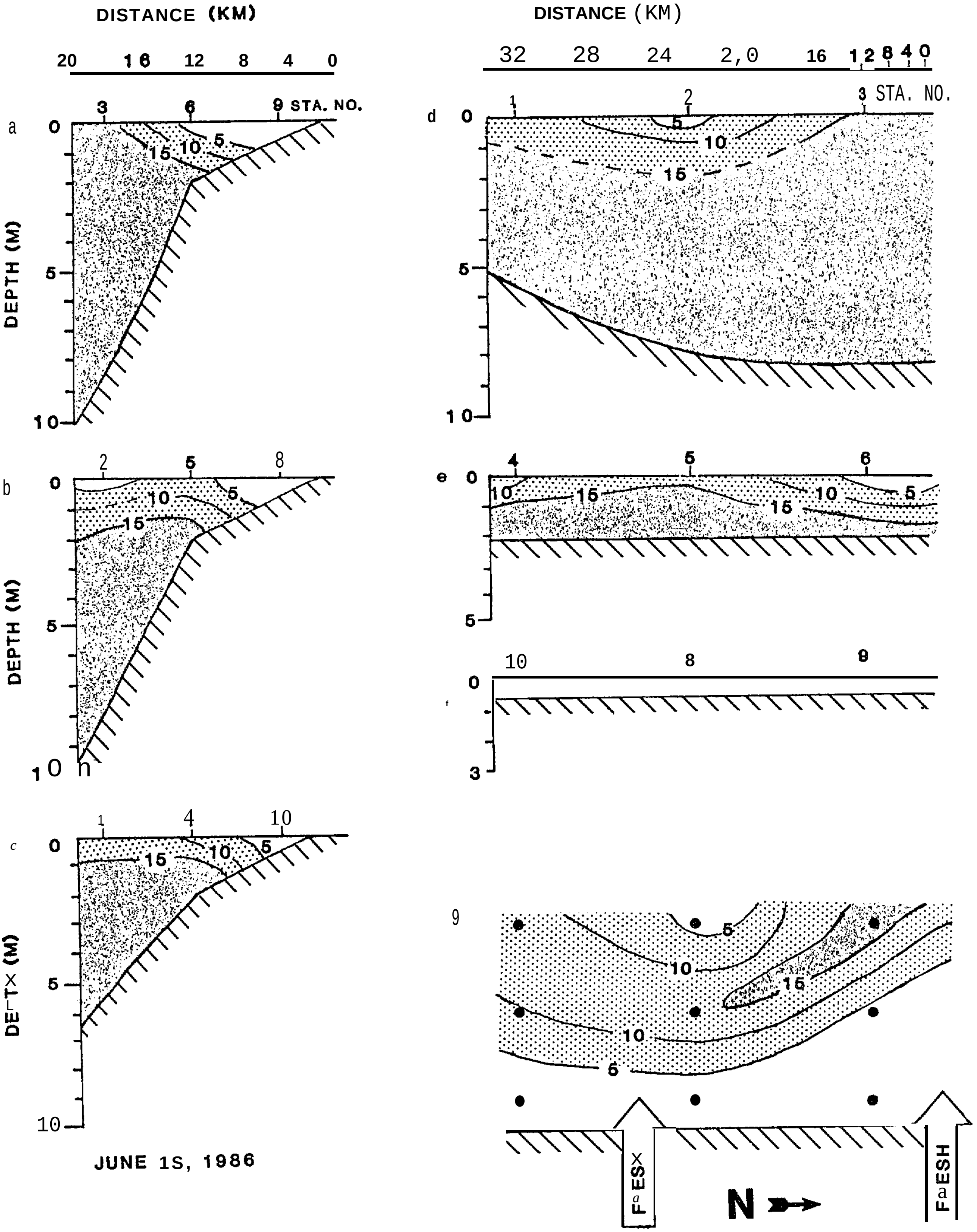


FIG. 3-3. Vertical section of salinity for the on/offshore direction (a-c) and the along-shore direction (d-f). Graphical depiction of study area showing sample stations, horizontal contours of surface salinity, and sources of freshwater input to the area (g) for the June 15, 1986 survey of the Yukon River Delta.

Satellite imagery from this day show similar distributions of surface temperature and water surface reflectivity (related to water clarity and total suspended solids (TSS), Groves and Stringer 1982) compared to the in-situ hydrographic samples. Figure 3-4 shows the Yukon Delta thermal and visible distributions on a regional scale. The thermal image (Figure 3-4a) indicates the warmer land, river, and nearshore water mass temperatures ranging from the warmest (red) to the somewhat cooler (yellow). As the river waters combine with more marine water on the delta platform they cool (green). Water temperatures in the river plume that extends beyond the delta front are cooler still (light blue). The Yukon River plume water can be seen as it moves off of the delta platform toward the west and then south in response to northeasterly winds. The solid light blue region corresponds to the 1 m thick layer of fresher (5-15 ppt), warm (5-10° C) water seen in the hydrographic data (Figure 3-3) on the delta platform. Just seaward of this region, thin plumes of the nearshore water can be seen moving offshore across the delta front, and overriding the brackish water (Figure 3-3). Cooler offshore water masses (darker blue) are distributed in a more or less random fashion beyond this area. Further offshore, near the edge of the picture, the northerly moving cooler Alaskan coastal water (purple) can be seen moving toward the Bering Strait.

Figure 3-4b also shows the corresponding visible image of the thermal configuration just discussed. In this image the colors, moving from red to yellow to green, indicate the reflectance (low to high) of an area. Groves and Stringer (1982) has shown thatTSS can be related to the reflectance of the water surface if other conditions are the same. Research conducted by Envirosphere Company in Stefansson Sound, Alaska (Hachmeister, et al. 1986) also shows there is a relationship between Secchi depth and TSS. Although there is not a strong functional relationship established between the parameters, it is intuitively apparent that inverse Secchi depth is related to TSS. Therefore, the relationship between the AVHRR surface reflectance image and inverse Secchi depth might also be related. In this image (Figure 3-4b), the land that is not covered with a large percentage of water appears as

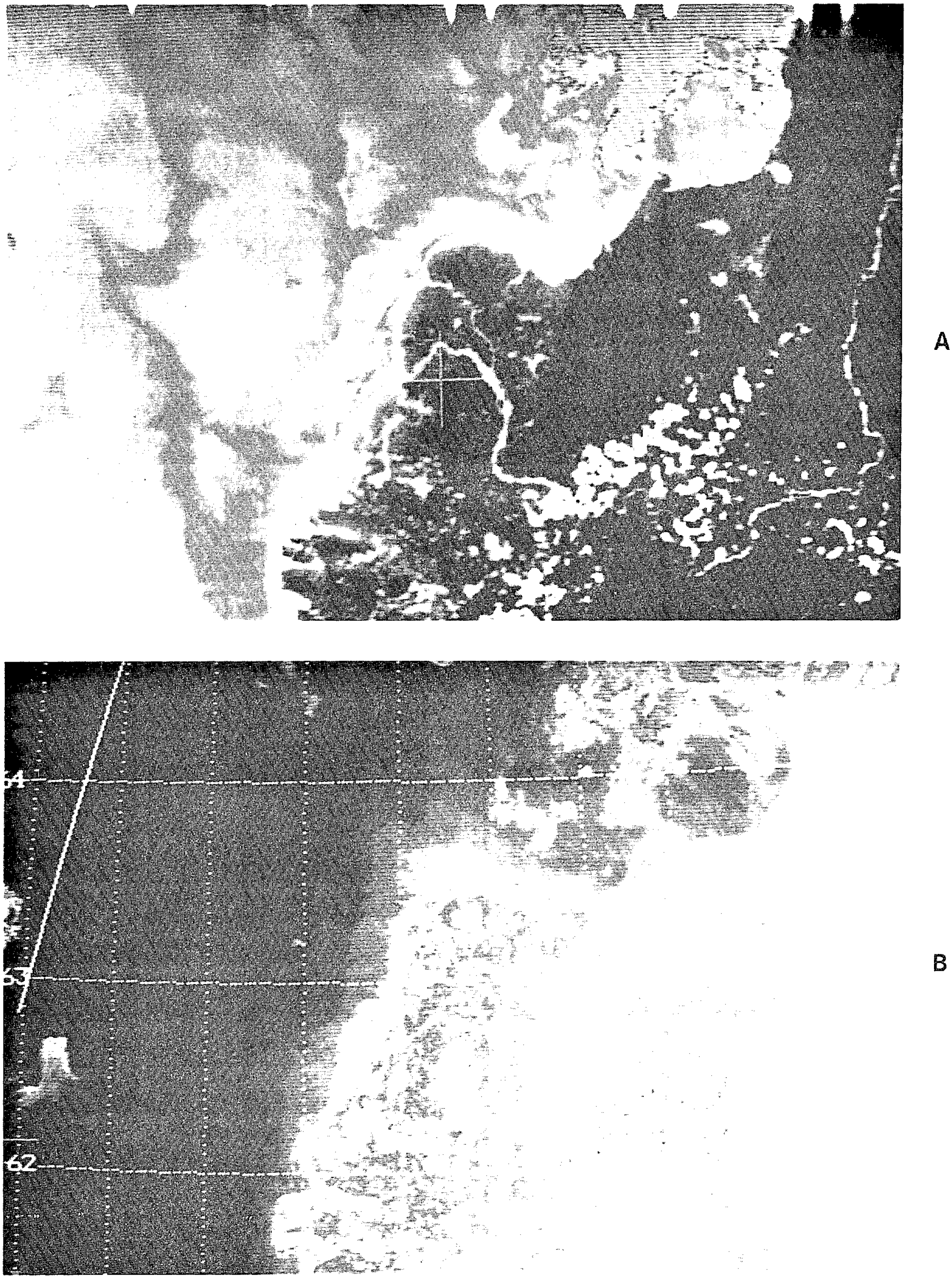


FIGURE 3-4

NOAA AVHRR Satellite Imagery of the Yukon River Delta, Approximate Scale 1:3 Million, June 15, 1986: A) Enhanced Thermal Infrared (Channel 4); 8) Enhanced Visible (Reflected) (Channel 1).

blue. The purple region shows areas of very high reflectance that results from the presence of clouds. Assuming that reflectance (color) is an indication of sediment concentration, we see that the heaviest sediment concentrations are on the delta. These concentrations decrease somewhat moving off the delta platform and within 20 km from the coast onshore/offshore gradients become quite low. The lowest levels of suspended sediment occur in the colder coastal water mass (purple) previously identified in the thermal image. The long narrow band of green, immediately to the north of the delta, suggests very high concentrations of sediments. This is a very shallow region of the coastline and high particulate concentrations could result from resuspended bottom sediments near the mouth of the northern channel of the Yukon. These suspended sediments are then advected by wind driven (NNE winds) currents toward the west. Other small patches of green are observed in the shallow nearshore water just west of Emmonak and south of the southern mouth of the river.

Figure 3-5 shows an enlargement of the Yukon Delta region of the satellite image previously discussed. Details of the coastline and river channels have been added to this image to allow easy reference to visible thermal features along the coastline. The sampling stations where hydrographic measurements were collected are indicated with their corresponding station numbers. In Figure 3-5a, the warmer water (yellow) is seen in the shallow nearshore region where solar heating has increased the water temperature to that of the coastal land masses. This is most evident in the region around station 9 and along the northern edge of the delta, just north of Middle Mouth of the Yukon river. In the 1985 fisheries report (Martin et al. 1986) we had thought that these regions might be influenced by a marine water return flow. However, it is evident from the AVHRR images and our site surveys that this region is dominated by warm water which results from the broad intertidal mudflats. During low tide this area is characterized by exposed mudflats and large shallow (<20 cm) tidal pools.

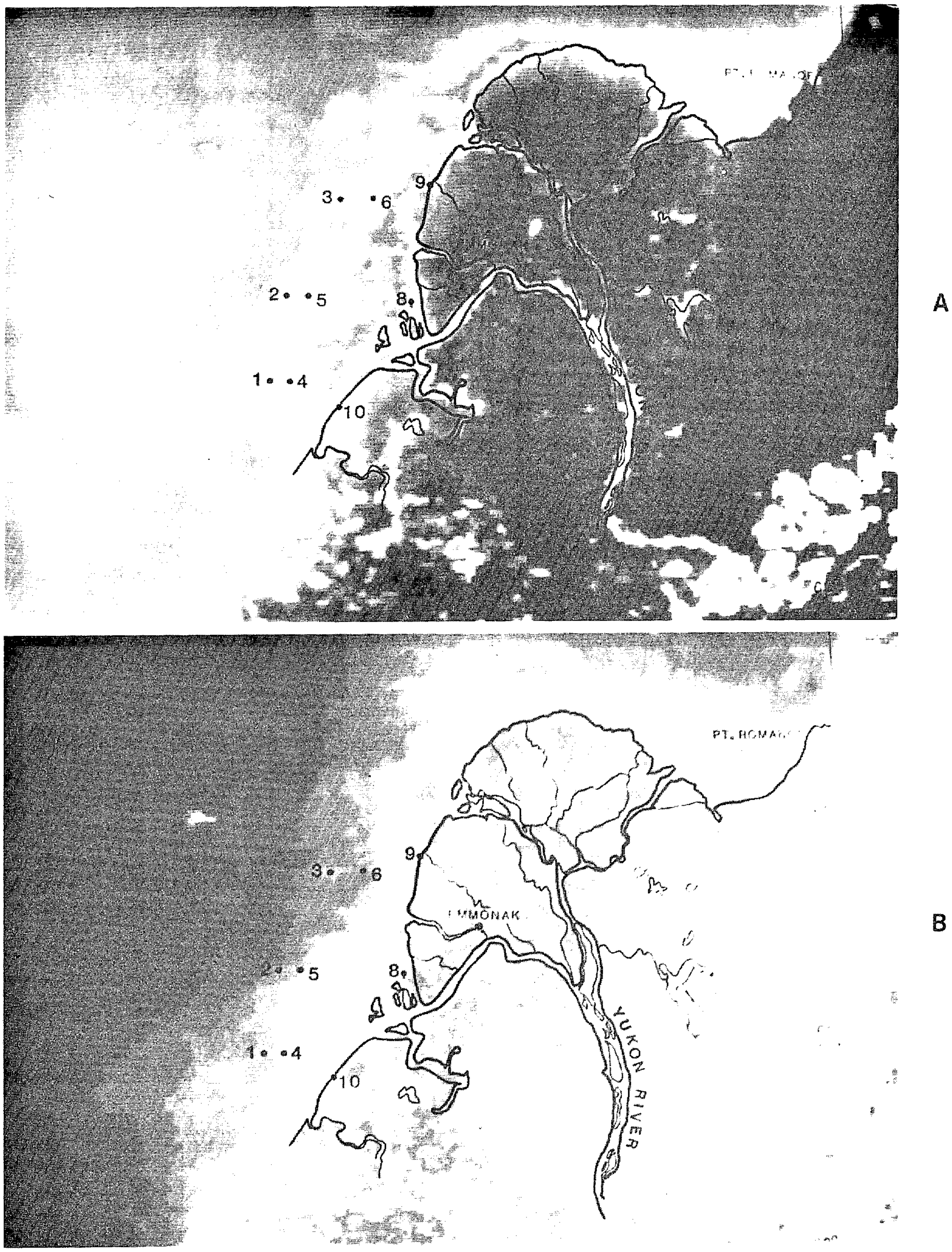


FIGURE 3-5

NOAA AVHRR Satellite Imagery of the Yukon River Delta, Approximate Scale 1:1.5 Million, June 15, 1986: A) Enhanced Thermal Infrared (Channel 4); B) Enhanced Visible (Reflected) (Channel 1).

Note that the river water is light blue and green in the channels and yellow where an image pixel (1 km by 1 km) overlaps the landmass (red) along the river bank. Detailed features of the plumes of light blue delta water moving off the delta platform can be seen as they override the cooler offshore water.

Surface temperature measurements collected on this day indicate that the offshore water (Stations 1, 2, and 3) ranged 10 - 15° C. The light blue water of the delta platform (Stations 4, 5, and 6) ranged 9 - 17°C and the shallow nearshore water was approximately 15 - 18° C. The light blue water just offshore of the north mouth of the river is very uniform in appearance which indicate temperatures were approximately 13 - 14°C. This region was identified as a region of possible intense mixing and sediment resuspension. The offshore region to the west of the delta platform appears very dynamic and extremely variable at small scales.

The corresponding visible image (Figure 3-5b) shows the details of the delta region with respect to the surface reflectance. The sediment plume (green) identified in Figure 3-4b can be seen in greater detail in this figure. In the region sampled by the measurement program, sediment concentrations are depicted by yellow through several shades of orange in two distant offshore zones defining the delta platform and the region just offshore of the delta front. In these zones the Secchi depth (which is inversely related to the TSS) ranged 0.2-1.2 m at stations 1-3 and 0.1-0.8 m at stations 4-6. Because no Secchi depths were recorded in offshore regions beyond the two zones described above, it cannot be determined how the further offshore distributions related to water clarity except that the reflectance is less and the clarity is assumed to be greater. Details of several higher turbidity regions can be seen south of the south mouth of the river near Station 10.

The high degree of spatial variability on the delta platform can be seen in Figure 3-6. Note that the subtle differences in temperature (Figure 3-6a) around the sampling stations would be advected

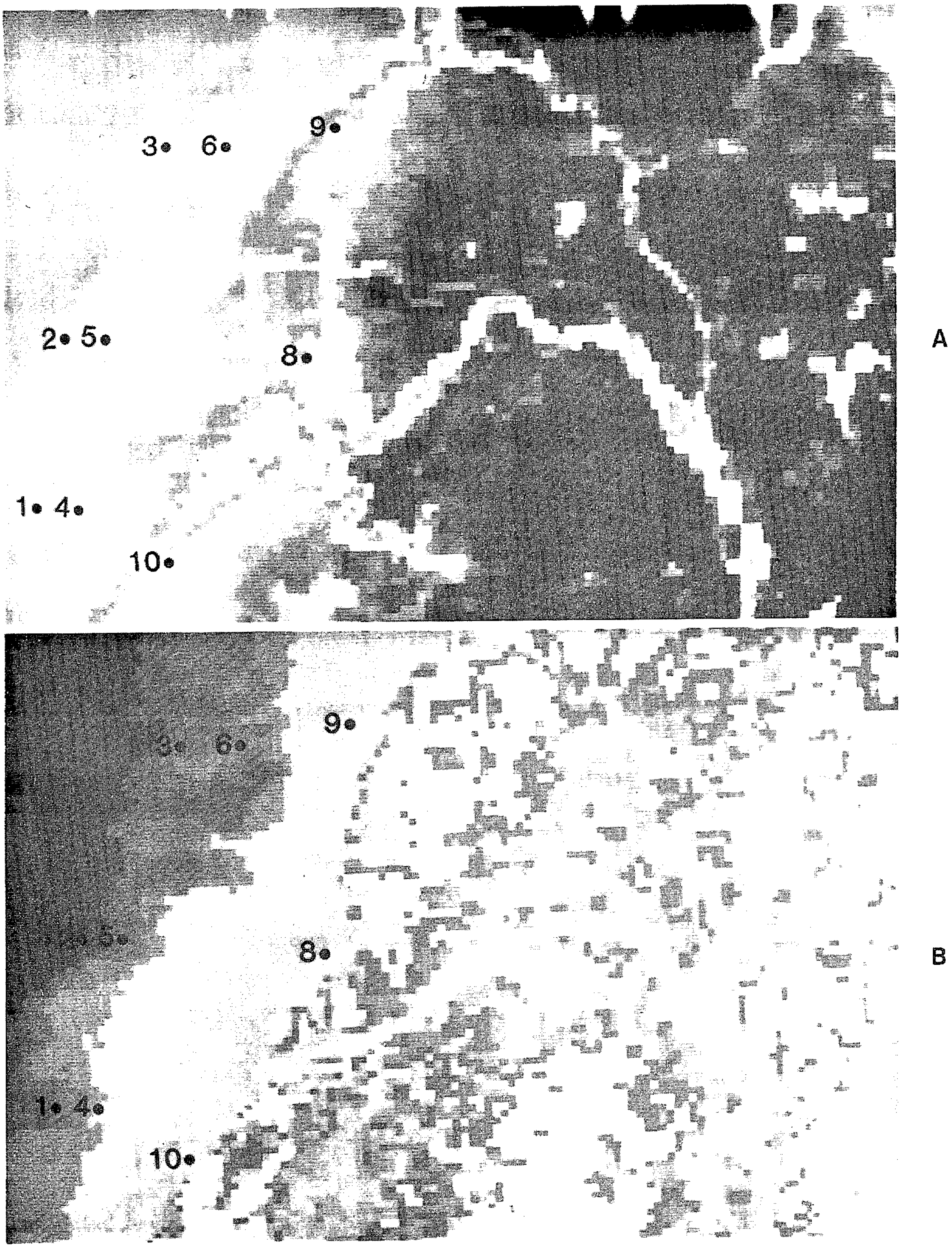


FIGURE 3-6

NOAA AVHRR Satellite Imagery of the Yukon River Delta, Approximate Scale 1:750,000, June 15, 1986: A) Enhanced Thermal Infrared {Channel 4); B) Enhanced Visible (Reflected) (Channel 1).

continuously across the delta by the wind driven current and that sampling of physical parameters on a given day is by no means synoptic relative to the advective changes occurring at a given station during the daily sampling period. Inland, the details of the river temperatures can also be seen more clearly. In the wider portions of the river, considerable difference in temperature can be seen between the river and the land. The visible image (Figure 3-6b) shows more distinction between the land mass (blue) and the water (orange) than did the thermal image. Note the offshore distance of Stations 9 and 10 in the visible image relative to the thermal image, where warm temperatures of the shallow water appear to extend the coastline offshore into the shallow water. The source of the highly turbid delta water can be seen in the central channel of the river where the color (TSS) of the river water is similar to that of the nearshore water.

June 19, 1986

During this survey, winds were 5 - 10 kts from the NNE. A considerable change had occurred in the hydrography of the study region in the three day period between the previous survey on 15 June and this survey. Fresher water ($\leq$5 ppt) extends beyond the outer station at all three of the sections (Figure 3-7). The sections show a considerable increase in the amount of fresher water in the region that occupied the upper 1 2 m of the water column at all stations. The intermediate salinity water (5 - 15 ppt) occupied most of the water column below the fresher water to a depth of 4 m. Examination of the wind field records indicate that no significant changes occurred from 15 - 19 June on the meteorology and it must be assumed that the observed hydrographic changes are a result of increased runoff and/or fresh water accumulation from the Yukon River (Figure 3-1). These conditions leave much of the delta platform with salinities less than 5 ppt. No indication of estuarine type water movement or upwelling are apparent on the delta platform in these data.

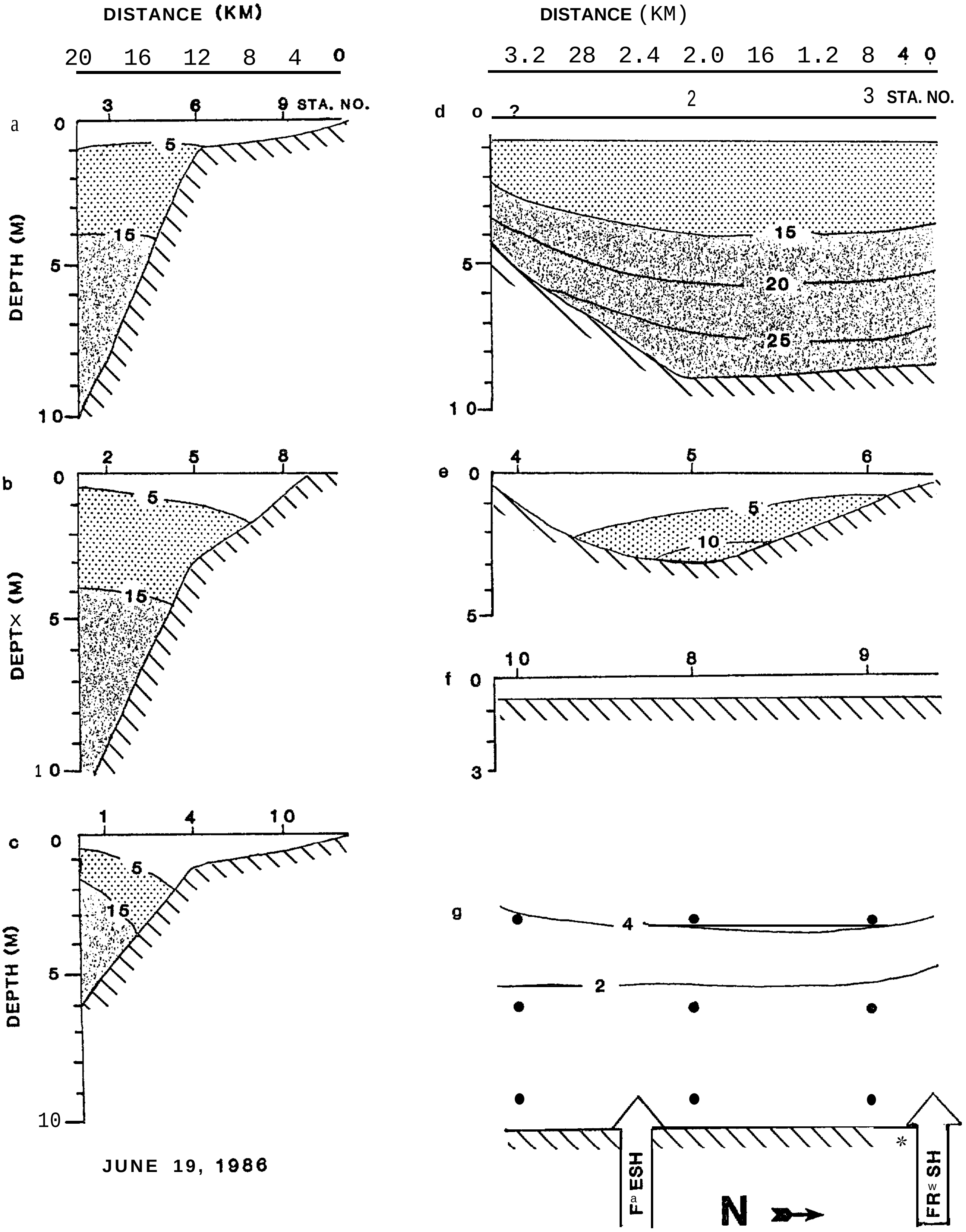


FIG. 3-7. Vertical sections of salinity for the on/offshore direction (a-c) and the along-shore direction (d-f). Graphical depiction of study area showing sample stations, horizontal contours of surface salinity, and sources of freshwater input to the area (g) for the June 19, 1986 survey of the Yukon River Delta.

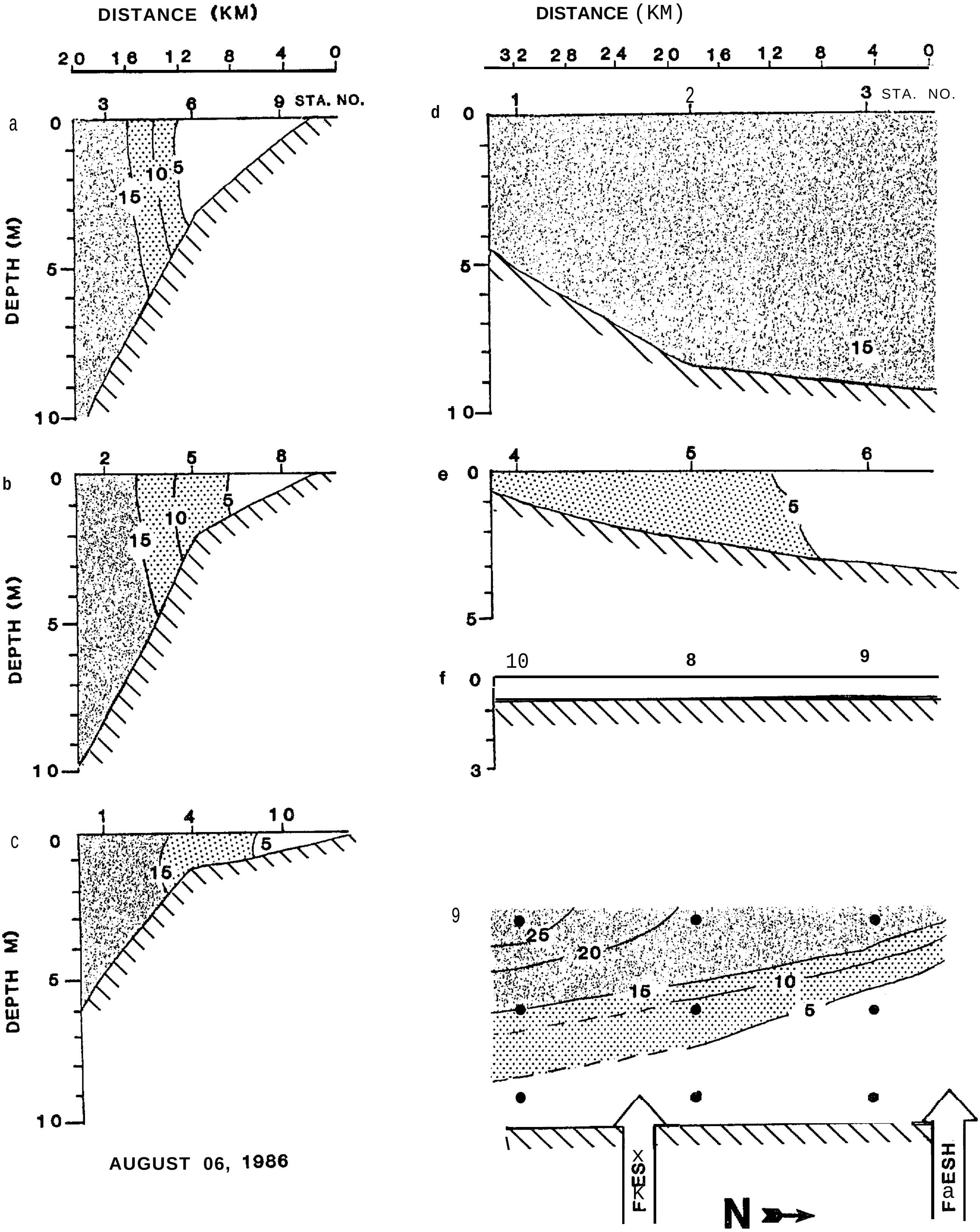
August 6, 1986

Winds were 5 - 10 kts from the NNE during this survey. Observed hydrographic distributions (Figure 3-8) are indicative of a vertically well mixed system which might be brought on by sustained high winds and strong vertical mixing. However, no meteorological data are available for the days preceeding the survey for verification of this hypothesis. Fresher water was generally confined to within 4 - 10 km of the coastline, Little vertical stratification is indicated in the salinity sections and almost all salinity variability is in the on/offshore direction. Examination of the available temperature data also indicate no vertical stratification, Intermediate salinity water extended offshore from the fresher water out to 12 - 16 km in a vertically well mixed band approximately 6 km in width. As in the survey of 12 June, the observed distribution of salinity suggests that the source of fresher water in the study region is from the north. No effects of wind induced upwelling was observed along any of the transect lines.

3.2 CATCH SUMMARY

3.2.1 Effort

The sampling effort (i.e., in terms of sample frequency and date of sampling) was not evenly distributed among the delta habitats (Tables 3-1 and 3-2). The shallow mudflat and tidal slough stations were very difficult to reach during the June and early July period 'when helicopter usage was prohibited in these areas. Almost a full day of travel was required to sample one pair (i.e., mudflat and tidal slough) of sample sites. Therefore, most of the effort was concentrated on obtaining replicate samples from stations 8 and 11 (Table 3-1), which were representative of typical mudflat and tidal slough habitats, respectively. When the helicopter restrictions were not in effect (i.e., August), several additional coastal locations (i.e., stations 8 12) were sampled in order to examine spatial differences among these habitats. Poor weather and boat unavailability were the primary



AUGUST 06, 1986

FIG. 3-8. Vertical sections of salinity for the on/offshore direction (a-c) and the along-shore direction (d-f). Graphical depiction of study area showing sample stations, horizontal contours of surface salinity, and sources of freshwater input to the area (g) for the August 6, 1986 survey of the Yukon River Delta.

TABLE 3-1
Summary of Sampling Effort (i.e., Number of Hauls) For Beach Seine and Purse Seine Gear During the Summer 1986 Survey of the Yukon River Delta

	Short Beach Seine[a]			
	Habitat/Station Tidal Slough			
Date	10	11	12	Total
6/10		2		2
6/14		2		2
6/17		2		2
6/22		2		2
6/24		2		2
6/25			2	2
7/12		2		2
7/13			2	2
8/04		2	2	4
8/05	2			2
TOTAL	2	14	6	22

	Long Beach Seine[b]		
	Habitat/Station Mudflats		
Date	8	9	Total
6/10	2		2
6/14	2		2
6/17	2		2
6/22	2		2
6/24	2		2
6/25		2	2
7/12	2		2
7/13		2	2
8/04	2	2	4
TOTAL	14	6	20

	Purse Seine		
	Habitat/Station River		
Date	13	14	Total
6/01		2	2
6/04	2		2
6/05	2		2
TOTAL	4	2	6

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a/ 30-meter haul.
b/ Round haul.

TABLE 3-2

Summary of Sampling Effort
(i.e., Number of Hauls)[a] For the Tow Net
During the Summer 1986 Survey of the Yukon River Delta

	Habitat/Station													
	Delta Front				Delta Platform					Lower River		Upper River			
Date	1	2	21		4	41	5	51	6	13	17	14	15	16	Total
5/31													1	1	2
6/01												7			7
6/02													3		3
6/04						2				3					5
6/05										3	15[b]				18
6/06	2		3			2									9
6/07											3				3
6/08											3				3
6/09										3	3				6
6/10											3				3
6/11											3				3
6/12	3	3		3	3		3		3						18
6/13										3	3				6
6/14										6[c]	3				9
6/15	3	3		3	3		3		3						18
6/17										3	3				6
6/18										3	3				6
6/19	3	3		3	3		3		3						18
6/20										5[c]	3				8
6/22										3	3				6
6/24										3	3				6
6/26										3	3				6
7/10											3				3
7/11				3	2										9
7/12										3	3				6
7/13											3				3
7/14	3	3		3	3										18
8/05										3	3				6
8/06	3	3		3											15
8/07										3	3				6
8/08										5	4				9
TOTAL	19	15	3	18	14	4	15	2	17	52	73	7	4	1	244

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a/ All hauls were 10 minutes except where indicated.
b/ One 10-minute tow and 14 5-minute tows.
c/ Five-minute tows.

factors restricting sampling of the delta front and delta platform. Ice blockage in the river mouth prohibited sampling prior to June 4th and stormy conditions during August prevented a second sample trip during this survey period (Table 3-2). The assignment of the primary sampling vessel (i.e., Munson boat) to another project after June 20th eliminated one offshore sampling trip during the latter part of June.

3.2.2 Species Composition and Distribution

The three sample surveys resulted in the capture of 26 species of fish (Table 3-3). Juvenile salmon ranked third in abundance and represented approximately 14 percent of the overall catch. Only sticklebacks and smelt were more abundant, each accounting for 40 and 29 percent of the catch, respectively. Most of the species caught were anadromous and pelagic type fishes, which was expected given the types of gear used and the environmental conditions sampled. However, a small number of marine and bottom type fishes were captured in the delta front and delta platform habitats.

The greatest variety and the largest number of fish species were caught in the delta platform and delta front habitats. Several marine bottom fish species (e.g., flounder, cod, and sculpin) were caught from these habitats despite the fact that only surface waters were sampled with the tow net. Ninespine sticklebacks, juvenile smelt, juvenile cisco, and juvenile chum salmon were the dominant species groups in these habitats. Mudflat and tidal slough habitats had a less diverse community which was mostly comprised of coregonid species. The lower river habitat was mostly composed of outmigrating juvenile salmon, juvenile cisco, and lamprey. A summary of all fish catches by species, station, and date is shown in Appendix Table B.

"TABLE 3-3

Number of Fish Caught By Species and Habitat During Summer 1986 in the Yukon River Delta

Species	Scientific Name	Habitat Delta Front	Delta Platform	Mudflat	Tidal Slough	Lower River	Upper River	All
Chinook Salmon	*Oncorhynchus tshawytscha*	33	41		1	444	177	696
Chum Salmon	*Oncorhynchus keta*	789	693	8	206	3079	60	4835
Pink Salmon	*Onrochynchus kisutch*					3	1	4
Arctic Char	*Salvelinus alpinus*		1			1	1	3
Sheefish	*Stenodus leucichthys*	1	17	52	5	257		332
Humpback Whitefish	*Coregonus pidschian*		3	73	27	4		107
Broad Whitefish	*Coregonus nasus*		2		6			22
Whitefish sp.		4	20	1;:	133	259		545
Bering Cisco	*Coregonus laurettae*		15	26	3			44
Least Cisco	*Coregonus sardinella*	9	130	39	23	44	6	251
Cisco sp.		629	897	23	35	1292		2876
Whitefish and Cisco					13	2		15
Boreal Smelt	*Osmerus eperlanus*	509	2564			5		3078
Smelt sp.		4214	4791	1				9006
Threespine Sticklebacks	*Gasterosteus aculeatus*				14			14
Ninespine Sticklebacks	*Pungitius pungitius*	9117	5500	44	1615			16276
Arctic Lamprey	*Lampetra japonica*	211	156			630		997
Lamprey sp.			1			5	22	28
Longnose Sucker	*Catostomus catostomus*			17		1		18
Northem Pike	*Esox lucius*				1			1
Burbot	*Lota lota*	4	170	15	48	34	8	279
Starry Flounder	*Platichthys stellatus*	3	7	43				53
Arctic Flounder	*Liopsetta glacialis*	7	47	25	176			255
Saffron Cod	*Eleginus gracilis*	173	23	1				197
Arctic Cod	*Boreogadus saida*	2	28					30
Fourhorn Sculpin	*Myoxocephalus quadricornis*	4	7		7			18
Sculpin sp.		1	1					2
Pacific Herring	Clu ea *harengus pallasi*	498	119					617
Tubenose Poacher	* i n s *barbata barbata*	1						1
Prickleback	*Lumpenus* sp.	3	2					5
Greenling	*Hexagrammos* sp.	3						3
Sandlance	*Ammodytes hexapterus*	3						3
TUTAL		16218	15235	51(J	2313	6060	275	40611
PERCENT		39.9%	37.5%	1.3%	5.7%	14.9%	0.7%	

3.3 CHINOOK SALMON

3.3.1 Migration Timing

Juvenile chinook salmon were caught on the first day of sampling in the Andreafsky River (stations 15 and 16 on May 31st) and the Yukon River (station 14 on June 1st) (Appendix Table B). Chinook juveniles were also present in the lower Yukon River on June 4th (Figure 3-9), which was the beginning of the sample program at stations 13 and 17. Juveniles were caught during all three survey periods, which indicate the outmigration was still in progress on August 8th, the last day of sampling. Catch per unit effort fluctuated greatly during the study period with the peak CPUE occurring during late June. Both sample stations showed similar trends in fish abundance over time, but the number of fish caught was consistently greater at station 17.

3.3.2 Distribution and Density

Juvenile chinook salmon were caught primarily in the delta front, delta platform, and lower river habitats (Table 3-4). No fish were caught at the mudflat sites but juveniles were caught in a tidal slough (i.e., Station 11) on one sample date. Fish were caught on the delta platform on the first day of sampling (i.e., June 4th) and occurred in this habitat prior to their occurrence in the delta front. Chinook salmon were caught in the delta front as late as July 13th, but were not detected in the delta platform at this time. Juvenile chinook salmon were not caught at any coastal or offshore station during the August survey despite their continued presence in the lower river.

The density of juvenile chinook salmon was highly variable over time and among habitats (Table 3-4). Temporal trends of density in the offshore habitats had unimodal patterns with peak densities occurring in mid-June. Densities in the river fluctuated greatly during the survey period with the largest peaks occurring during the latter half of June. The temporal trend in density in the offshore habitats did

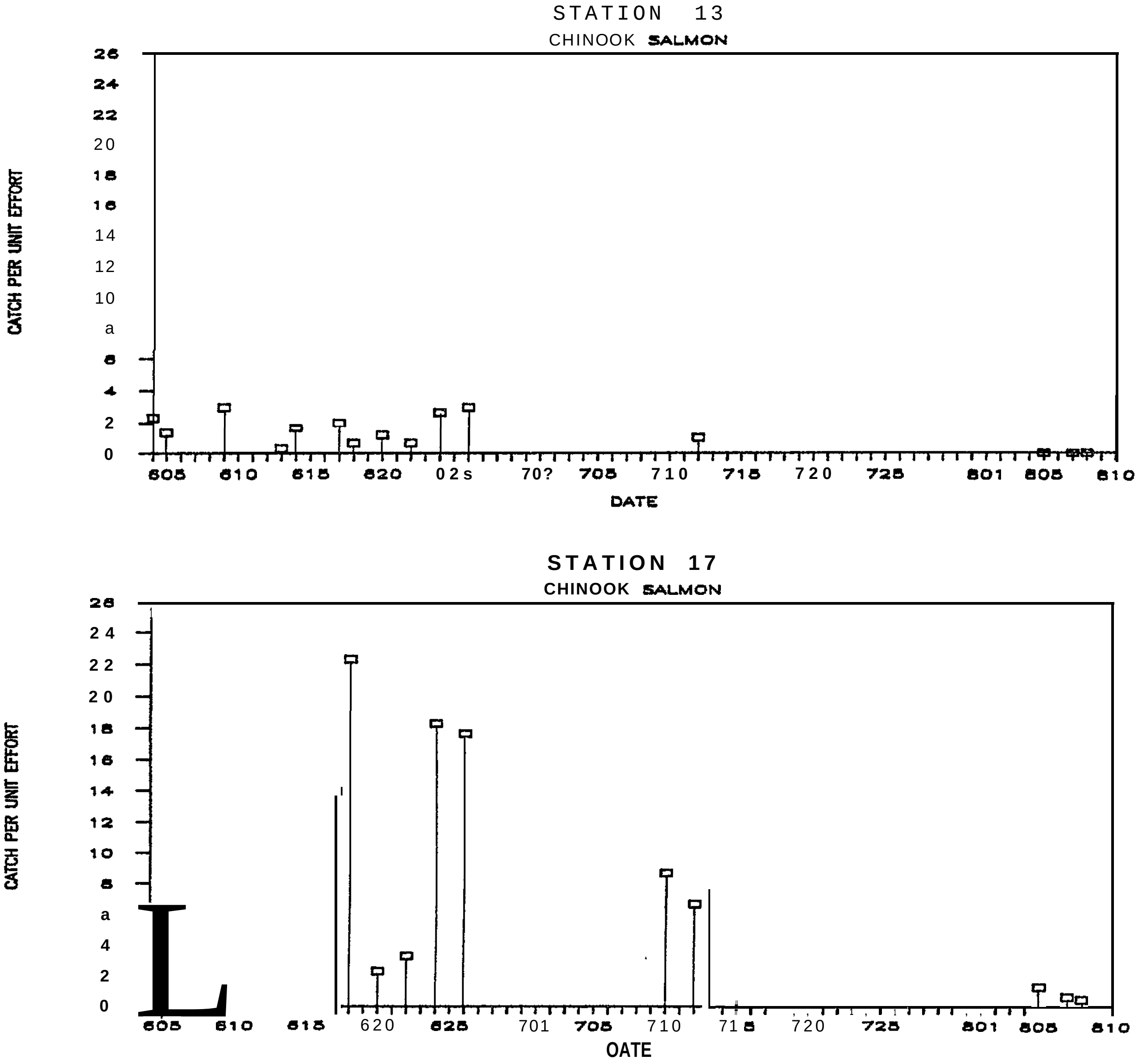

Fig. 3-9: Catch per unit effort of juvenile chinook salmon during summer 1986 from the lower river, stations 13 and 17, of the Yukon River Delta.

TABLE 3-4

Estimated Average Density (no/km^2) of Juvenile Chinook Salmon During Summer 1986 in the Offshore, Coastal, and Lower River Habitats of the Yukon River Delta

	Habitat/Station																	
	Delta Front				Delta Platform				Mudflats			Tidal Slough				Lower River		
Date	1	2	3	Mean	4	5	6	Mean	8	9	Mean	10	11	1.2	Mean	13	17	Mean
6/04					171a/	-	-	171	-					-		798		798
6/05						-	-							-		456	1756	1539
6/06	0	0		0	0	171a/	-	86	-					-			-	-
6/07														-			570	570
6/08														-			114	114
6/09														-		026	1254	1140
6/10									u		D		0	-	0		570	570
6/11				-										-			456	456
6/12	342	684	1140	722	342	342	0	228						-				-
6/13														-		114	0	57
6/14	-							-	0		0		0	-	0	570	456	532
6/15	114	228	1026	456	684	684	2052	1 40						-				
6/17							-		0		0		2165	-	2165	684	4788	2736
6/18														-		228	7638	3933
6/19	0	114	0	38	0	114	114	76						-		-	-	-
6/20														-		410	798	556
6/22									0		0		0	-	0	228	1140	684
6/24									0		0		0	-	0	912	6270	3591
6/25										0	0			0	0			
6/26														-		1026	6042	3534
7/10	0		0	0	171		u	86						-			2964	2964
7/11														-				
7/12									0		0		0	-	0	342	2280	1311
7/13	0	114	u	38	0	0	o	0		0	0			0	0		2736	2736
7/14														-				
8/04									u	0	0	. -	0	0	0			
8/05												0		-	0	0	456	228
8/06	0	u	o	0		u	u	0						-				
8/07														-		0	228	114
8/08														-		u	171	76

---

a/ Estimated from catches at stations 41 or 51.

not appear to follow the density trends in the lower river. Comparisons among habitats, excluding the river, indicates the greatest density occurred in the tidal slough on June 12th. The absence of juveniles in this habitat at any other time indicates that the duration of habitat utilization was short term. Average densities of fish were generally greater in the delta platform than the delta front, but the difference between both habitats was relatively small.

Juvenile chinook salmon densities varied among stations within a habitat type. During the period of peak densities in the delta front (i.e., 6/12 and 6/15), there was a trend of increasing fish density from south to north (Table 3-4). This trend is not apparent in the delta platform, where fish densities were similar among two of the three stations during this time period. In the lower river, densities were consistently greater at station 17 than at station 13.

3.3.3 Size Composition

Juvenile chinook salmon ranged in size from 69 mm to 128 mm (Appendix Table B). Fish caught in the lower river during early June had a slightly greater mean length and a greater variation in size (i.e., larger standard deviation) than fish caught during late June (Figure 3-10). More than one length frequency mode is apparent during several sample periods which indicates more than one cohort size group was outmigrating from the Yukon River. The length frequency of a small number of fish (i.e., 8 fish) caught in August was not plotted. But the large variations in fish lengths from this sample (range 85 - 115 mm) indicates more than one size group of juveniles may occur at this time (Appendix Table B). Temporal trends in size compositions of chinook salmon caught in other habitats were not analyzed because catches were too small for a useful size frequency analysis.

A comparison of fish lengths among habitats during the period of peak abundance offshore (i.e., 6/12/86 - 6/15/86) indicates a close similarity in size composition among the delta front , delta platform, and lower river (Figure 3-11). Fish from all three habitats had a

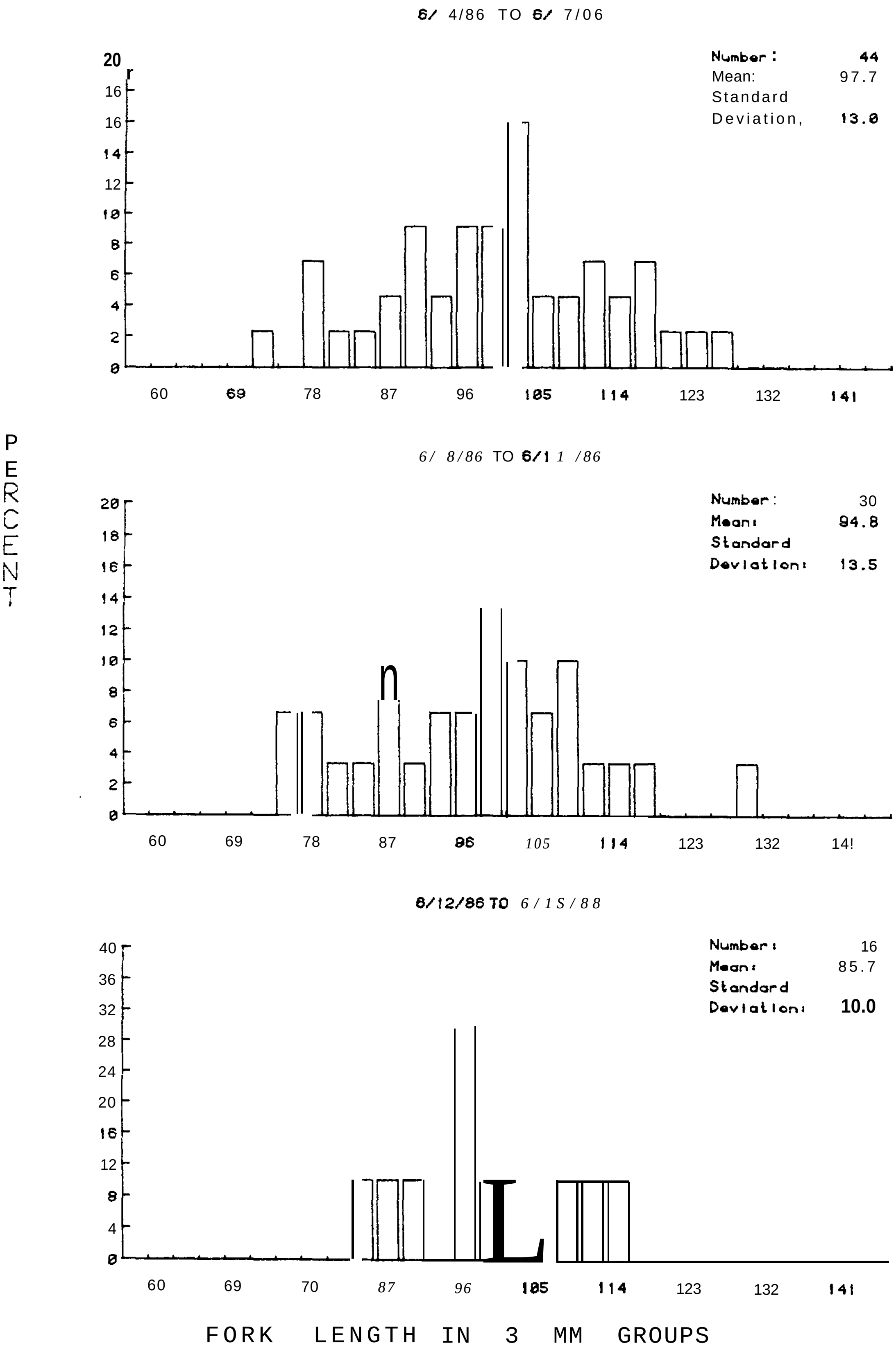

Fig. 3-10: Length frequency of juvenile chinook salmon by time period during summer 1986 from the lower river, stations 13 and 17, of the Yukon River Delta.

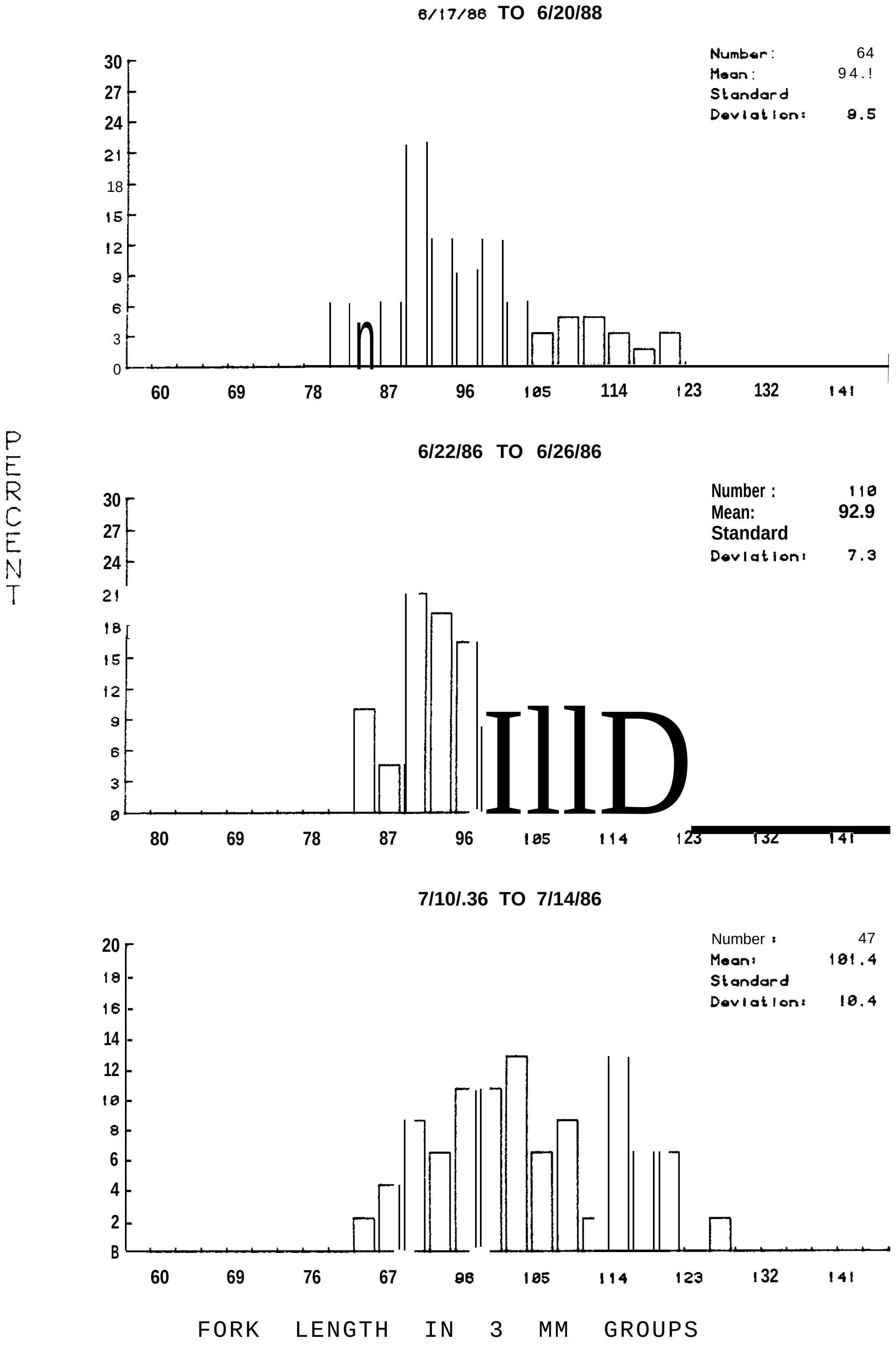

Fig. 3-10 (continued)

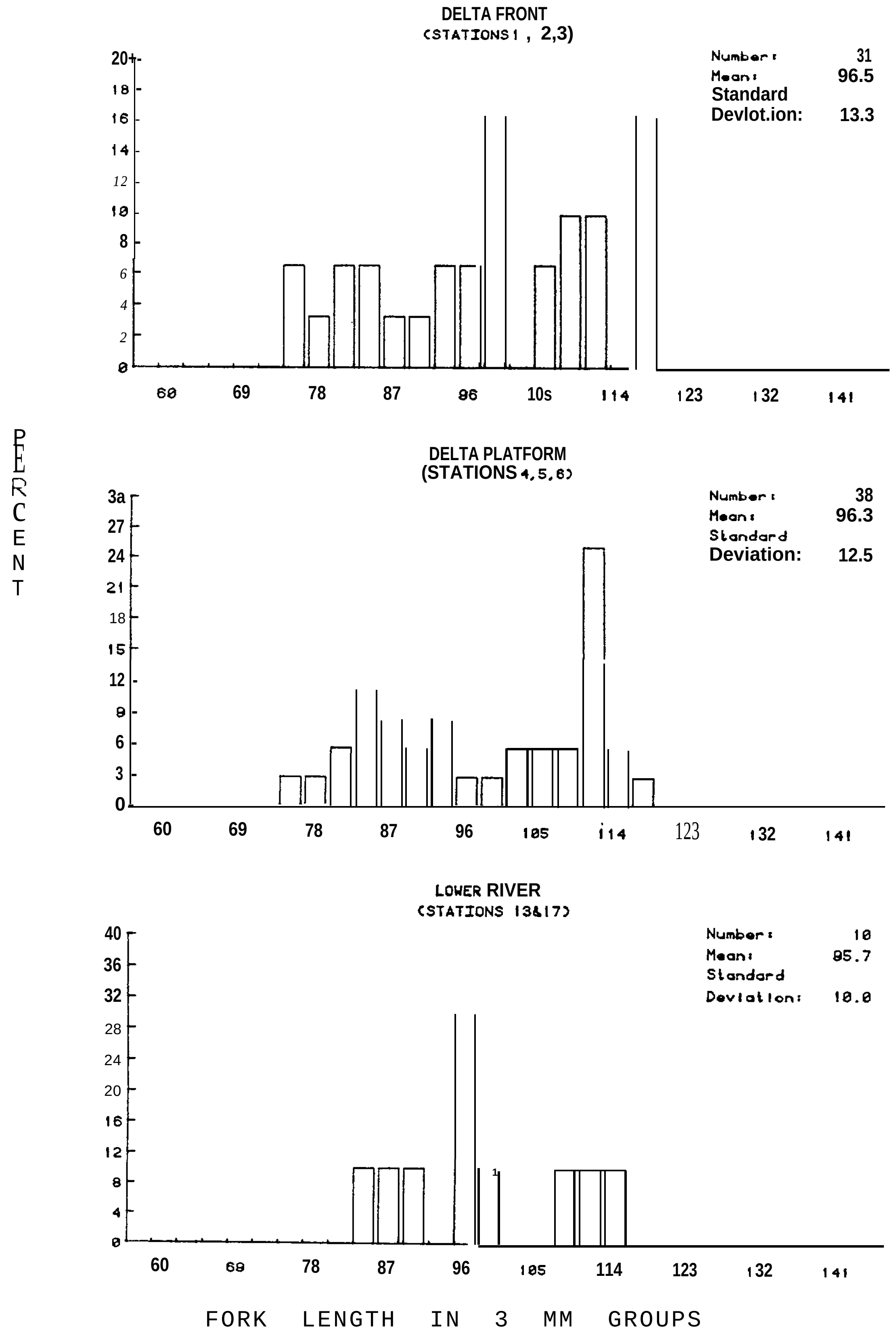

Fig. 3-11: Length frequency of juvenile chinook salmon during the period 6/12/86 to 6/15/86 from the lower river, delta platform, and delta front habitats of the Yukon River Delta.

bimodal size distribution with the nadir at approximately 102 mm and an average length of about 96 mm. Differences in size composition were evident, however, among the stations within the delta front and delta platform habitats (Figure 3-12 and 3-13). The percentage of small fish (i.e., <102 mm) and large fish (i.e., >102 mm) is not uniform among stations. A greater percentage of large fish occur at the northern stations (i.e., stations 3 and 6) than at the southern stations (i.e., stations 1 and 4).

3.3.4 Associated Environmental Conditions

The chinook salmon environmental associations for temperature, salinity, and visibility are shown in Tables 3-5 to 3-7, respectively. The diagonal from top left to bottom right on the temperature and salinity tables represents mixed water. Deviation from this diagonal represents stratified conditions. In most cases juvenile chinook salmon catches were associated with stratified conditions. Most fish were caught in relatively warm surface water (i.e., >6°C) with moderate to low salinity (i.e., <20 ppt) and cool bottom water (i.e., <6°C) with moderate to high salinity (i.e., >15 ppt). The largest catch of juvenile chinook salmon was associated with surface water temperatures that ranged ?31O″C, salinities that ranged 10-15 ppt, and water visibility that ranged greater than 0.5 m.

Highest catches were more associated with the deeper subtidal habitats (i.e., delta platform and delta front) than with the shallow intertidal habitats. Catches were not associated with any particular water depth in the offshore habitats.

3.4 CHUM SALMON

3.4.1 Migration Timing

Juvenile chum salmon were present in the catch during all three sample surveys (Figure 3-14). Low numbers of juvenile were caught in the Andreafsky River (stations 15 and 16) and Yukon River {station 14)

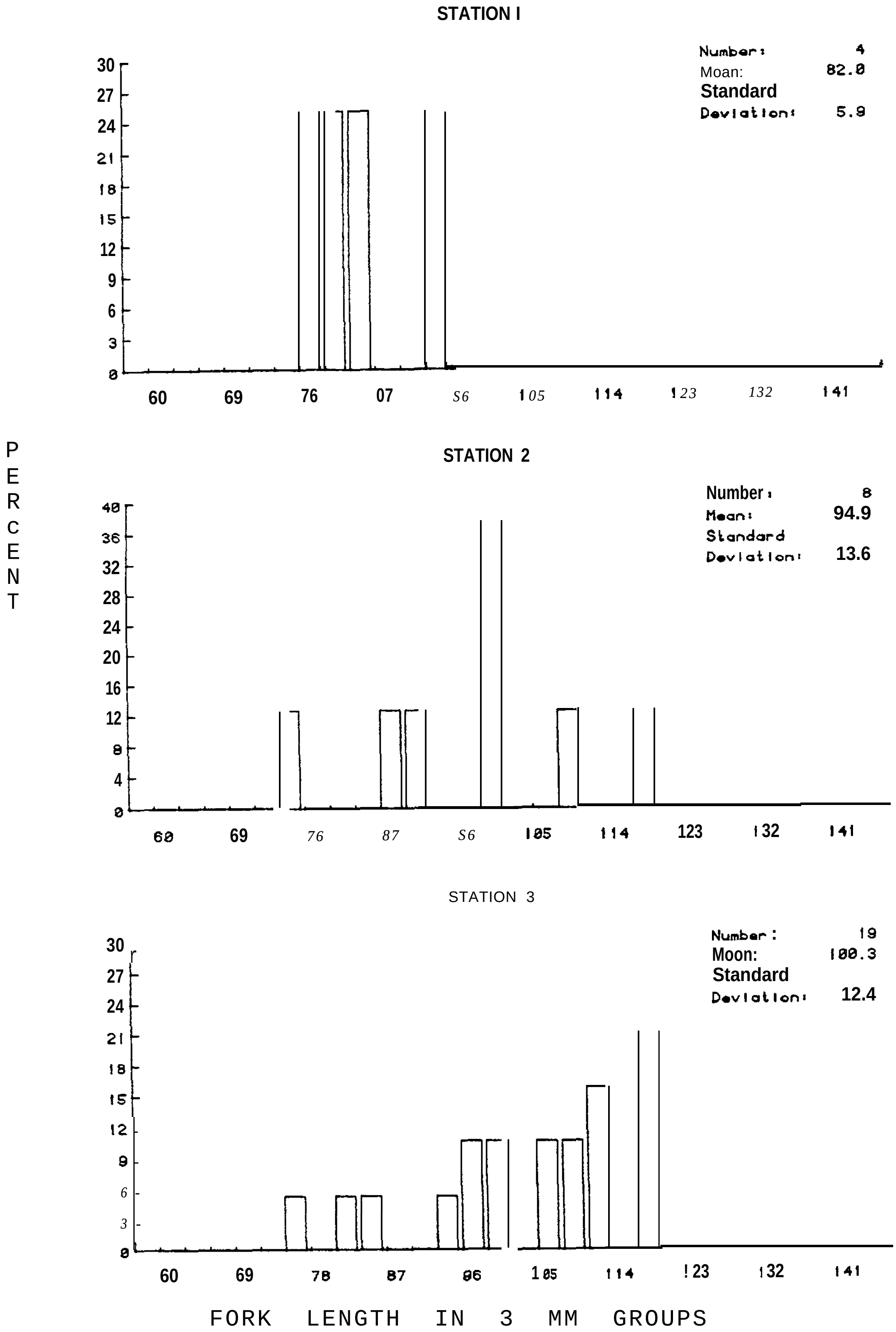

Fig. 3-12: Length frequency of juvenile chinook salmon during the period 6/12/86 to 6/15/86 from the delta front, stations 1, 2 and 3, of the Yukon River Delta.

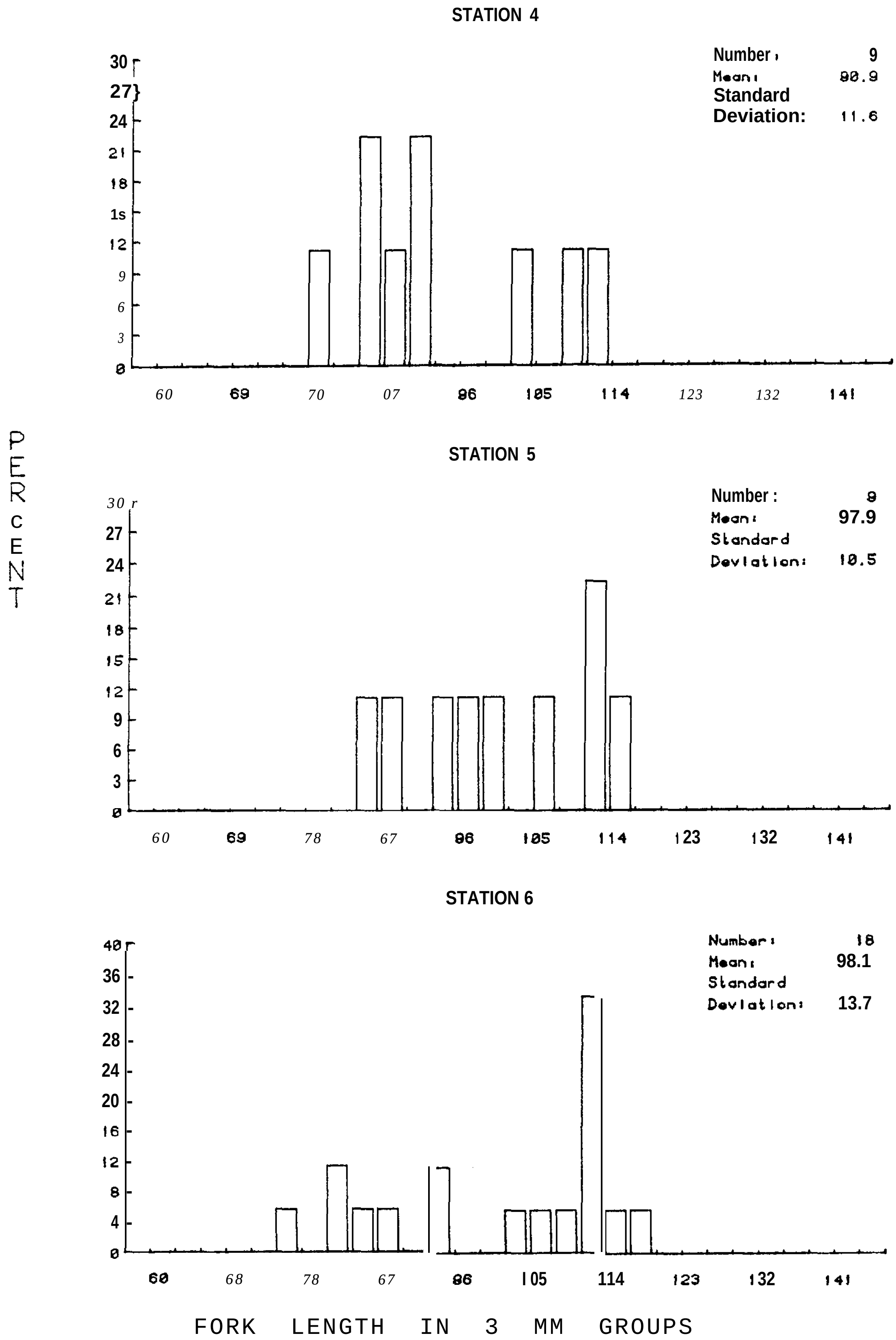

Fig. 3-13: Length frequency of juvenile chinook salmon during the period 6/12/86 to 6/15/86 from the delta platform, stations 4, 5 and 6, of the Yukon River Delta.

TABLE 3-5

Percentage Adjusted Catch of Chinook Salmon Associated With Surface and Bottom Temperature in the Delta Front and Delta Platform Habitats of the Yukon River Delta During June 12-19, 1986

Bottom Temper-ature (“C)	SurfaceTemperature (“C)										Total
	<0	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	>16	
<o					-						
0-2					8.2	27.2	12.9	2.7	5.4		56.5
2-4						16.3	0.0				16.3
4-6						8.2					8.2
6-8							0.0	16.3			16.3
8-10											0.0
10-12	-						2.7				2.7
12-14								0.0			0.0
14-16	-										
>1s											
TOTAL						8.2	51.7	15.6	2.7	21.8	-

TABLE 3-6

Percentage Adjusted Catch of Chinook Salmon Associated With Surface and Bottom Salinity in the Delta Front and Delta Platform Habitats of the Yukon River Delta During June 12-19, 1986

Bottom Salinity (ppt)	Surface Salinity (ppt)								Total
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	
0-5	0.0	-							0.0
5-10	2.6	-			-				2.6
10-15	-	-							
15-20	-	15.4	7.7						23.1
20-25	2.5	7.7	15.4						25.6
25-30	0.0	9.0	16.7	23.1					48.7
30-35	-	-							
35-40	-	-							
TOTAL	5.1	32.1	39.7	23.1					

TABLE 3-7

Percentage Adjusted Catch of Chinook Salmon Associated With Water Visibility in the Delta Front and Delta Platform Habitats of the Yukon River Delta During June 12-19, 1986

Visibility (m)	Adjusted Catch (Percent)
0.-0.1	----
0.1-0.2	0.3
0.2-0.3	7.1
0.3-0.4	----
0.4-0.5	6.2
0.5-0.6	10.7
0.6-0.7	21.4
0.7-0.8	11.6
0.8-0.9	11.7
0.9-1,0	----
>1.0	32.1

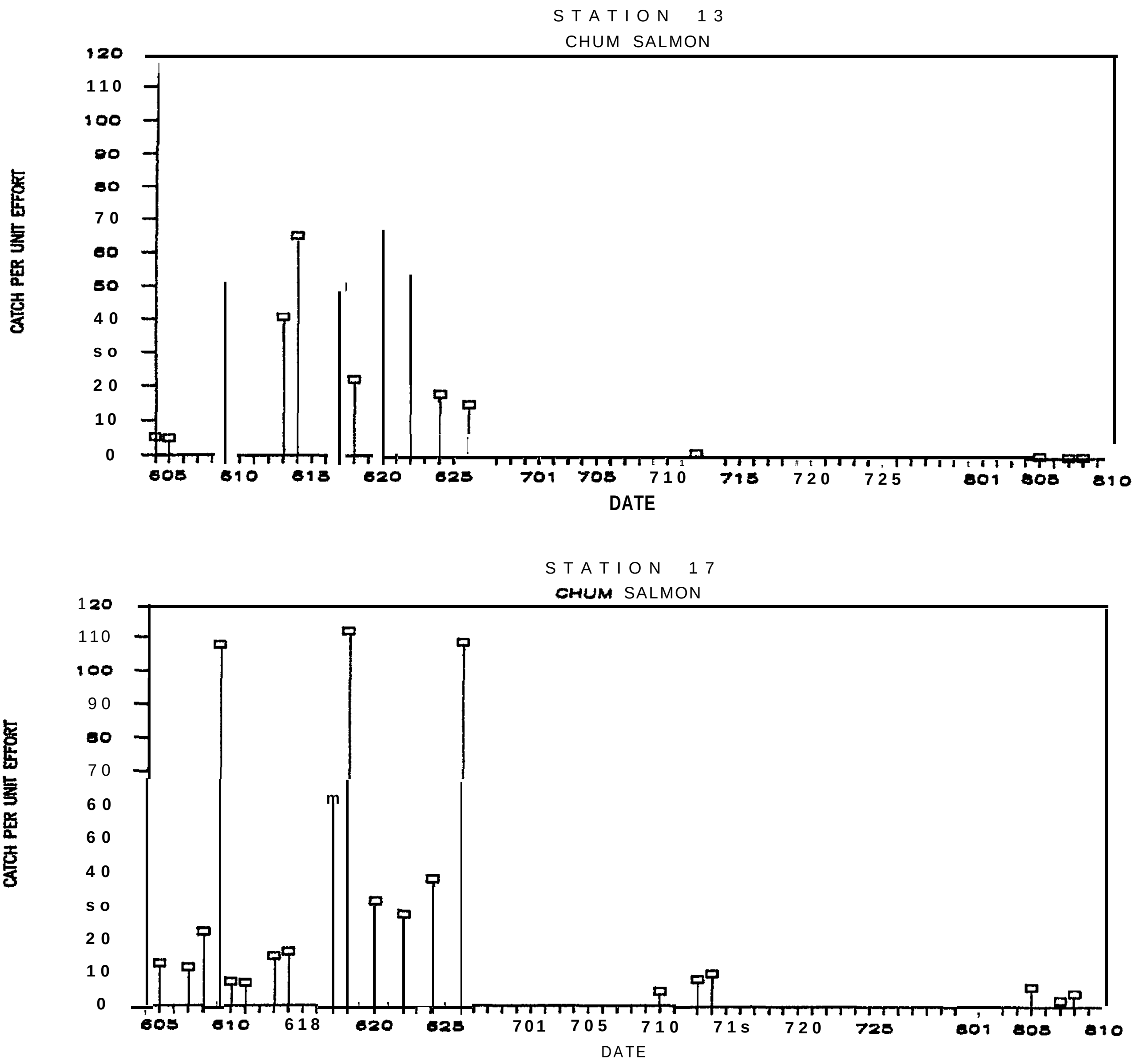

Fig. 3-14: Catch per unit effort of juvenile chum salmon during summer 1986, from the lower river, stations 13 and 17, of the Yukon River Delta.

during the first few days of sampling (i.e., May 31st and June 1st) (Appendix Table B). Catches were also low at the lower river stations during the first week of June. Catches increased greatly during the second week of June and CPUE fluctuated over a broad range during the remainder of the first survey period. Catches peaked three times at each station (i.e., stations 13 and 17), but the timing of the peak catches were not similar between both stations except for the first peak, which occurred on June 9th. During July and August, the CPUE at both sample stations was reduced to 10 or less fish and fluctuations were very small.

3.4.2 Distribution and Density

Juvenile chum salmon were caught in all five habitats during the summer, but the duration of fish occurrence was variable among habitats (Table 3-8). Fish were present in early June on the first date that each habitat was sampled. Juveniles were caught in the mudflat and tidal slough habitats for a short period during June and were caught in the delta front and delta platform habitats from early June to early August.

Densities of juvenile chum salmon were highly variable among habitats and over time (Table 3-8). Densities were an order of magnitude greater in the tidal slough (station 11) than at any other location. Densities peaked in the coastal habitats during mid-June and were highest in the offshore habitats during late June. During the period of peak density (i.e., 6/12 to 6/19), densities at the delta front showed a declining trend between stations 1 and 3. No trend was evident among delta platforms stations during the same time period.

3.4.3 Size Composition

Juvenile chum salmon ranged in length from 29 mm to 107 mm with the majority of fish being less than 70 mm (Appendix B). In the lower Yukon River at least three size groups were caught during the survey period (Figure 3-15). A group of large fish (i.e., group 1) with an

TABLE 3-8

Estimated Average Density (no/km^2) of Juvenile Chinook Salmon
During Summer 1986 in the Offshore, Coastal, and Lower River Habitats of the Yukon River Delta

	Habitat/Station																
	Delta Front				Delta Platform				Mudflats			Tidal Slough				Lower River		
Date	1			Mean	4			Mean	8		Mean	10			Mean	13		Mean
6/04	-	-	-		171a/	-	-	171								18Z4	-	
6/05	-	-	-		-	-	-	-								1710	4400	395Z
6/06	0	342a/	-	205	513a/	342a/	- 428	-									-	
6/07																	3990	3990
6/08																	7638	7638
6/09																18012	36936	27474
6/10									9092		9092	-	19481		19481		Z508	2508
6/11					-	-											2394	2394
6/12	6498	7182	1824	5168	4788	4446	342	3192										-
6/13									-						-	13908	5130	9519
6/14				-		-			12122		12122	-	426407		426407	22230	5586	16682
6/15	20634	0488	1254	10792	2052	11970	15390	9804										
6/17									0		0		0		0	17100	21318	19209
6/18	-			-				-								7524	38304	22914
6/19	16872	1172	9918	12654	9918	21774	6840	12844										-
6/20																23393	10830	18682
6/22									0		0		0		0	18810	9462	14136
6/24									3031		3031		0		0	604Z	13110	9576
6/25										0	0			0	0	-	-	
6/26																5016	37164	Z1090
7/10																	1482	1482
7/11	0		285(I	1710	171		0	86										
7/12									0		0		0		0	342	Z850	1596
7/13										0	0			0	0		34Z0	3420
7/14	456	114	114	228	114	0	456	190										
8/04									0	0	0		0	0	0	-	-	
8/05							-					0	-		0	228	2052	1140
8/06	0	228	0	76		0	114	57								-		
8/07																114	684	399
8/08																137	1368	684

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a/ Estimated from catches at stations, 21, 41, or 51.

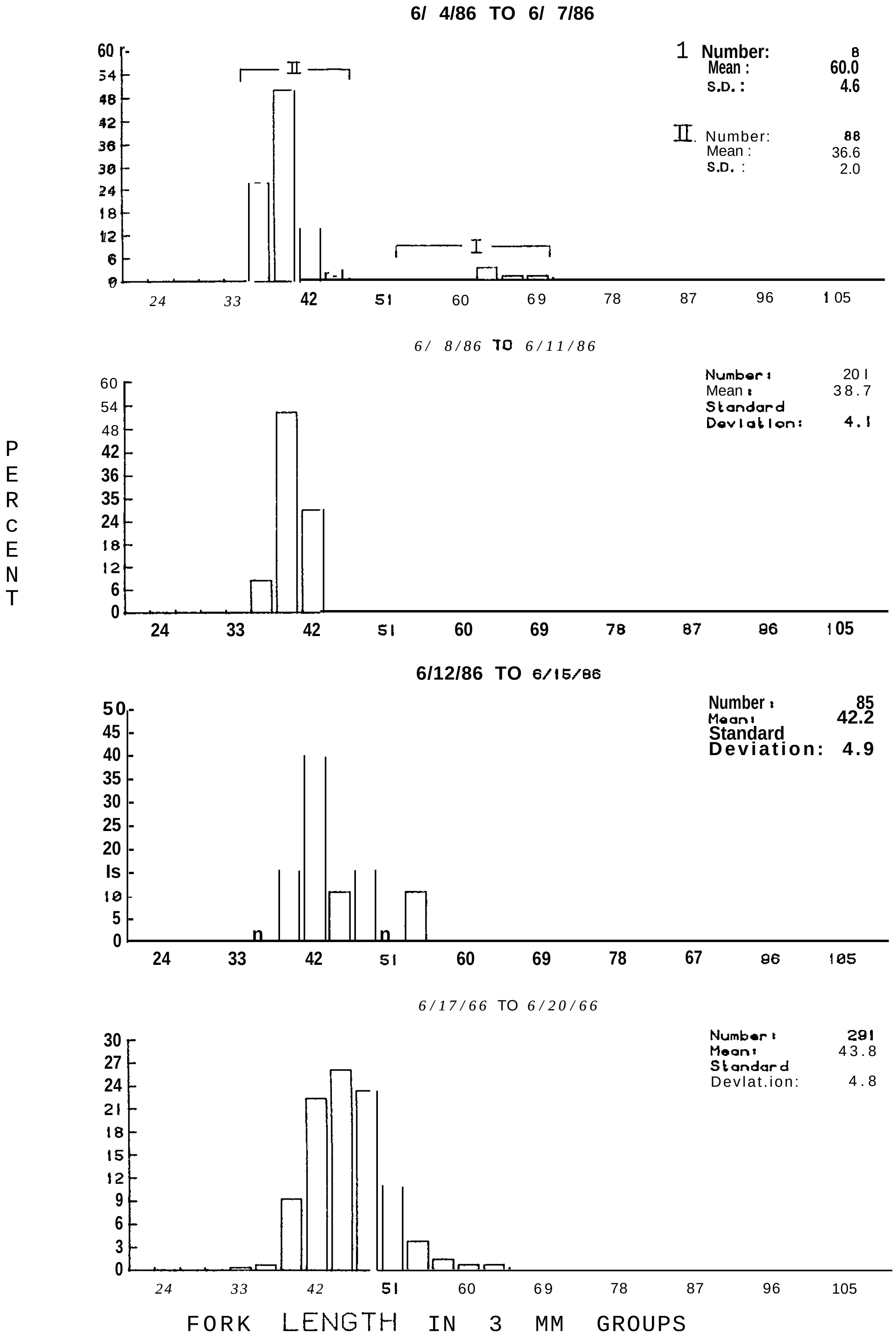

Fig. 3-15: Length frequency of juvenile chum salmon by time period during summer from the lower river, stations 13 and 17, of the Yukon River Delta.

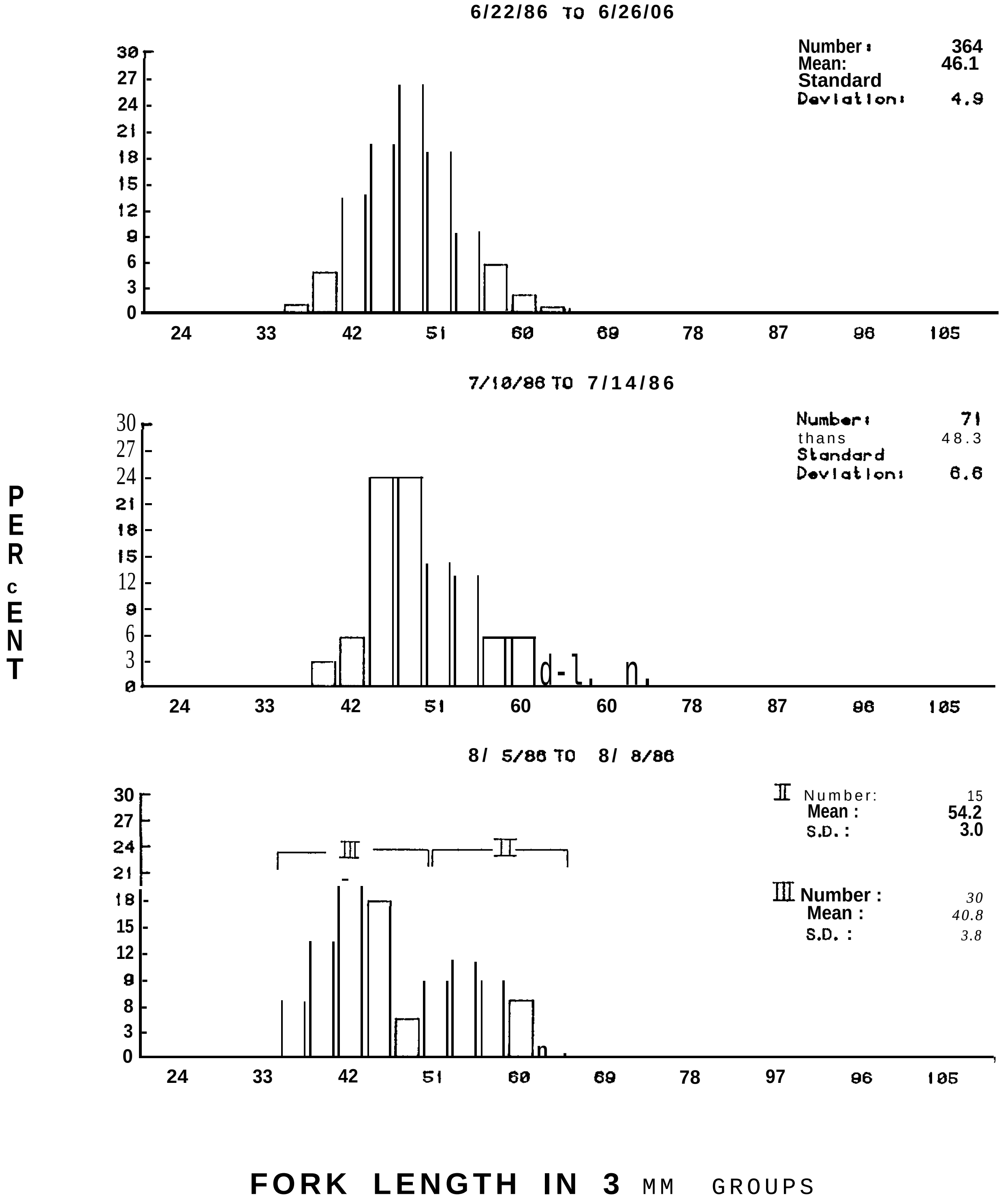

Fig. 3-15 (continued)

average length of 60 mm and a second group of smaller juveniles (i.e., group II) with an average length of 37 mm were caught during the first sample period. Size group I fish were not as abundant as fish from size group II and were not detectable in the catch after the June 20th sampling period. Size group II fish were present throughout the survey period and were identified as having an average length of 54 mm by the August sampling period. A third group of new smaller size fish with an average length of 41 mm were also caught during the August sampling period.

Size composition of juvenile chum salmon varied among different habitats during the same time period. The average size of fish in the lower river were slightly larger than fish from coastal or offshore habitats (Figures 3-16, 3-17, and 3-18). One size group of smaller fish were caught in the tidal slough and mudflat habitats (Figure 3-16, and Appendix B). Whereas, two size groups of fish were caught from the delta platform and delta front stations (Figure 3-16, and Appendix C). Also, several very large juveniles (i.e., 85, 93, and 107 mm fish, Appendix B) were caught from the offshore stations. but were not caught in the river.

3.4.4 Associated Environmental Conditions

Chum salmon environmental associations for temperature, salinity, and visibility are shown in Tables 3-9 to 3-11, respectively. Juvenile chum salmon catches were strongly associated with warm (i.e., 10-15"C) low salinity (i.e., <10 ppt) surface waters and stratified conditions. Catches were not associated with any particular water visibility level . Also, catches were highly variable among deep (i.e., delta front) and shallow habitats (i.e., delta platform and mudflat areas), which suggests that catches were not associated with any particular depth.

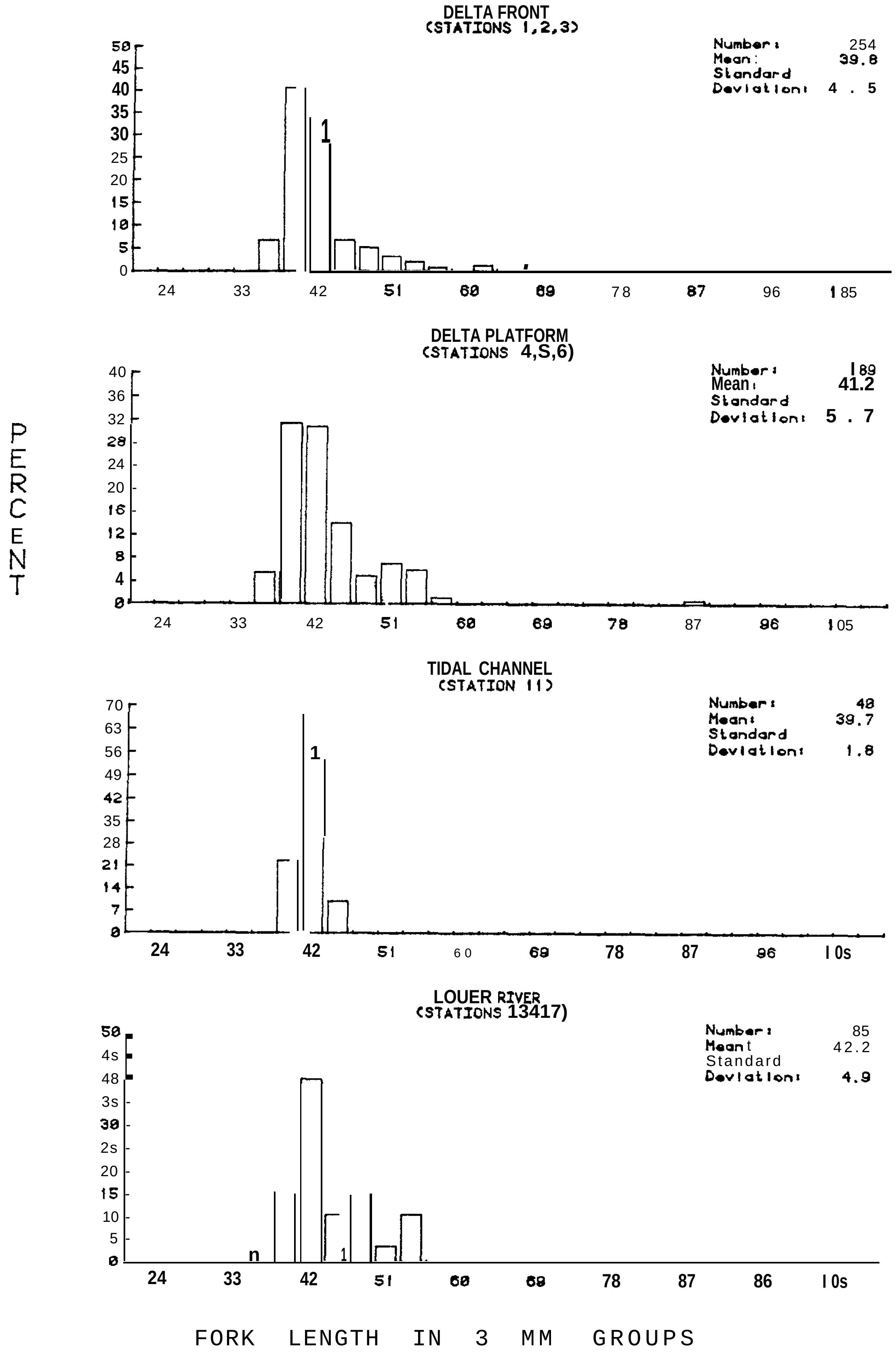

Fig. 3-16: Length frequency of juvenile chum salmon during the period 6/12/86 to 6/15/86 from offshore, tidal slough, and lower river habitats of the Yukon River Delta.

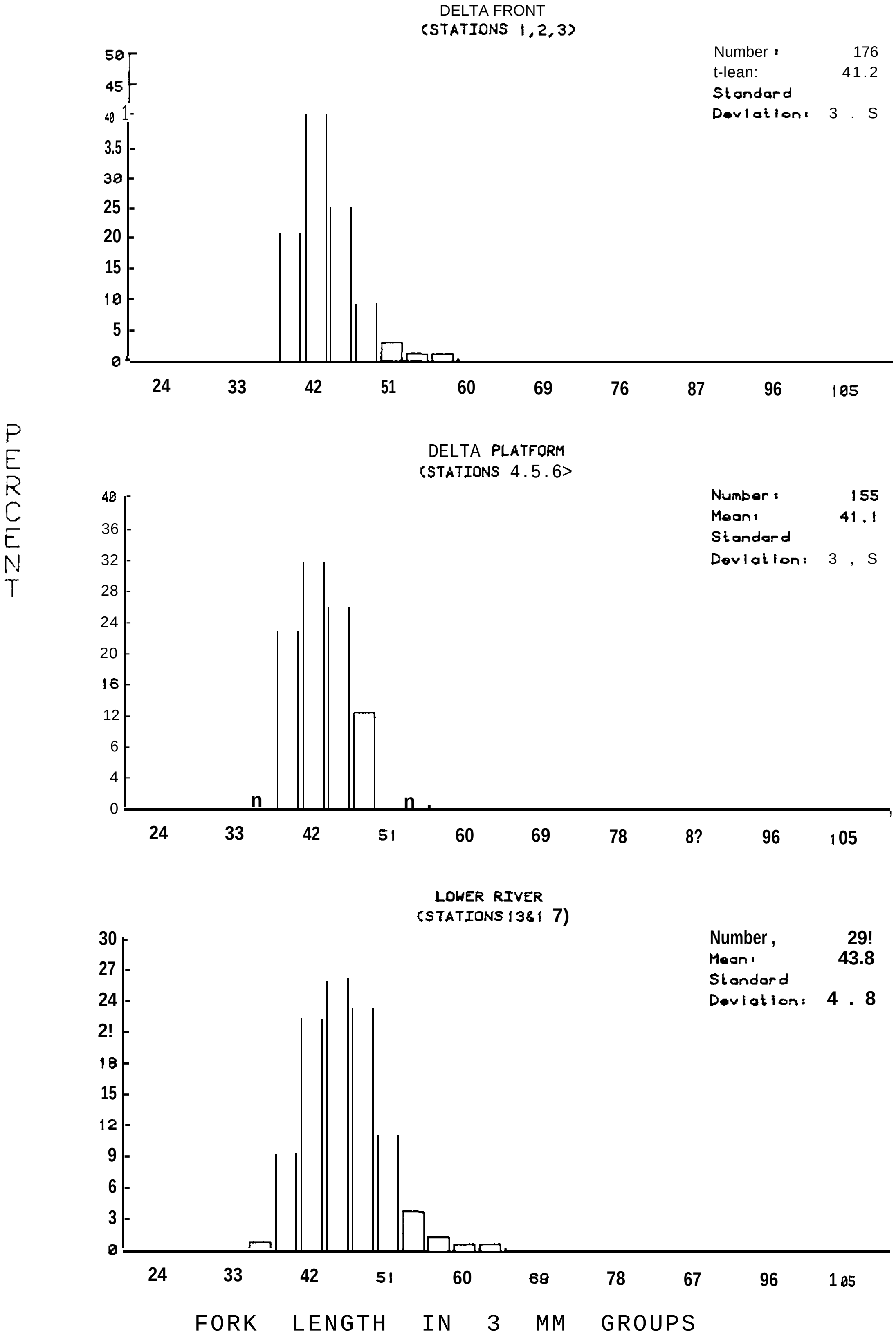

Fig. 3-17: Length frequency of juvenile chum salmon during the period 6/17/86 to 6/20/86 from offshore and lower river habitats of the Yukon River Delta.

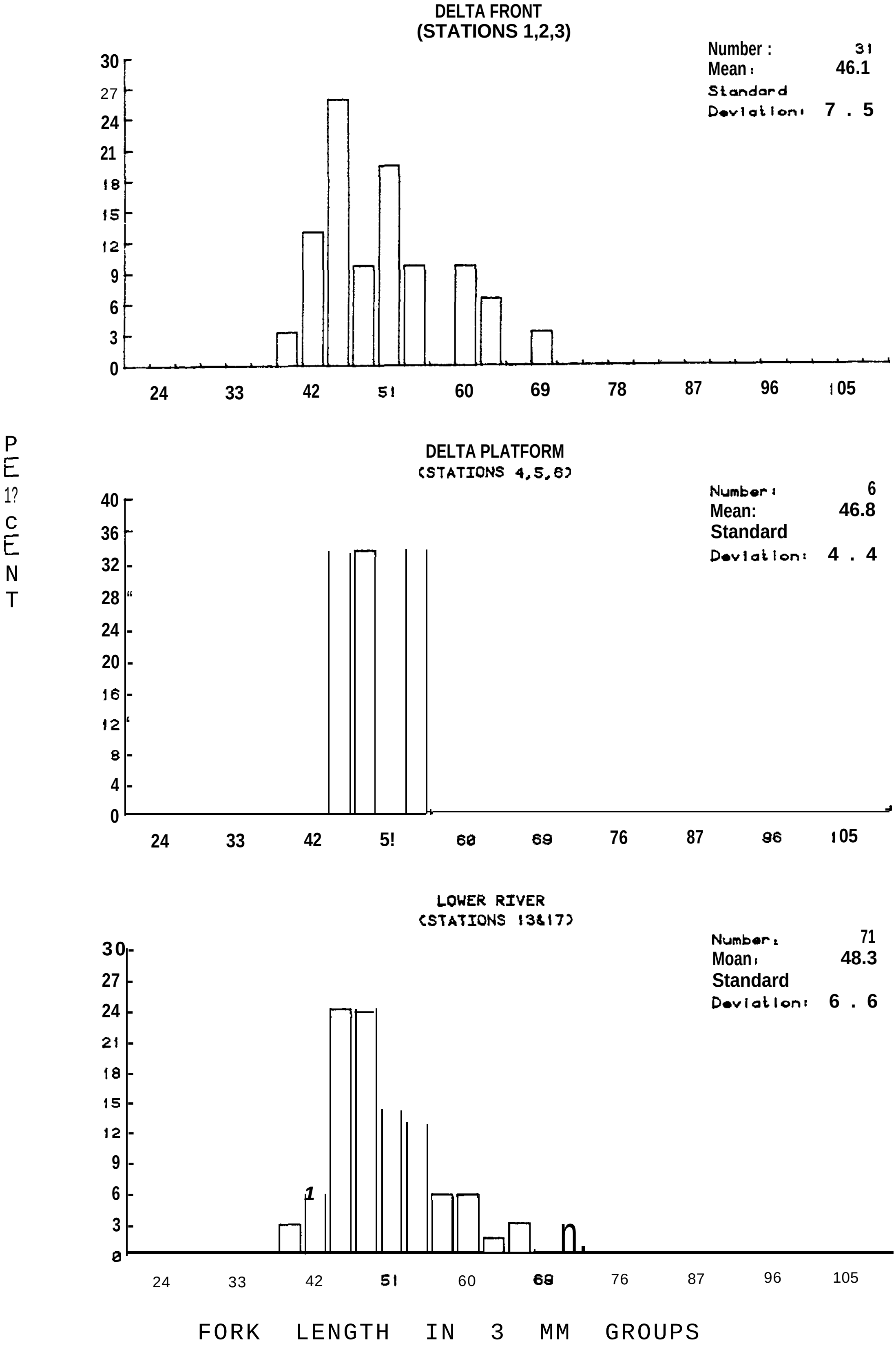

Fig. 3-18: Length frequency of juvenile chum salmon during the period 7/10/86 to 7/14/86 from offshore and lower river habitats of the Yukon River Delta.

TABLE 3-9

Percentage Adjusted Catch of Chum Salmon Associated With Surface and Bottom Temperature in the Delta Front and Delta Platform Habitats of the Yukon River Delta During June 12-19, 1986

Bottom Temper- ature (°)	Surface Temperature ("C)										Total
	<0	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	≥16	
<0											
0-2					5.3	1.5	4.9	16.8	8.5		37.0
2-4						1.7		8.1			9.8
4-6						3.9					3.9
6-8								13.7	9.8		23.5
8-10	-										
10-12	-						17.7				17.7
12-14	-							8.1			8.1
14-16	-										
≥16											
TOTAL	-				5.3	7.1	22.6	46.7	18.3		

TABLE 3-10

Percentage Adjusted Catch of Chum Salmon Associated With Surface and Bottom Salinity in the Delta Front and Delta Platform Habitats of the Yukon River Delta During June 12-19, 1986

Bottom Salinity (ppt)	Surface Salinity (ppt)								Total
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	
0-5	9.8								9.8
5-10	21.4								21.4
10-15									
15-20		11.8	4.7	-					16.5
20-25	16.6	4.4	2.0	-					23.0
25-30	10.4	13.7	4,1	1.2					29.4
30-35									
35-40									
TOTAL	58.2	29.9	10.8	1.2	-	-	-	-	

TABLE 3-11

Percentage Adjusted Catch of Chum Salmon Associated With Water Visibility in the Delta Front and Delta Platform Habitats of the Yukon River Delta During June 12-19, 1986

Visibility (m)	Adjusted Catch (percent)
0-0.1	----
0.1-0.2	6.2
0.2-0.3	23.4
0..3-0.4	----
0.4-0.5	12.7
0.5-0.6	9.9
0.6-0.7	26.7
0.7-0.8	3.7
0.8-0.9	14.5
0.9-1.0	----
>1.0	2.8

3.4.5 Otolith Microstructure and Increment Periodicity

Sample Composition

Otoliths were extracted from 491 fish for examination of microstructure. The sampled fish ranged in length from 33.0 mm to 68.4 mm and were representative of specimens collected from 11 stations on 16 separate dates. Among all the specimens examined, 109 (22 percent) had otolith preparations from which no data could be collected, 19 (4 percent) had inherent problems in the physical structure of the otolith which also prevented data collections, and 24 (5 percent) were lost during dissection or preparation. Thus, 339 (69 percent) otoliths remained, upon which the results of this study were based.

Among the specimens examined, the number of post-hatching otolith increments ranged from 11-59 with a mean of 25.1 (Figure 3-19). There was a positive relationship between fish length and the number of post-hatch otolith increments (Figure 3-20).

Otolith Increment Periodicity

A key element in these otolith analyses was the ability to determine elapsed time by counting otolith increments produced with a known periodicity. To determine this periodicity, we analyzed otoliths from fish held in net pens to test the relationship between increments accrued and days elapsed during the experiment. The number of increments accrued was determined from the difference in the mean number of increments for fish collected at the start and at the end of a six-day holding period. Experimental results are shown in Table 3-12.

The results from each fish holding experiment were grouped according to the size of the test fish because differences in fish size affect increment number as shown in Figure 3-20. Changes in increment number can only be evaluated in three of the experimental groups where differences in fish size were not significant (Table 3-ii?).

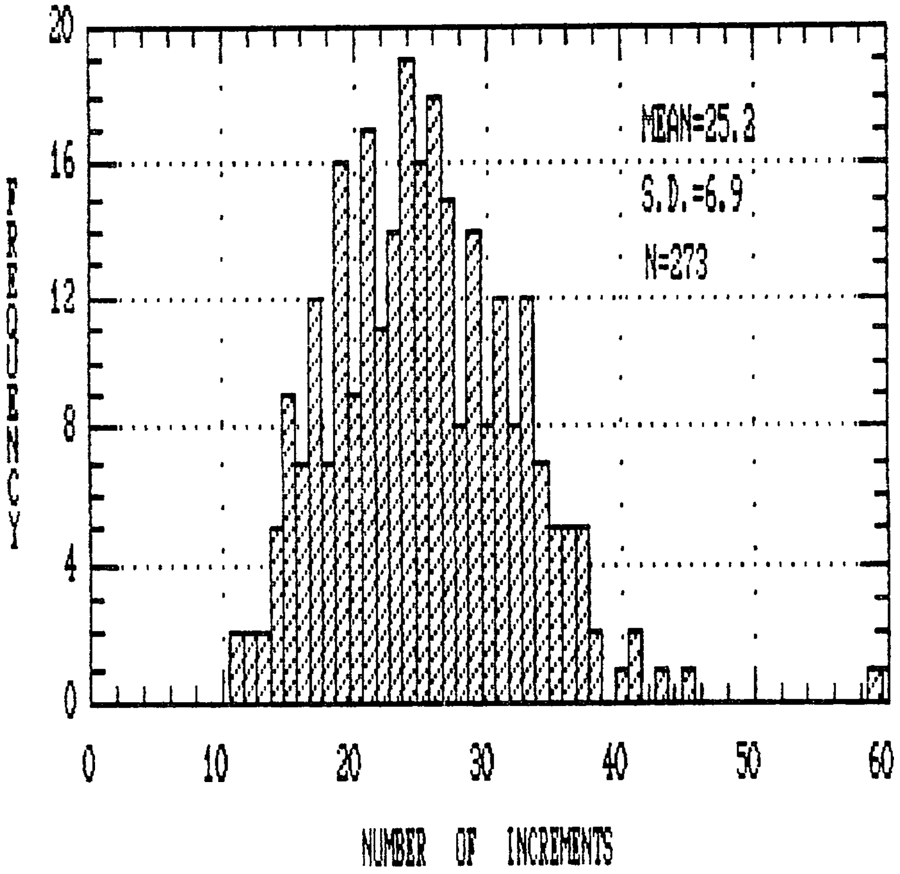

Fig. 3-19: Post-hatching otolith increment frequency for chum salmon collected during summer 1986 from the Yukon River Delta.

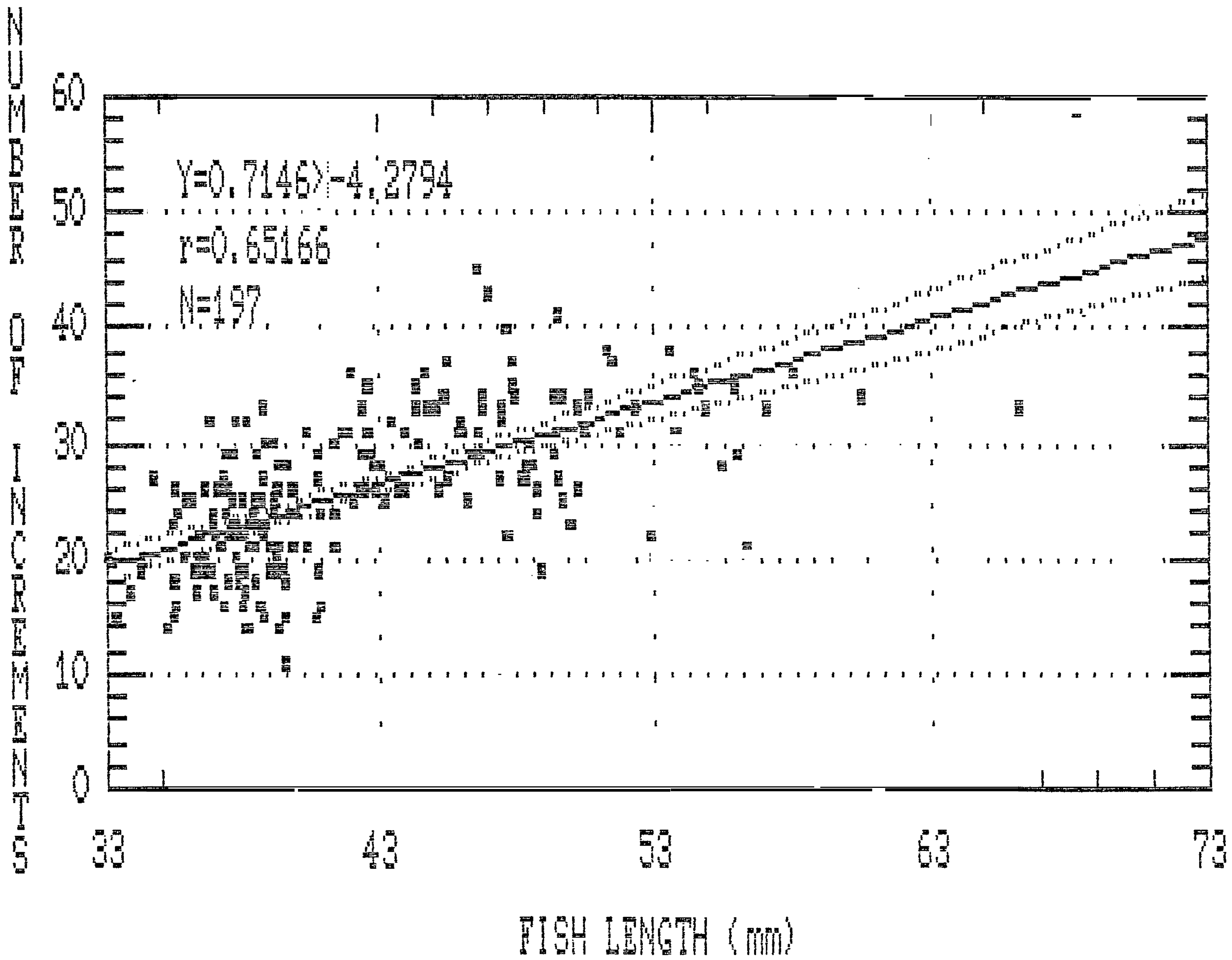

Fig. 3-20: Regression of post-hatch otolith increment number on length of chum salmon.

TABLE 3-12

Results of T-Tests on Fish Length and Otolith Increment Number, and Estimated Increment Periodicity For Chum Salmon From the Fish Holding Experiments

			Fish Length				Increment Count				
Experiment	Beginning or Ending Date	Sample Size	Range	Mean	S.D.	Signif. of t	Range	Mean	S.D.	Signif. of t	Periodicity (d/increment)
1a	6-14-86	24	34-52	40.1	4.6	0.469	14-33	22.6	5.5	0.019	1.6
	6-20-86	13	39-43	41.1	1.6		21-36	26.4	4.2		
1b	6-14-86	8	39-41	39.6	0.6	0.679	17-28	22.0	5.2	0.077	1.5
	6-20-86	7	39-41	39.8	0.9		23-36	25.9	4.6		
2a	6-20-86	23	38-55	44.3	4.5	0.014	4-33	24.0	5.4	0.004	0.8
	6-26-86	6	48-51	49.3	1.4		9-42	32.0	8.7		
2b	6-20-86	5	48-52	49.5	1.9	0.814	20-27	24.0	2.9	0.042	0.8
	6-26-86	6	48-51	49.3	1.4		19-42	32.0	8.7		

Results from the t-test on increment number (Table 3-12) indicate there was a significant increase ($p \leq 0.05$) in two of the test groups (i.e., la and 2b). Mean increment number increased by 3.8 or 8 increments, depending on experimental group, during the six day experimental period. This increase results in an increment periodicity that ranges from 0.8 to 1.6 d/increment. This large variation between the two experiments may be a function of the different size groups of fish that were tested.

In order to provide a better understanding of the potential effects of fish size or life stage on increment periodicity, an estimate of increment periodicity for alevins was examined. In this method incremental periodicity is assumed to be equal to the quotient of the number days between hatching and emergence; and the number of post-hatch otolith increments at the time of emergence. Studies conducted by Trasky (1974) and Francisco (1976, 1977) concerning the development of fall chum salmon in the Delta River (a tributary to the Yukon River) found that the time period from hatching to emergence ranged 25-48 days and averaged 39 days at temperatures ranging 1.1-1.5°C. Bakkala's (1970) comprehensive review of chum salmon studies indicated a period of 30 to 50 days, depending on water temperature, was needed for development. The temperature regime during the alevin stage for most Yukon chum is likely to be within the range observed in the Delta River. Therefore, a period of 40 days was assumed to be the most reasonable period for alevin development. The number of otolith increments at emergence was determined from the otolith data. Several studies on the early development of fall chum salmon from Yukon River tributaries found that most fry emerge at lengths of 31-36 mm (Raymond 1981, Francisco 1977, and Francisco and Dinneford 1977). Fifteen chum otoliths were examined from fish that were ≤36 mm. The number of post-hatch increments in these fish ranged 14-27 with an average of 19.8. Therefore, based on this data the increment periodicity during the alevin stage is estimated to be at least 2 days (i.e., 40/19.8 = 2.02). A greater increment periodicity is possible because all of the fish that were examined were button-up-fry which had emerged at some earlier date. Thus the average number of post-hatch increments at emergence was most likely less than the number observed from button-up-fry. These data also show that daily increments at this life stage are highly unlikely, because development time from hatching to emergence requires more than 14-27 days.

3.4.6 Residency

The primary purpose of the otolith study was to measure the time elapsed after an individual fish reached the estuary in order to provide an estimate of residency. This would be accomplished by counting the number of otolith increments that are formed after the point of transition from freshwater growth to estuarine growth. The product of this count and the increment periodicity would be equivalent to the duration of estuarine utilization. The criterion for determining the beginning of estuarine residency was identified by Volk et al. (MS) and Neilson et al. (1985) as the region in which there was a step-wise increase in increment width near the edge of the otolith compared to the width of previous increments. This change in increment width was associated with an increase in growth rate, which corresponded with entry into an estuary.

Otoliths from juvenile chum salmon that were caught on the delta platform and delta front were examined for the presence of changes in increment width. This examination was focused on the outermost 16 post-hatch increments because this region of the otolith would have been formed during the last 13 to 26 days (assuming increment periodicity of 0.8 or 1.6, Table 3-12) before fish capture (Figure 3-21). A one-way analysis of variance test of increment width by increment number indicated no significant difference ($p \leq 0.05$) in increment width. Therefore, no transition in increment width could be identified and estimates of estuarine residency, if any, could not be determined from the otolith data.

The relative age of the juvenile outmigrant chum that utilize each habitat can be determined from the number of post-hatch increments if we assume that all fish had a similar history of changes in increment periodicity. A comparison of mean increment number for fish among different habitats during the peak outmigration period indicates that

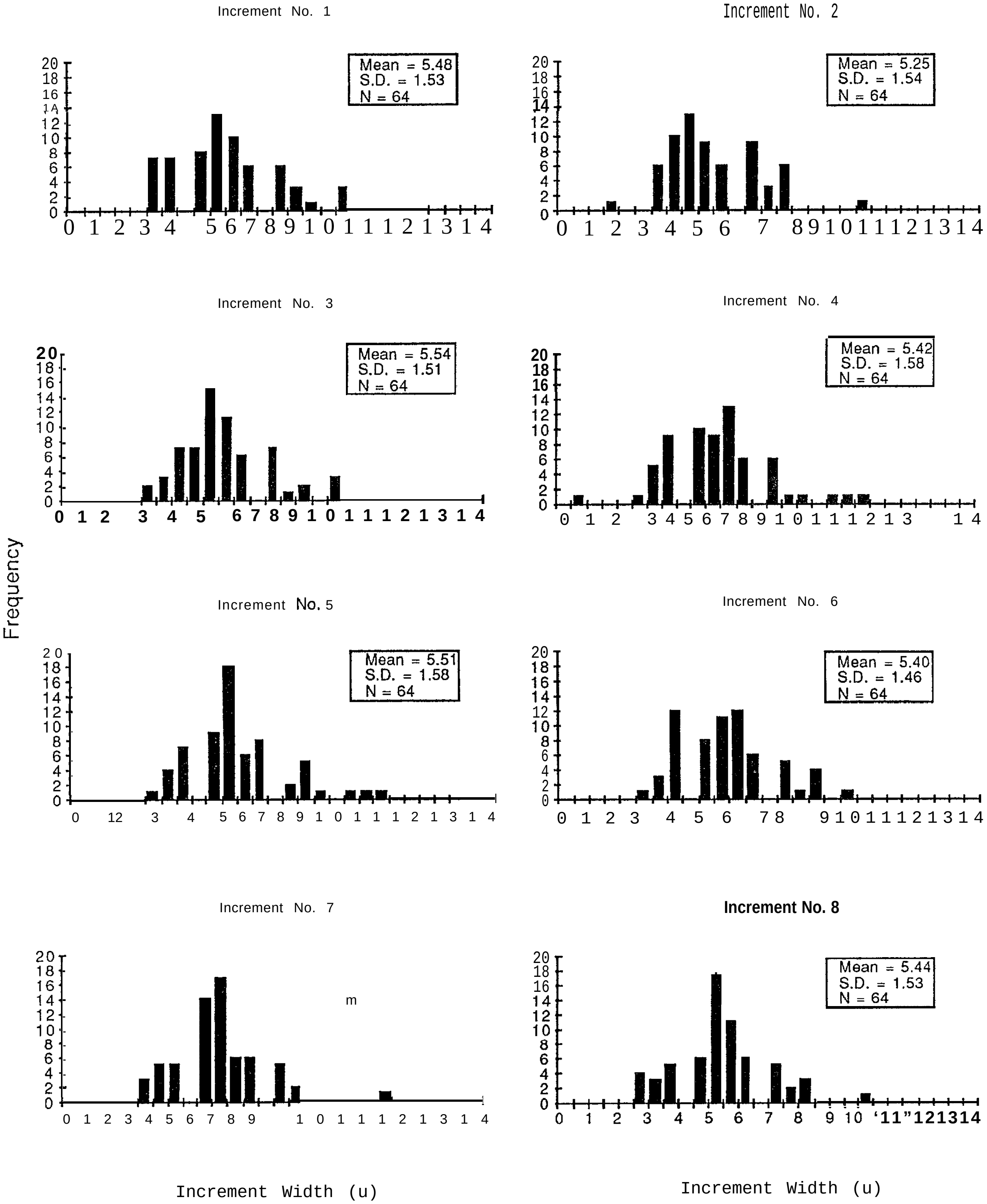

Fig. 3-21: Frequency histograms and statistics of otolith increment widths for 16 outer increments from chum salmon caught in the delta platform and delta front of the Yukon River Delta.

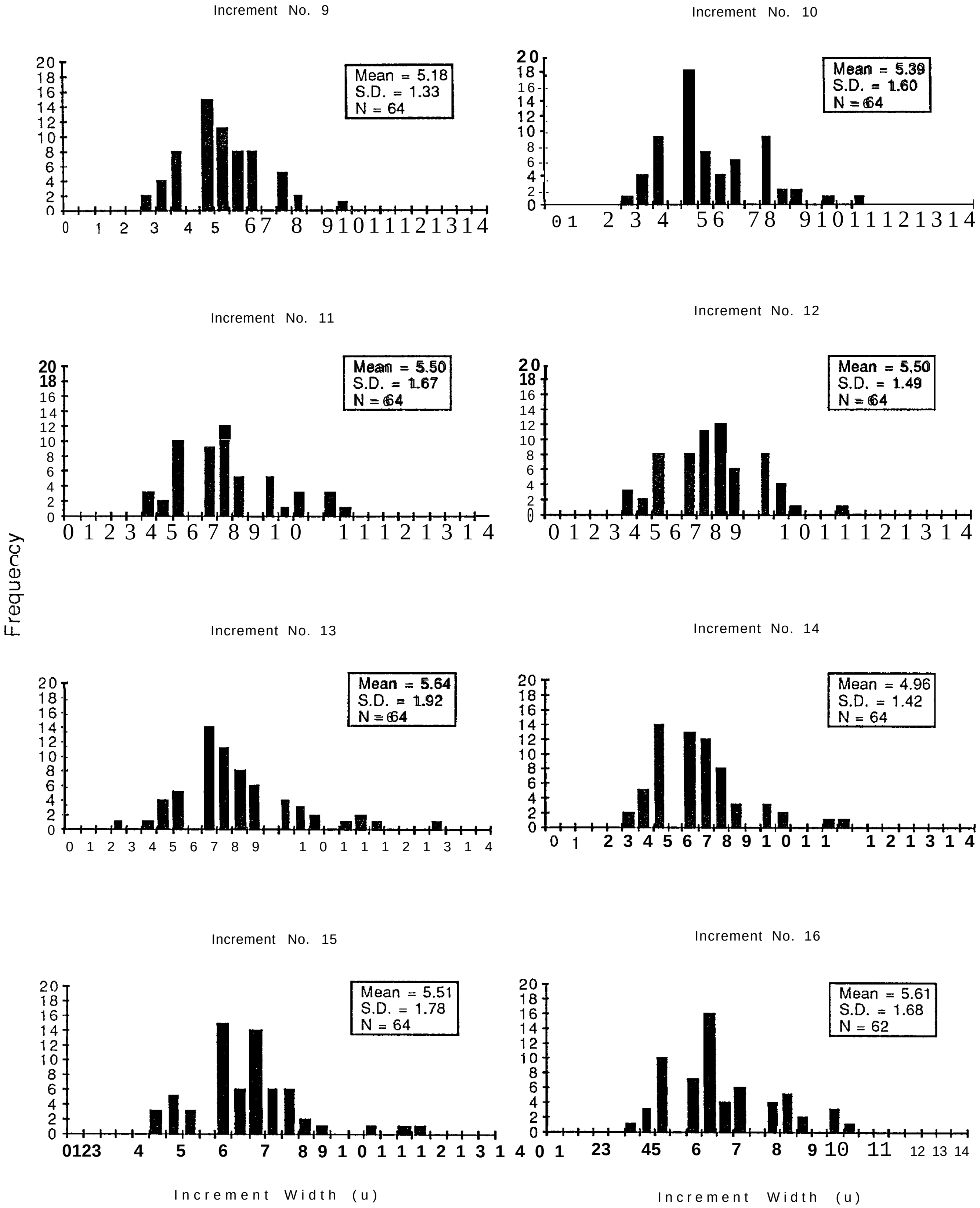

Fig. 3-21, continued.

fish in the lower river have significantly more ($p \leq 0.05$) increments than fish in the nearshore and offshore habitats (Table 3-13). This suggests that juvenile chum in the lower river are approximately 6 to 11 days older (assuming increment periodicity is either 0.8 or 1.6 from Table 3-12) than juveniles in other habitats.

3.4.7 Growth

Three size groups of juvenile chum salmon were identified in the lower river during the outmigration period (see Section 3.4.1). Fish in size groups I and III (Figure 3-15) were caught only during early June or early August, respectively. Therefore, fish length data were insufficient to make any estimates of growth rate for these two groups. Fish in size group II, however, were present throughout the three sample surveys (Figure 3-15). Outmigrants averaged 36.8 mm in early June and 54.2 mm in early August. A regression of fish length by time after the first sample date indicates the population growth rate was 0.31 mm/day during the outmigration period (Figure 3-22). This growth rate is most likely biased on the low side of true growth rate because of immigration and emigration, to and from the study area, respectively. Also, the validity of this growth rate is based on the assumption that group II fish all hatched at approximately the same time.

3.5 OTHER FISHES

Catch results for sheefish, whitefish, cisco, smelt, and herring are presented in this section because these species are considered important for either commercial or subsistence fisheries. Catch results for other lesser important species are only presented in Appendix Table B.

TABLE 3-13

Mean and 95 Percent C.I. of Otolith Increment Number For Juvenile Chum Salmon By Habitat and Results of a Multiple Range Test on increment Number Among Habitats. Data From the Period of Peak Outmigration, June 10-24, 1986

Location	Stations	N	Mean	95 Percent C.I.	Similarity[a]	
Tidal Channel	11	16	19.9	17.7-22.1	x x	
Delta Front	4,5	30	20.1	18.1-22.1	x x	
Delta Platform	1,3	23	21.2	19.7-22.7	x x	
Lower River	13, 17	39	27.0	24.8-29.3		x

---

[a] Non-overlapping x's indicate groups that are significantly different at the 0.05 level. Data was tested by the Student Newman Keuls Procedure.

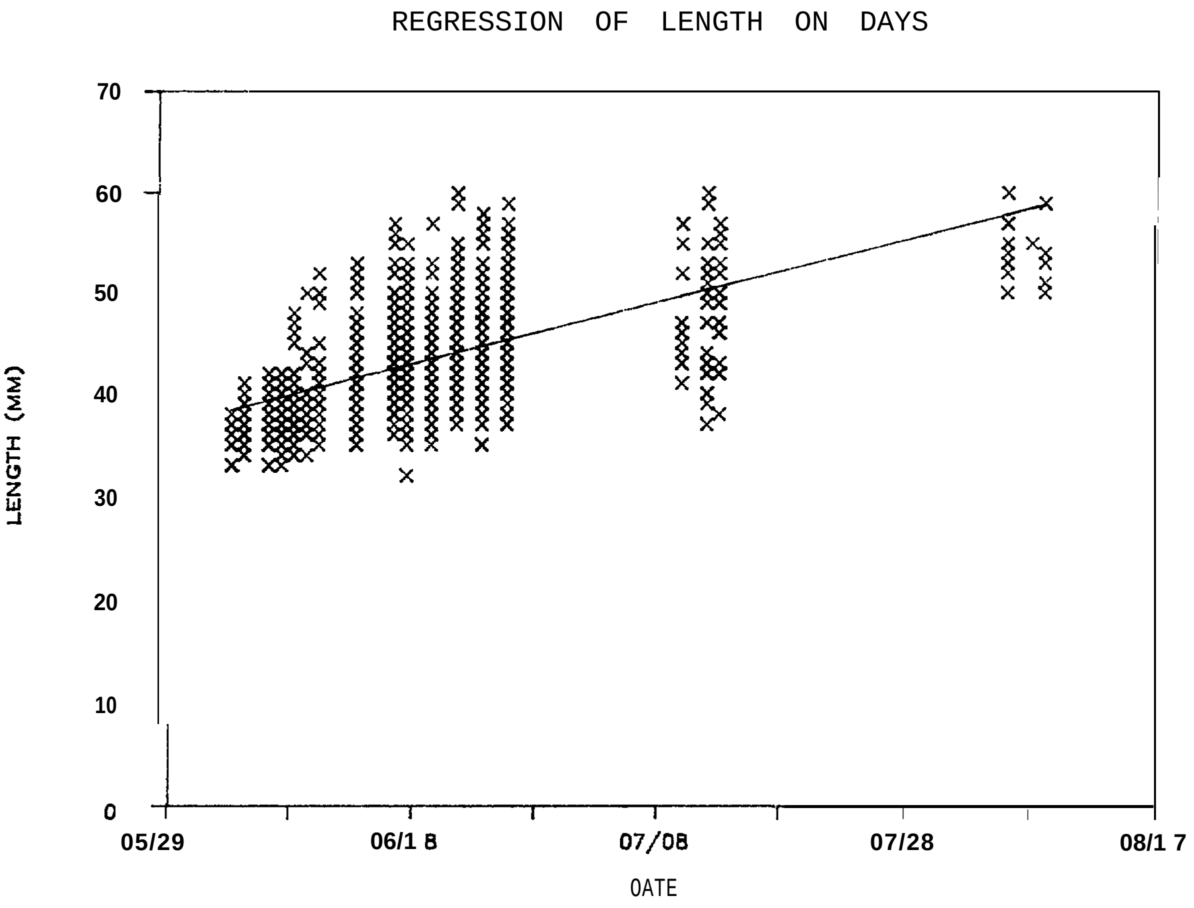

Fig. 3-22: Plot of length with time for juvenile chum salmon caught in the lower Yukon River (i.e., stations 13 and 17, Group II) during summer 1986. Line fitted by regression where y = 37.16 + 0.31x, N= 1107, r= 0.58.

3.5.1 Migration Timing

Juvenile sheefish, juvenile whitefish, and juvenile cisco were the only important anadromous species that were caught in significant numbers in the lower river (Table 3-3). Smelt are also anadromous, but no juveniles were caught in the lower river during the three sample surveys. The timing of the juvenile outmigration of coregonids was similar among all three species (Figure 3-23). Low numbers of fish were caught during June and August and peak catches occurred during the July survey. Juvenile cisco were approximately three times more abundant than juvenile sheefish and juvenile whitefish.

3.5.2 Distribution and Density

Cisco's were the most broadly distributed of all the coregonid fishes that were caught during 1986 (Tables 3-14, 3-15, and 3-16). High densities of cisco were found in both coastal and offshore habitats. Whereas, sheefish and whitefish were more concentrated in the coastal habitats. Sheefish had the most restrictive distribution with most fish occurring at the mudflat stations. Their temporal distribution and abundance were not directly related to the July outmigration period since many older individuals of each species were caught during the June survey. Whitefish were generally the most abundant of the coregonid fishes with mean habitat density ranging up to 43,000/km.

Boreal smelt, juvenile smelt, and Pacific herring were caught predominantly at the delta front and delta platform stations (Table 3-3). Boreal smelt were caught only during the June survey, whereas, juvenile smelt were most abundant during the July and August surveys (Table 3-17). Juvenile smelt densities ranged up to $300{,}000/km^2$, which is the highest density of any species caught from the offshore habitats. Pacific herring were caught during all surveys and were most abundant at the delta front during July.

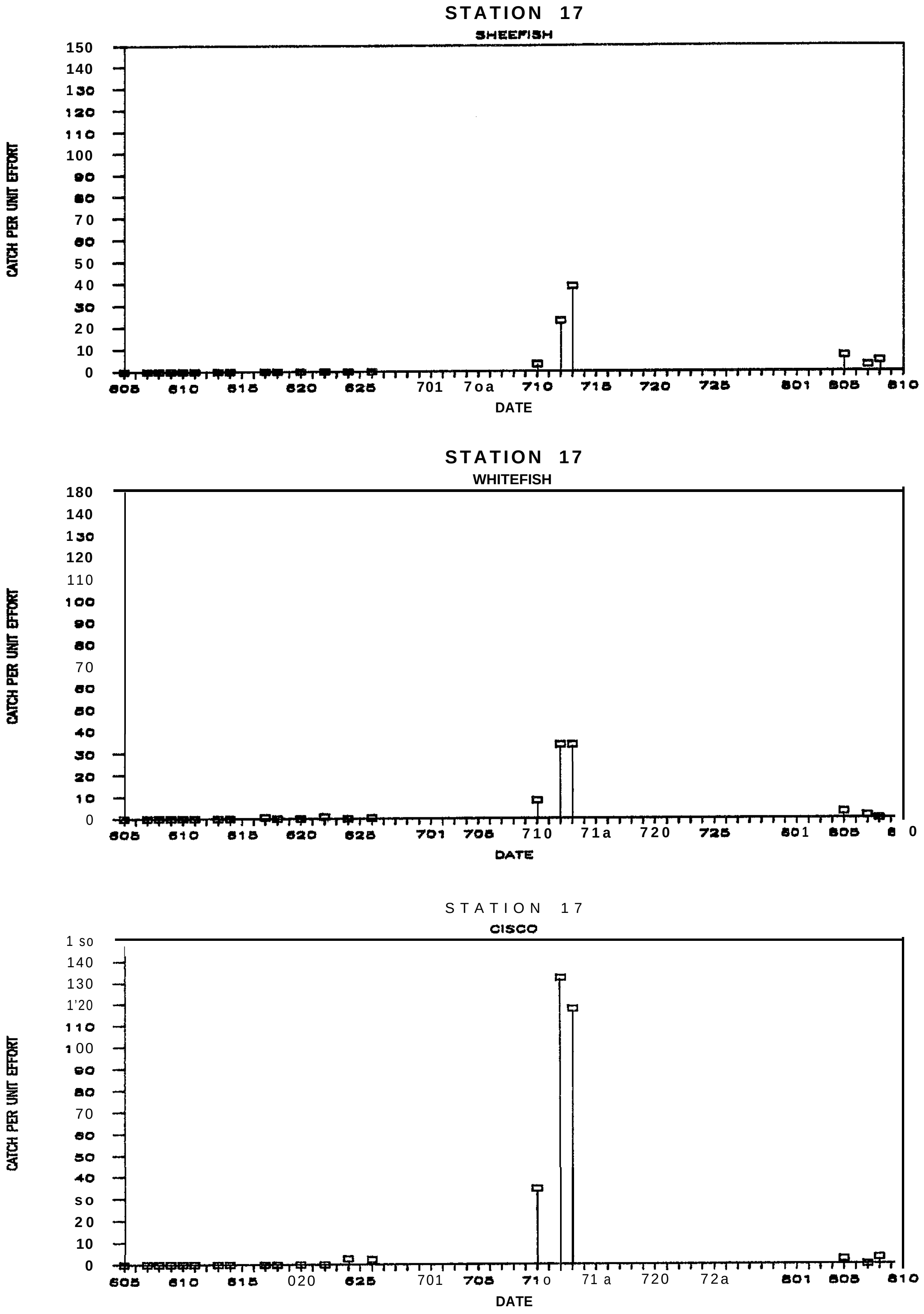

Fig. 3-23: Catch per unit effort of juvenile sheefish, juvenile whitefish, and juvenile cisco during summer 1986, from the lower river, station 17, of the Yukon River Delta.

TABLE 3-14

Estimated Average Density (no/km^2) of Sheefish During Summer 1986 in the Offshore, Coastal, and Lower River Habitats of the Yukon River Delta

	Habitat/Station																	
	Delta Front				Delta Platform				Mudflats			Tidal Slough				Lower River		
DATE	1	2	3	Mean	4	5	6	Mean	8	9	Mean	10	11	12	Mean	13	17	Mean
6/04					171		-	171								0		0
6/05							-									0	0	0
6/06	U	0		0	u	0	-	0										
6/07							-										0	0
6/08							-										0	0
6/09							-									0	0	0
6/10							-		3031		3031		0		0		0	0
6/11							-										0	0
6/12	U	U	0	0	u	0	0	o										
6/13							-									0	0	0
6/14							-		15153		15153		0		0	0	0	0
6/15	0	0	0	U	0	0	0	0										-
6/17							-		6061		6U61		2165		2165	0	0	0
6/18							-									0	0	0
6/19	0	0	0	0	0	0	0	u										
6/20							-									0	0	0
6/22'							-		18183		18183		0		0	0	0	0
6/24							-		3031		3031		0	-	0	0	0	0
6/25							-			3031	3031			0	0			
6/26							-									0	0	0
7/10							-	-									1140	1140
7/11	0		0	U	171		171	171										
7/12							-		9092	-	9092		0		0	342	7866	4104
7/13			-		-	-	-	-	-	12122	12122			0	0	-	13224	13224
7/14	U	0	114	38	114	342	1140	532										
8/04							-		0	87885	43942	-	8658	0	4329	-	-	-
8/05							-					0			0	228	2394	1311
8/06	U	0	U	0		0	0	0										-
8/07							-									570	912	741
8/08							-									274	1625	874

TABLE 3-'5

Estimated Average Density (no/km^2) of Whitefish (i.e., Humpback Whitefish and Broad Whitefish) During Summer 1986 in the Offshore, Coastal, and Lower River Habitats of the Yukon River Delta

	Habitat/Station																	
	Delta Front				Delta Platform				Mudflats			Tidal Slough				Lower River		
Date		2	3	Mean	4	5	6	Mean	8	9	Mean	10		2	Mean	3	7	Mean
6/04	-	-	-	-	285	-	-	285	-	-	-	-	-	-	-	0	-	0
6/05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	61	-
6/06	0	0	-	0	1083	0	-	542	-	-	-	-	-	-	-	-	-	-
6/07			-	-			-	-	-	-	-	-	-	-	-	-	0	0
6/08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
6/09	-	-	-	-	-	-	-	-							-	0	0	0
6/10	-	-	-	-	-	-	-	-	8 83	-	8 83	-	4329	-	4329	-	0	0
6/11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
6/12	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-
6/13	-	-					-	-			-	-	-	-	-	0	0	0
6/14	-	-	-	-	-	-	-	-	11112	-	2	-	0	-	0	0	0	0
6/15	0	0	0	0	0	0	0	0	-	-	-	-	-	-			-	-
6/17							-	-	4041	-	4041	-	7215	-	7215	0	76	38
6/18									-	-	-	-	-	-	-	76	0	38
6/19		0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-
6/20			-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
6/22	-	-	-	-	-	-	-	-	11112	-	11112	-	2165	-	2165	0	4	57
6/24	-	-	-	-	-	-	-	-	17173	-	17173	-	2886	-	2886	0	0	0
6/25	-	-	-	-	-	-	-	-	-	43437	43437	-	-	476 9	47619	-	-	-
6/26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	38	19
7/10					-	-	-	-	-	-	-	-	-	-	-	-	ᴲ50	950
7/11	0	-	5≈	ᴲ	0	-	0	0										
7/12					-	-	-	-	242*4	-	24244	-	2886	-	2886	304	3838	2071
7/13					-	-			-	4041	4041	-	-	5772	5772	-	3838	3838
7/14	0	0	0	0	38	0	0	3	-	-	-	-	-	-	-	-	-	-
8/04	-	-	-	-	-	-	-	-	63	68691	42427	-	6595	≈ 65	9380	-	-	-
8/05	-	-	-	-	-	-	-	-			-	28139	-	-	28139	0	342	1
8/06	0	0	0	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-
8/07	-	-	-	-	-	-			-	-	-	-	-	-	-	0	152	76
8/08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	≈3	0	13

TABLE 3-16

Estimated Average Density (no/km^2) of Cisco (i.e., Least Cisco and Bering Cisco) During Summer 1986 in the Offshore, Coastal, and Lower River Habitats of the Yukon River Delta

	Delta Front				Delta Platform				Mudflats			Tidal Slough				Lower River		
Date	1	2	3	Mean	4	5	6	Mean	8	Y	Mean	10	11	12	Mean	13	17	Mean
6/04					**2280**			2280								0		0
6/05																0	15	
b/06	0	u		0	**3078**	0		1539										
6/07																	0	0
6/08																-		0
6/09									-	-	-	-	-	-	-	38	19:	114
6/10									12122	-	12122	-	722	-	722		0	0
6/11																	0	0
6/12	0	0	0	0	0	76	418	165										
6/13															-	38	0	19
6/14									6061	-	6061		8658	-	8658	38	0	25
6/15	0	0	0	0	0	38	874	**304**		-					-		-	
6/17									2020	-	2020		5051	-	5051	0	0	0
6/18								-								0	0	0
6/19	0	u	76	25	0	0	38	13										
6/20																0	0	0
6/22									6061	-	6061		5772	-	5772	0	0	0
6/24									7071	-	7071	-	0	-	0	0	380	190
6/25									-	24244	24244	-		0	0			
6/26																190	266	228
7/10																	3952	3952
7/11	1938		17062	11012	**3135**		34257	18696				-						-
7/12									1010	-	1010	-	2886	-	2886	14934	15086	15010
7/13									-	9092	9092		-	17316	17316		13414	13414
7/14	1444	3268	988	1900	**3458**	3382	2318	**3053**										
8/04									0	21214	10607	-	1443	1443	1443			
8/05	-											722			722	76	266	171
8/06	38	38	38	38		418	76	247									-	
8/07																190	266	228
8/08		-														91	342	203

TABLE 3-17

Estimated Average Density (no/km^2) of Boreal Smelt, Smelt sp., and Pacific Herring During Sumner 1986 in the Delta Front and Delta Platform Habitats of the Yukon River Delta

	Boreal Smelt								smelt Sp.								Pacific Herring							
	Delta Front				Delta Platform				Delta Front				Delta Platform				Delta Front				Delta Platform			
Date	1	2	3	Mean	4	5	6	Mean	1	2	3	Mean	4	5	6	Mean	1	2	3	Mean	4	5	6	Mean
6/04	-	-	-		22059	-	-	22059	-				0	-	-	0	-				0			0
6/05	-	-	-	-	.	.	.							-	-	.								
6/06	o	o	-	0	48906	1539	-	25223	2565	0	-	1026	0	0	-	0	0	1824		1094	0	171		86
6/07	.	.	.	.	-	-	-			.	-	.		-	-				-	.			-	
6/08	-	-	-		-	-	-	.						-	-	-			-			.		
6/09	-	-	-		-	-	-		.					-	-		-			-				
6/10	.	.	.		--		.	.	.	.				-	-						.	.	-	-
6/11	-	-	-		--		-		.					-	-									
6/12	114	0	0	38	0	228	27360	9196	0	0	0	0	0	0	0	0	0	0	114	38	114	684	2508	1102
6/13	--		-		-	-	-	.						-	-		.							
6/14	-	-	-	.	-	-	-				.			-	-			.	.			.		
6/15	114	228	0	114	0	456	0	152	0	0	0	0	0	0	20976	6992	0	798	0	266	0	2736	6042	2926
6/17	--		-		-	-	-							-	-									
6/18	-	-	-		-	-	-							.	-	-								
6/19	38190	16644	2736	9190	46512	72162	97242	71972	0	0	0	0	0	0	0	0	1254	6384	1026	2888	0	228	0	76
6/20	--		-		-	-	-	.						-	-	-								
6/22	-	-	-		.	.	.					.	-	-	-	-			.	.	.	.		
6/24	-	-	-		.	.	.						.	.	.	-					.	.		.
6/25	--		-		-	-	-							-	-	-		-						
6/26	-	-	-		--		-		.			.		-	-	-		-	-					
7/10	--		-		.	.	-				.	-	.	-	-		-	-	-					
7/11	0	-	o	0	0	-	0	0	312075	-	26562	140767	215460	-	135603	175532	7866	-	7980	7934	1197	-	0	599
7/12	-	-	.		-	-	-			-	-	.		-	-		.	.	.					
7/13	--		-		-	-	-		.	.	-	.		-	-		--		.				-	
7/14	0	0	0	0	0	0	0	0	17214	80940	64410	54188	177270	54150	36594	89338	15960	10374	1596	9310	228	0	0	76
8/04	-	-	-		-	-	-	.	-	-	-		--		-		-	-	-		-			
8/05	--		-		.	.	-		-	-	-	.	-	-	-		-	-	-	.	-		-	
8/06	0	0	0	0		0	0	0	26790	18810	35910	27170	-	20520	2622	11571	114	1254	2850	1406	-	114	0	51
8/07	-	-	-		--		.		-	-	-		--		.		-	-	-		-	-		
8/08	-	-	-	-	-	-	-		--		-		-	-	-		--		.					

4. DISCUSSION

4.1 CHINOOK SALMON

4.1.1 Outmigration

The outmigration period for juvenile chinook salmon most likely begins before ice breakup and probably extends to early autumn. Catches of chinook smelts on the first day of sampling indicates that outmigration was in progress before the 1st of June. Similarly, catches of smelts during the August survey suggests the migration extended past this time. Chinook salmon smelts began migrating out of the upper Yukon River tributaries as early as mid April (Table 4-1) and could have reached the delta by early May. For example, smelts leaving the Delta River on April 12th could reach the Yukon Delta by May 1st if the fish moved passively with the current. Assuming a minimum current velocity of 1 m/s a fish could move at a rate of 86.4 km/day and would require approximately 20 days to travel from the Delta River to the mouth of the Yukon River. If juveniles leaving the upper river tributaries during August continue to outmigrate (Table 4-1) the end of the outmigration period could extend to early September.

The catch of chinook salmon smolts peaked on several dates during June and July with the largest catches occurring during late June. These results suggest that the peak of the outmigration occurred during the latter part of June. Since sampling was not conducted during early July it was not possible to know if another peak occurred. However, the migration timing for smelts from upper river tributaries (Table 4-1) indicates that most of these smelts would have reached the delta during mid to late June if fish travelled at a minimum rate of 86 km/day. Some stocks (e.g., Delta River) however, exhibit a very early outmigration from the upper river and result in a peak movement through the Delta that probably occurs during May. The declining trend in catches during early June (Figure 3-5) may indicate the tail end of an early outmigrating stock.

TABLE 4-1

Outmigration Timing and Size at Outmigration of Chinook Salmon Smelts from the Yukon River Drainage (Adapted from Table 3 in Raymond, 1981)

River	Distance a/ (km)	Outmigration Dates From	To	Peak	Mean Length (mm)	n	Reference
Yukon	2,462	5-21*	6-23	5-29	76.3	130	Walker 1976
		5-26	6- 1	5-28	88.0	31	"
Hodzana	1,443	6- 2	8-17	6- 5	78.8	57	Gissberg and Benning 1965
				7-10			"
Delta	1,659	4-12	5-16	4-28	93.0	22	Francisco 1977
				5-14			"
Salcha	1,553	5-16*	6- 8*	5-26	73.0	488	Trasky 1974
				6- 4			"
Chena	1,496	5-14*	6-20	6- 1	76.7	51	Ross 1973-1975
		5- 3	5-30	5-9	79.6	187	"
		5- 7	5-23	5-14	86.2	22	"
		5- 4	5-16	5-11	75.0		Williamson 1981
Clear Creek	1,380	4-30*	5-22	5- 8	71.3	38	Raymond 1981
Yukon	101	6- 8	7- 7*	6-13	96.0	14	Barton 1979
Yukon	25	6- 4*	8- 8*	6-18	96.8	313	This report

---

a/ Distance from the mouth of the Yukon River.

* Indicates that the outmigration was in progress when the sampling started or ended.

Information on the outmigration timing for chinook salmon smelts from other western Alaska Rivers is not well documented. No information, for example, could be found for the Kuskokwim River. However, several years of outmigration data are available from the Susitna River, which is located along the south central coast of Alaska and has freezeup and breakup timing similar to that of the mid-river tributaries of the Yukon River. In the Susitna River, chinook salmon presmolts were found to have moved out of river slough habitats by early May (Stratton 1986) and large numbers of smelts were caught in the lower river immediately following ice breakup in late May (Roth et al., 1986). This suggests that the smelt outmigration in the Susitna River probably begins in late winter-early spring, which is similar to the timing indicated by data from the Yukon River. The smelt outmigration in the Susitna River also peaks during late June and smelts continue to dribble out through to September (Roth et al., 1986, Roth and Stratton 1985).

The age composition of outmigrant juvenile chinook salmon was not determined but the size composition of the juveniles suggests that ages 0, 1, and older individuals probably occurred in the catch. Juveniles caught during June were most likely age 1 and older because the length of all fish exceeded 69 mm. Chinook salmon fry (i.e., age 0) would likely be much smaller than 69 mm during this period. For comparison, juvenile chinook salmon fry in the Delta River, Chena River, and Clear Creek during June ranged 31-45 mm, 32-62 mm, and 34-40 mm, respectively (Francisco 1977, Walker 1983, and Raymond 1981). Whereas, age 1 smelts from the Delta River at the same time ranged 71-110 mm (Francisco 1977). During the period of July through August it is possible that age 0 fry could be mixed together with age 1 and older chinook salmon smelts. Juveniles caught during the July and August surveys ranged 82-123 mm. The smaller individuals would fit within the size range of outmigrant age 0 chinook salmon caught in the Susitna River, which ranged 40-88 mm in July and 46-94 mm in August (Roth and Stratton 1985). Only a small percentage of the juveniles caught during this period were small enough to be considered age 0 smolts. Therefore, if age 0 smelts actually existed they probably represent only a minor portion of the total smelt outmigration Scales collected from adult chinook salmon, which were caught in the lower Yukon River indicate that fish with less than one year of freshwater growth represent a very small percentage of the total adult population (John Wilcox, ADF&G personal communication).

4.1.2 Distribution and Habitat Utilization

There was a large variation in the density of juvenile chinook salmon among the coastal and offshore habitats. The results suggest that the outer delta platform and the delta front habitats are utilized to a greater extent than the mudflat or tidal slough habitats. The one time capture of chinook smolts in the tidal slough at Station 11, and their absence from this site and the adjacent mudflats, indicates that utilization of nearshore habitats was limited. This apparent absence of smelts is probably real and not due to low sampling effort, since these stations were sampled five times during June and the northern most stations (i.e., Station 9 and 12) were also sampled once during this period.

The distribution of juvenile chinook salmon in the Yukon Delta may be affected by river outflow in the sub-ice channels. The high discharge during the outmigration period results in a very strong flow of freshwater that moves out the sub-ice channels to the delta front. Juveniles migrating downstream in the major distributaries could be carried 20 to 30 km offshore and would completely bypass the nearshore and most of the delta platform habitats. In the Columbia River, chinook salmon yearlings were mostly found migrating in mid-river and most fry were found nearshore (Dawley et al. 1985). Since outmigrants in the Yukon River were composed largely of yearlings and older smelts it is likely that most of these chinook smelts did not encounter the nearshore habitats and were flushed out to the delta front. A small portion of the outmigrants, however, were entrained in the small distributary channels and were not carried across the delta platform. These fish encounter the nearshore areas and utilize the mudflat and tidal slough habitats. The juveniles that were caught in a tidal slough at Station 11 could have migrated out from any number of small distributaries that were located within 5 km of this site.

The relationship between fish size and habitat preference may also be an important factor affecting the distribution of juvenile chinook salmon in the Yukon River Delta. Generally, the smallest juveniles were found in the nearshore areas of the inner estuary and the larger juveniles occur in the offshore areas of the outer estuary. In some cases there appears to be a threshold size governing the movement into deeper or higher salinity waters (Healey 1982). In the Nanaimo River Estuary when fry migrants reached 70 mm they began to leave that habitat. Also, yearly smelts mostly occurred in the outer estuary during April-June, after which they migrate away from the coastal waters (Healey 1980). In the Yaquina Bay Estuary of Oregon small juvenile chinook (average 88 mm) were found in the nearshore areas of the upper estuary and larger juveniles (average 106 mm) were found in the offshore areas (Meyers 1980). Reimers (1973) also found a similar size related distribution for juvenile chinook in the Sixes River Estuary. In the Yukon Delta the juvenile outmigrants were all larger than 69 mm. These larger juveniles may have reached the threshold size required for movement into deeper and higher salinity water. This would explain why chinook smelts occurred most often in the vicinity of the delta front where intermediate salinity conditions prevailed.

The catch results suggest that environmental conditions in the surface water may affect the distribution and abundance of juvenile chinook salmon in the Yukon Delta. Surface water quality is considered to be most important because the vertical distribution of juveniles in other estuaries indicates that juvenile salmon are concentrated near the top 2-3 meters (Stober et al. 1973, Dawley et al. 1985). Also, the catch data from this survey are only representative of the surface water environment because the tow net sampled to 1.8 m deep. In the Yukon Delta most juveniles were caught in the delta front and outer delta platform areas where visibility was greater than 0.5 m and surface waters were relatively cool (i.e., 8°-10°C) with intermediate salinities (i.e., 5-15 ppt). Determination of which factor or combination of factors is affecting this distribution is not possible because the environmental conditions are physically related. Each environmental factor along could have an effect on habitat utilization. For example, juveniles may be seeking areas with higher visibility because turbid water may inhibit feeding. Studies with juvenile rainbow trout and juvenile coho have found that feeding is significantly reduced or ceased when turbidity levels exceed a specific threshold (Noggle 1978, Olsen et al. 1973, Brett and Groot 1963). If this relationship applies to juvenile chinook salmon, then this would explain why there was a greater utilization of the offshore areas. Based on the distribution of turbid waters from the AVHRR images, (Figure 3-4 to 3-6) smolts must move 10-20 km offshore in order to find waters with a Secchi disk depth greater than 0.5m.

Outmigrants also could have been seeking a more optimal temperature level. Brett (1952) has determined that temperatures of 9-14°C are the preferred range for chinook salmon. Temperatures in the river and in the offshore areas were within this range during the peak outmigration period. However, temperatures in the nearshore areas ranged up to 19.1°C and were greater than the preferred range most of the time. These warmer conditions may explain why utilization of the nearshore habitats was limited.

Salinity levels could also affect the distribution of juvenile chinook salmon. During June the discharge from the Yukon River is so large that estuarine conditions do not exist within 10-20 km of the coastline. Juvenile chinook would not find brackish water until they migrated out to the outer delta platform and delta front. The intermediate salinity levels that occur in these areas may be needed as a transition zone for juveniles while they adapt to saltwater conditions. As the river discharge declines during the summer, this zone of intermediate salinity water progressively moves closer to the coastline. By August the delta front was dominated by marine water and the transition zone had moved far into the delta platform but not into the nearshore areas. No juvenile chinook were caught at either the nearshore or offshore stations at this time. The absence of fish in the catch could be due to their low density at this time and/or their utilization of the transition areas on the delta platform which were not sampled.

Evidence from other investigations suggests that the distribution and abundance of juvenile salmon in estuaries is influenced by the abundance of food. Healey (1978) found that the abundance of juvenile chinook salmon was positively correlated with the amount of food in their stomachs in different regions of the Georgia Strait. He concluded that these results suggest that the young salmon congregate in the best feeding areas. Healey (1982) also indicated that the growth and abundance of chinook salmon was greater in the Nanaimo Estuary compared to the Nitinat Estuary because food resources were greater in the latter. Food habits studies of juvenile chinook salmon have found larval fish were the primary component in the diet for smelts in the outer estuaries of Yaquina Bay and Georgia Strait (Myers 1980, Healey 1978) and ranked third in importance in the Nanaimo Estuary (Healey 1982). In the Yukon Delta high densities of juvenile smelt were found in the delta front. These fish and zooplankton in this estuarine zone may influence the abundance of juvenile chinook salmon in the Yukon Delta as well.

4.1.3 Residency

There was no difference in the average size or size composition of the juvenile outmigrants among the lower river, delta platform, and delta front habitats during the peak outmigration period. This would suggest that juveniles were not residing in the offshore habitats long enough for changes in average size to be detectable. The duration of residence, if any, is probably very short because the smelts were large enough to move into the marine environment. The majority of the smelts leaving the Yukon River reared for one or two years in freshwater. In other rivers, these older smelts generally do not utilize the nearshore waters, but instead migrate directly to the outer estuary and coastal marine environment (Healey 1982). Healey (1983) observed that these “stream type” chinook salmon occur predominantly in Alaska rivers and larger rivers (e.g., Fraser and Columbia Rivers) south of Alaska. He found that these larger smelts utilized the coastal waters of Georgia Strait for about two months and then moved further seaward in Juan de Fuca Strait during late summer. Samples were not collected from the outer portion of the delta front and the prodelta. Therefore, it is unknown whether juvenile chinook salmon utilize these deeper water habitats. It is possible that the areas sampled in this survey represent a transition zone that is located just on the inner edge of what may be the primary estuarine rearing area for Yukon smelts.

4.2 CHUM SALMON

4.2.1 Outmigration

The outmigration period for juvenile chum salmon from the Yukon River appears to begin prior to ice breakups and probably extends to early autumn. Since juveniles were caught on the first and last days of sampling it is reasonable to assume that fish were migrating prior to June and continued after the August survey. Chum fry migrating from upper river tributaries in early April (Table 4-2) could reach the delta by early May, which is several weeks prior to ice breakup. Similarly, fry leaving upper river tributaries during late August (e.g., Hodzana River, Table 4-2) would not reach the delta until early September. In 1985 the field survey continued to September 18th and juvenile chum were caught as late as September 13th (Martin et al. 1986).

The highest catch of chum salmon fry occurred on June 18th but other high catches also occurred throughout the month of June. During 1985 the peak catches occurred during June 20-25 (Martin et al., 1986) and during 1977 Barton (1983) had the largest catches on June 13-15. These results would suggest that the peak timing of the juvenile chum outmigration occurs during mid to late June. A similar timing for the peak outmigration of chum salmon was observed in the Noatak River in Kotzebue Sound (Merritt and Raymond 1983) and in the Susitna River in

TABLE 4-2

Outmigration Timing and Size at Outmigrationof Chum Salmon Smelts from the Yukon River Drainage (Adapted from Table 3 in Raymond, 1986)

River	Distance[a/] (km)	Outmigration Dates From	Outmigration Dates To	Outmigration Dates Peak	Mean Length (mm)	n	Reference
Delta	1,659	4-17	5-27	4-24	34.2	92	Francisco 1976
		4- 2	5-25*	4-28	34.6	1,426	"
				5-18			"
		4- 9	4-20	4- 9	32.0	72	Dinneford and Francisco 1977
				4-18			"
Salcha	1,553	5-16*	6- 8*		39.5	106	Trasky 1974
		5-10	5-30	5-20	34.6	27	Francisco 1976
Chena	1,496	5-22	7- 3*	6-12	41.3	142	"
		5- 8	6-27	5-8	36.2	139	"
		5- 6	6- 7	5-21	35.9	228	"
		5- 2	5-18	5-11	35.0		Williamson 1981
Hodzana	1,443	6-2	8-24*	6- 5	39.2	474	Gissberg and Benning, 1965
Tanana	1,378	5- 9*	6-22*	6- 2	35.8	274	Raymond and Saugstad, 1986
		5-14*	6- 5	5-22	36.5	201	Raymond and Saugstad, 1986
Redo	719		5-13*		33.6	7	Fred DeCicco, unpub. 1981 data
Bear Creek	636	5-22	6-20*		38.2	69	"
Anvik	530	5-22	7-26*		36.0		Buklis, 1983
Innoko	512		5-25*		33.6	7	Fred DeCicco, unpub. 1981 data
Yukon	101	6- 7*	7- 2	6-13	41.0	265	Barton 1979
Yukon	25	6- 4*	8- 8*	6-18	43.7	1,078	This Report

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a/ Distance from the mouth of the Yukon River.

* Indicates that the outmigration was in progress when the sampling started or ended.

Cook Inlet (Roth and Stratton 1985, Roth et al. , 1986). This timing of the peak outmigration is later than chum fry outmigrations from rivers further south. In the Fraser River the peak of chum salmon outmigration occurs during late April and early May (Levy and Northcote 1982), and in Puget Sound streams the migration peaks typically from late March to early May (Simenstad et al., 1982).

The presence of more than one size group and the large average size (i.e., 60 mm) of one group of chum salmon outmigrants suggests migration timing and juvenile size may be related to different stocks. The larger fish (i.e., group I, Figure 3-15) that outmigrated during early June were most likely fall chum salmon. Most juvenile chum begin to emigrate from Yukon River tributaries at approximately 35 mm in length (Figure 4-2). In order to grow to an average size of 60 mm these fish would have had to emerge from 30 to 80 days earlier, assuming a growth rate of 0.3 - 0.8 mm per day (from table 4-4). Fall chum salmon which spawn in tributaries with upwelling groundwater (Buklis and Barton, 1984) are known to emerge during April in many upper Yukon River tributaries (Francisco 1976, Dinneford and Francisco 1977). For example, in the Delta River water temperature in a fall chum salmon redd was 6.6°C during November 1975 and fry were emerging as early as April 2 the following spring (Francisco 1977). These fish would have sufficient time to grow to 60 mm by early June. These large size chum may also be hatchery fish that were liberated from the Clear Creek Hatchery by the Alaska Department of Fish and Game (ADF&G). Approximately 1 million chum fry averaging 49.5 mm were released on May 5-6, 1986, into Clear Creek (tributary of Nanana River) (Jim Raymond, ADF&G, personal communication).

The smaller size chum caught during June were most likely summer chum salmon. This stock of fish generally spawns in lower river runoff streams (Buklis and Barton, 1984) where development is slow, hence emergence from these tributaries does not begin until mid to late May (see Bear Creek, Anvik R., and Innoko R. Table 4-2). Since less time is required to reach the delta from these tributaries, the small size of summer chum fry indicates very little growth occurred since emergence. A second group of similarly small chum fry occurred during

August (Group 111, Figure 3-15) and may be summer chum salmon, as well . The reason for this unusually late outmigration, and the life history of these later summer outmigrants, needs further investigation.

4.2.2 Distribution and Habitat Utilization

Juvenile chum salmon were more widely distributed and occurred more frequently in the offshore habitats than in the coastal habitats. These results suggest that the outer delta platform and the delta front habitats were utilized to a greater extent than the mudflat or tidal slough habitats. Although the highest density of juvenile chum was detected in a tidal slough (i.e., Station 12, Table 3-8), their inconsistent utilization of this habitat sUggests this was not an important environment. Similarly, the low frequency of occurrence in mudflat habitats suggests this environment may not be important as well.

The spatial distribution of juvenile salmon in the Yukon River Delta is unlike the distribution of chum observed in other estuaries. In small estuaries of British Columbia (i.e., Nanaimo, Cowichan, and Courtenay), Healey (1982) observed the following general pattern. Upon entry to the estuary juvenile chum would utilize the shallow intertidal marsh and fringe areas during high tide. During low tide fish would concentrate in flowing tidal creeks and adjacent delta channels. Habitat utilization was size related and as fish grow they progressively moved from the inner to the outer estuary. A similar pattern of habitat utilization for chum fry in Puget Sound estuaries was described by Simenstad et al. (1982). In the Fraser River Delta significant numbers of chum fry utilize the side channels and sloughs for rearing until the fish reach an average size of 46 mm (Levy and Northcote, 1982). Chum fry that bypass the sloughs and leave the river are dispersed by the plume and occur in nearshore nursery areas away from the delta (Heal ey 1980). After rearing in these shallow water environments, juvenile chum from the Fraser move into deeper water habitats in the Strait of Georgia where they reach an average size of 90-100 mm during the period of peak abundance (i.e., June - early July).

The difference in the distribution of juvenile chum in the Yukon Delta compared to other estuaries may be related to the different hydrographic conditions. The nearshore environment of the Yukon Delta is very different than those typical of small estuaries in British Columbia or Puget Sound. For example, true estuarine conditions do not occur in the nearshore habitats of the Yukon Delta during the outmigration period. The intertidal mudflat areas are typically freshwater dominated, very shallow (<0.5 mm), highly turbid, and relatively warm (see AVHRR images Figure 3-4 to 3-6). During the ebb tide, generally 1-2 km of mudflats are dewatered and only small shallow ponds (<20 cm deep) or shallow streams from tidal sloughs remain. Chum salmon that may utilize this habitat would have to move out quickly to the subtidal areas to find refuge. These subtidal areas would likely be poor habitat as they are very shallow, with no vegetation, and have sand-silt substrates. Therefore, much of the coastal habitats are not very suitable or accessible for juvenile rearing. Only the coastal areas adjacent to the large distributaries where the tidal flats are less extensive would be more accessible for juvenile rearing. Also, only the juveniles that migrate along the rivers edge are likely to find these nearshore habitats. As described for juvenile chinook salmon, outmigrant chum salmon in the major distributaries will most likely be distributed to the delta front by the strong river outflow.

Habitat utilization by juvenile chum salmon within the Yukon Delta distributaries and tidal channels is probably very similar to the Fraser River Delta. Data from the 1985 Yukon survey (Martin et al., 1986) indicate a broad distribution of juvenile chum in active distributaries, adjacent tidal channels, and lake outlet streams. Movement into tidal channels and outlet streams, however, was related to tidal backwater effects as juveniles were seldom found in these habitats at low tide, even though many of these channels were accessible at this time. The amount of river discharge during June probably affects fish distribution and habitat access as well. During 1985 most of the delta was covered by water, whereas during 1986 many of the smaller channels and distributaries were not connected to the river.

Utilization of the outer delta platform and delta front by juvenile chum was greater than utilization of the coastal habitats. The small average size of juveniles found in these habitats suggests that little or no rearing is occurring in this environment and that juveniles must be rearing in some other habitat before migration to open ocean. The average size of chum juveniles in the offshore habitats was slightly smaller than outmigrants from the river during the same time period (see Figure 3-16 to 3-18). The relative age of these fish was also less than fish from the river (see Table 3-13). This would indicate that all but the largest and oldest outmigrants from the river were probably moving directly to the delta front. Most of the fish utilizing the delta platform and delta front habitats were in the 40-50 mm size category and all the fish were less than 70 mm. In other estuaries the size of chum salmon juveniles at migration from inshore to deeper estuarine habitats ranged 40-75 mm and the size at migration from deeper estuarine habitats to the open ocean ranged 70-130 mm (Table 4-3). Therefore, compared to other estuaries the small size of juvenile chum utilizing the delta front indicates that this habitat may function as the inner estuary or staging area for juveniles before movement to deeper water habitats. The deeper water in the prodelta (Figure 2-2) may serve as the outer estuary for juvenile outmigrants and may be an important habitat prior to ocean migration. On the other hand, juvenile chum could move out from the Yukon plume and northward with prevailing current (Truett 1985) and rear in the deeper offshore habitats of Norton Sound. Healey (1980) examined the distribution of chum juveniles in Georgia Strait during summer and found that juveniles were less abundant in the Fraser plume than in other regions. Further investigations of the delta front, prodelta and Norton Sound, are necessary in order to identify the spatial and temporal utilization of this preocean rearing habitat.

4.2.3 Determining Residency With Otoliths

The results of the otolith analysis suggest that increment periodicity may not be constant for the early life stages of juvenile chum salmon. Periodicity appears to range from approximately 2 d/increment for pre-

TABLE 4-3

Sizes of Chum Salmon Juveniles in Estuarine Habitats
(Adapted from Iwamoto and Sale, 1977)

Location	Size (mm) at Migration	Reference
	Migration From Inner to Outer Estuary	
Big Qualicum, B.C.	75	Allen (1974)
Puget Sound, Washington	50-60	Feller (1974)
Hood Canal, Washington	40-50	Schreiner (1977)
Bellingham Bay, Washington	65	Tyler (1964)
	Migration From Outer Estuary to Open Ocean	
Big Qualicum, B.C.	120	Allen (1974)
Little Port Walter, Alaska	130	Lagler and Wright (1962)
Hokkaido, Japan	70-100	Sano and Kobayashi (1952)

emergent alevins to 0.8 d/increment for 50 mm outmigrant fry. The question is, is this wide variation in increment periodicity real? Research has shown that increment formation rates can vary from both less than and greater than one per day (Campanca and Neilson 1985). Environmental variables such as photoperiod, temperature, and feeding regime are known to have an influence on the rate of otolith deposition (Neilson and Geen 1982, 1985; Jones 1984). Juvenile chum salmon in the Yukon River would experience large variations in physical environmental conditions during the alevin and fry outmigrant stages. For example, photoperiod (at 64°N) varies from 13 hr/d during the alevin-early fry stage (i.e., early April) to 23 hr/d during the peak of the outmigration (i.e., mid-June). Water temperature during this period will range from 5°C to 15°C. Food supply would vary greatly in quantity and quality as fish change from indigenous to exogenous feeding and as they migrate from a clear tributary to a turbid river and through the delta/estuarine environment. Therefore, a variation in increment formation rate is not unlikely for Yukon chum salmon.

This apparent variation in increment periodicity for Yukon chum salmon prohibits us from estimating fish age or elapsed time from increment counts. Instead, the number of increments can only be viewed as a relative measure of age. More information is needed on factors that may cause a transition in increment periodicity and when these transitions occur during juvenile development.

The results of the 1986 otolith analysis do not concur with the results from 1985 concerning residency. The 1985 results suggested that juvenile chum may have been residing in some delta habitats. This interpretation was based on: 1) the identification of an outer edge zone where increment width showed a stepwise increase over the preceding increments; and, 2) the assumption that this zone corresponded with the transition from a riverine to an estuarine or delta environment. It is now evident, however, from the analysis of a large number of otoliths in 1986 that the outer edge zone identified in

1985 was the post-hatching zone. Therefore, the wider increments in this zone were not an indicator of estuarine residency but rather an approximate measure of age and a record of growth since hatching.

4.2.4 Residency

Residency of juvenile chum salmon in the offshore habitats examined in this study was either not occurring or was too short (i.e., less than 1 to 2 weeks) to be detected. The slight difference in size composition of outmigrants from the lower river compared to juveniles from the delta front or delta platform during the same time periods (Figures 3-16 to 3-18) indicates that juveniles could not have been residing for very long. The young relative age of the juveniles in the offshore habitats compared to the age of juveniles in the river supports this hypothesis. Juvenile chum are most likely moving through the lower river, bypassing the coastal habitats, and moving directly to the delta front. Fish in the delta front apparently do not reside long and continue their outmigration either to a deeper estuarine habitat or to the open ocean.

The short residence of juvenile chum salmon in the Yukon Delta is not uncommon compared to residency in other estuaries. Healey (1979) found that residence times in the Nanaimo Estuary varied between 0 and 18 days over two years of observations. In the Fraser River Delta, chum residency in tidal marsh channels ranged up to 11 days (Levy and Northcote 1982) and in the Skagit River Delta chum residency ranged 0 to 12 days (Foley, personal communication cited in Shepard 1981). Healey (1979) showed that juveniles arriving early during spring remained longer than fry arriving later. Iwamoto and Salo (1977) cite several studies indicating that fish size influenced distribution and residency. In the Yukon Delta neither migration timing nor fish size seem to affect estuarine residency since no residency was detected.

4.2.5 Growth

In the Yukon Delta growth rates of chum salmon were not affected by the transition from a riverine environment to the shallow delta platform and delta front. Growth rate was uniform during the last 13 to 26 days prior to fish capture, as demonstrated by the consistency in otolith increment widths (Figure 3-21). These results suggest that juvenile chum in the Yukon River do not require the shallow nearshore habitats for growth as do, for example, chum in estuaries of British Columbia and Puget Sound (Healy 1982, Simenstad et al 1982). These results also suggest that food availability in the Yukon River may not be a limiting factor during the outmigration period. Food habits studies that were conducted in 1985 (Martin et al. 1986) showed that only 16 percent of the chum stomachs examined were empty. Therefore, outmigrant chum must be obtaining sufficient food in order to maintain a fairly uniform growth rate.

Growth rate of juvenile chum salmon was not measured during this study but was estimated from fish length data. This growth rate estimate (i.e., 0.31 mm/d) is probably biased on the low side because of the effects of immigration and emigration on the size of fish in the sample population. This estimate indicates that the growth rate of chum salmon in the Yukon River is similar to the growth rates reported for chum in other freshwater environments (Table 4-4).

4.3 VULNERABILITY TO OIL AND GAS DEVELOPMENT

The vulnerability of a habitat to impacts from a potential oil spill is largely dependent upon the location and elevation of the habitat. In the Yukon Delta, habitats can be ranked in order of their relative vulnerability as follows:

TABLE 4-4

Growth Rate of Juvenile Chum Salmon in Freshwater

Location	Habitat	Growth Rate (mm/d)	Temperature (°C)	Reference
Susitna, R, AK	Freshwater	.25-.45[a]	3.6-11.8	Roth and Stratton (1985), Roth et al. (1986)
Laboratory, B.C.	Freshwater	.66-.82[b]	14.0°-16.00	Le Brasseur (1969)
Clear Creek, Yukon R, AK	Freshwater	.22[a]	1.8°-10.00	Raymond (1981)
Yukon R, AK	Freshwater	.31[a]	6.8°-17.10	This Report

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[a] Represents a population growth rate (after Ricker 1975) computed from mean length data.

[b] Fish fed on excess ration grew at 5.4 percent body weight per day. Converted to mm/d for 40 mm and 50 mm fish using length-weight regression from Roth et al. (1986).

1) delta front and delta platform
2) intertidal mudflats and tidal sloughs
3) active distributaries
4) inactive distributaries and connected lakes

Therefore, juvenile salmon that utilize the delta front or delta platform would be the most vulnerable to impacts from oil because these habitats are in close proximity to the oil and gas lease area (Figure 2-1). Whereas, fish that may occur in inactive distributaries or connected lakes would be the least likely to be impacted because oil would only reach these habitats by a large storm surge event.

Results from this investigation and the 1985 fish investigations (Martin et al ., 1986) indicated that the major distributaries, nearshore habitats near the distributary mouths, the outer delta platform, and the delta front are primarily utilized as a migration corridor for juvenile salmon. An oil spill during the outmigration period that may reach any of these habitats could have a significant impact on Yukon river salmon stocks. Based on the 1985 data, Martinet al. (1986) indicate that the nearshore habitats (i.e., inner delta platform and tidal sloughs) were the most important for juvenile salmon and that an impact in these habitats would have the greatest effect on those populations. However, based on the 1986 data, it is evident that the nearshore habitats are not as important as previously thought. Additional fish sampling in the offshore areas indicates that the outer delta platform and the delta front are more important for the juvenile outmigrant populations. The 1986 data also suggests that the prodelta may be a very important rearing area for juvenile chum salmon prior to their ocean migration. If the latter is true, fish that utilize the prodelta would be the most vulnerable to oil impacts because this habitat is partially located within the proposed OCS lease area. More information is needed concerning the distribution and duration of habitat utilization in the prodelta and Norton Sound region in order to assess potential impacts from oil and gas development.

The distribution of sheefish and whitefish observed in this survey and in the 1985 survey (Martin et al. 1986) indicates that the intertidal mudflats and tidal sloughs are the most important habitats utilized by these species. These species and their populations would be highly vulnerable to an oil spill that reached the nearshore environment. Similarly, juvenile cisco were very abundant in the nearshore habitats and in the delta platform. Unlike juvenile salmon, the juvenile whitefish, sheefish, and cisco do not migrate far beyond the nearshore environments. Instead, they utilize these shallow coastal habitats for rearing throughout the summer and early fall. In winter, however, these habitats are frozen and the coregonids are assumed to move into the deeper active distributaries within the delta. This continuous, year-round utilization of the delta habitats makes the coregonid species potentially vulnerable to oil and gas development during all seasons.

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APPENDIX A
WATER QUALITY DATA AND PHYSICAL CONDITIONS DURING SUMMER 1986 IN THE YUKON RIVER DELTA

Station	Date	Depth (m)	Bottom Conductivity (mmhos/cm)	Bottom Salinity (ppt)	Bottom Temperature (°C)	Surface Conductivity (mmhos/cm)	Surface Salinity (ppt)	Surface Temperature (°C)	Secchi Depth (m)	Sea State[a]
1	6/06	7.5	22.3	26.1	0.0	15.0	14.3	3.9	0.7	2
1	6/12	6.0	23.7	27.4	0.4	16.0	14.1	7.2	0.9	3
1	6/15	5.5	24.4	27.3	1.1	10.7	8.0	13.2	0.5	4
1	6/19	5.0	25.7	23.6	6.3	5.7	3.8	12.0	0.2	3
1	7/11	5.5			8.6			16.0	0.3	3
1	7/14	6.0			11.7			13.0	0.4	2
1	8/06	5.0	30.0	26.6	9.4	30.0	27.0	9.8	0.5	2
2	6/12	9.0	24.0	28.3	0.0	9.2	7.1	10.8		3
2	6/15	8.0	24.2	28.0	0.1	6.3	4.3	15.2	0.3	2
2	6/19	9.0	25.5	29.2	0.0	6.0	4.1	11.9	0.2	3
2	7/14	9.0			10.3			14.9	0.2	2
2	8/06	8.5	27.1	23.8	9.7	22.1	18.8	10.2	0.3	2
3	6/12	8.0	23.9	29.2	0.0	14.9	12.9	8.2	0.8	4
3	6/15	8.5	24.3	29.2	0.0	19.5	16.4	10.0	1.1	3
3	6/19	8.5	25.3	27.2	3.2	6.3	4.6	12.1	0.2	1
3	7/11	8.5			5.5			14.5	1.2	4
3	7/14	9.0			9.5			15.5	0.2	3
3	8/06	9.0	30.8	27.1	10.1	23.4	19.8	10.7	0.5	2
4	6/12	1.5	19.9	19.9	4.1	14.1	12.1	8.0	0.8	3
4	6/15	2.0	23.3	23.9	3.5	16.8	13.9	9.6	0.5	2
4	6/19	1.0	2.1	1.4	12.6	2.4	1.3	12.1	0.2	3
4	7/11	1.5			15.3			16.0	0.3	3
4	7/14	1.5			13.9			14.1	0.2	2
5	6/12	2.0	21.5	23.6	1.5	11.3	9.0	10.2	0.6	3
5	6/15	2.0	19.9	18.3	6.5	8.5	6.0	14.7	0.7	2
5	6/19	3.0	7.8	5.7	10.9	2.4	1.5	11.6	0.2	3
5	7/14	1.7			13.9			14.9	0.2	3
5	8/06	3.5	11.6	9.1	10.8	10.3	7.9	11.0	0.3	2
6	6/12	2.0	23.6	27.9	0.3	8.3	6.6	10.9	0.5	3
6	6/15	2.0	20.0	18.7	6.2	5.7	3.5	17.2	0.4	3
6	6/19	3.5	3.6	5.2	11.8	2.6	1.5	12.3	0.2	1
6	7/11	2.0			16.0			16.2	0.1	3
6	7/14	2.5			15.0			15.0	0.2	3
6	8/06	3.0	2.9	3.0	11.1	2.4	1.7	11.2	0.2	2

APPENDIX A (Continued)
WATER QUALITY DATA AND PHYSICAL CONDITIONS DURING SUMMER 1986 IN THE YUKON RIVER DELTA

Station	Date	Depth (m)	Bottom Conductivity (mmhos/cm)	Bottom Salinity (ppt)	Bottom Temperature (°C)	Surface Conductivity (mmhos/cm)	Surface Salinity (ppt)	Surface Temperature (°C)	Secchi Depth (m)	Sea State a/
8	6/10	0.5	1.2	0.8	9.4					2
8	6/14	0.3	1.3	1.0	15.2				0.2	2
8	6/17	0.5						15.4	0.3	2
8	6/22	0.5	2.1	1.3	17.0				0.4	1
8	6/24	0.5	1.0	0.7	10.0			-	0.2	2
8	7/12	0.7						14.5	0.2	2
8	8/04	0.3						11.7	0.1	1
9	6/25	1.0	1.8	1.4	9.1	1.8	1.3	9.2	0.1	2
9	7/13	0.5						13.5	0.3	2
9	8/04	0.5						12.5	0.2	2
10	8/05	0.6						10.1	0.6	1
11	6/10	1.5	1.3	1.0	8.5	1.3	0.9	8.7	0.5	1
11	6/14	1.5	1.5	0.9	19.1	1.4	0.8	17.8	0.8	2
11	6/17	2.0						16.1	0.5	1
11	6/22	1.0	3.8	2.6	12.7	3.8	2.7	13.5	0.9	0
11	6/24	0.5	1.0	0.6	10.2	1.0	0.6	10.2	0.6	1
11	7/12	2.0						13.5	0.2	1
11	8/04	1.5						10.8	0.1	1
12	6/25	1.5	2.2	1.7	8.4	2.2	1.8	8.8	0.3	1
12	7/13	2.0						13.5	0.4	0
12	8/04	2.0						11.5	0.5	1
13	6/04	10.0	1.4	0.9	6.5	1.2	0.9	6.8	0.2	2
13	6/05	9.0	1.1	0.8	7.6	1.1	0.8	7.6	0.2	0
13	6/09	9.0	1.3	0.8	9.9	1.3	0.8	10.2	0.4	2
13	6/13	10.0	1.3	0.8	12.7	1.4	0.9	12.9	0.3	2
13	6/14	6.0	1.3	0.8	13.3	1.3	0.8	13.3	0.2	2
13	6/17	9.0	2.7	1.8	14.6	2.9	1.9	14.6	0.3	2
13	6/18	9.0	2.0	1.2	13.7	2.1	1.1	13.8	0.2	3
13	6/20	9.5	2.1	1.3	13.8	2.6	1.4	13.8	0.2	1
13	6/22	10.0	2.5	1.8	14.6	2.7	1.8	14.5	0.2	0
13	6/24	10.0	1.0	0.6	14.4	1.0	0.6	14.3	0.2	3
13	6/26	10.0	1.9	1.3	13.6	1.5	0.9	13.7	0.2	3
13	7/12	10.0			17.0			17.1	0.2	3
13	8/05	10.5			12.7			13.0	0.1	3
13	8/07	10.5	0.7	0.3	12.6	0.7	0.4	12.8	0.2	2
13	8/08	9.5	0.7	0.3	12.8	0.7	0.3	12.7	0.1	1

APPENDIXA (Continued)
WATER QUALITY DATAAND PHYSICAL CONDITIONS DURING SUMMER 19861NTHE YUKON RIVER DELTA

Station	Date	Depth (m)	Bottom Conductivity (mmhos/cm)	Bottom Salinity (ppt)	Bottom Temperature (°C)	Surface Conductivity (mmhos/cm)	Surface Salinity (ppt)	Surface Temperature (°C)	Secchi Depth (m)	Sea State[a/]
14	6/01	10.0						4.9	0.1	1
15	5/31							9.1	0.9	0
15	6/02	6.0	1.1	1.1	8.0	1.1	0.8	8.2	0.9	1
16	5/31									0
17	6/05	10.0						9.0		0
17	.6/07	9.5	1.2	0.8	9.4	1.2	0.8	9.3	0.2	1
17	6/08	10.0	1.2	0.8	10.1	1.3	1.0	10.0	0.2	1
17	6/09	8.0	1.2	0.8	10.2	1.2	1.0	10.2	0.3	1
17	6/10	9.0	1.2	0.8	11.5	1.1	0.8	11.4	0.4	2
17	6/11	8.0	1.2	0.9	11.8	1.2	0.8	11.8	0.3	0
17	6/13	8.5	1.1	0.6	13.1	1.2	0.9	13.2	0.3	2
17	6/14	10.0	1.4	0.9	13.9	1.4	0.9	13.8	0.2	2
17	6/17	10.0	2.1	0.8	14.7	2.4	1.4	14.9	0.2	2
17	6/18	11.0	2.4	1.6	13.6	2.3	1.0	13.8	0.2	2
17	6/20	10.0	2.1	1.3	13.6	2.7	1.7	13.9	0.2	1
17	6/22	7.0	2.5	1.6	14.5	2.8	1.8	14.6	0.2	0
17	6/24	9.0	1.0	().6	14.4	1.0	0.6	14.5	0.2	2
17	Ii/26	9.0	1.5	1.0	13.6	1.6	1.0	13.7	0.2	2
17	7/10	11.0	5.6	2.7	17.9	5.7	2.5		0.2	1
17	7/12	10.0		.	16.4			16.7	0.2	1
17	7/13	10.0			17.0			17.1	0.2	1
17	8/05	8.0			12.8			12.8	0.1	1
17	8/07	9.5	0.7	0.4	12.5	0.7	0.4	12.5	0.1	1
17	8/08	9.5	0.7	0.4	12.7	0.7	0.5	12.7	0.1	1
17	8/08	9.5	0.7	0.4	12.7	0.7	0.5	12.7	0.1	1
21	6/06	13.0	23.4	28.5	0.0	8.7	8.3	4.1	1.0	2
41	6/04	2.0	1.1	1.1	3.5	1.2	0.8	3.4	0.2	2
41	6/06	1.0	1.3	1.1	3.9	1.3	1.1	3.9	0.2	2
51	6/06	2.5	22.0	25.4	0.0	6.6	5.5	5.4	0.3	2

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a/ World Meteorological Organization sea state scale

APPENDIXB

FISH CATCH AND FISH LENGTH STATISTICS GROUPED BY SPECIES , STATION, AND DATE FOR THE 1986 SUMMER SURVEY OF THE YUKON RIVER DELTA

CHINOOK SALMON

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
1	6/12	Tow Net	3	3	1.00	1.73	3	83.33	77	90	6.51
	6/15	Tow Net	1	3	0.33	0.58	1	78.00	78	78	
2	6/12	Tow Net	6	3	2.00	1.00	6	94.17	72	116	14.73
	6/15	Tow Net	2	3	0.67	1.15	2	97.00	87	107	14.14
	6/19	Tow Net	1	3	0.33	0.58	1	88.00	88	88	
	7/14	Tow Net	1	3	0.33	0.58	1	101.00	101	101	
3	6/12	Tow Net	10	3	3.33	0.58	10	103.90	82	115	9.69
	6/15	Tow Net	9	3	3.00	5.20	9	96.33	74	115	14.46
4	6/12	Tow Net	3	3	1.00	1.73	3	92.00	82	105	11.79
	6/15	Tow Net	6	3	2.00	1.73	6	90.33	76	110	12.53
	7/11	Tow Net	1	2	0.50	0.71	1	95.00	95	95	
5	6/12	Tow Net	3	3	1.00	1.00	3	100.33	92	112	10.41
	6/15	Tow Net	6	3	2.00	1.00	6	96.67	83	109	11.36
	6/19	Tow Net	1	3	0.33	0.58	1	98.00	98	98	
6	6/15	Tow Net	18	3	6.00	5.57	18	98.11	72	116	13.65
	6/19	Tow Net	1	3	0.33	0.58	1	102.00	102	102	
11	6/17	Beach Seine-75	1	2	0.50	0.71	1	115.00	115	115	
13	6/04	Tow Net	7	3	2.33	1.53	7	92.71	69	125	17.90
	6/04	Purse Seine	3	2	1.50	0.71	3	95.00	77	109	16.37
	6/05	Tow Net	4	3	1.33	1.53	4	99.75	75	122	22.38
	6/09	Tow Net	9	3	3.00	2.65	9	101.33	72	128	17.20
	6/13	Tow Net	1	3	0.33	0.58	1	93.00	93	93	
	6/14	Tow Net	5	6	1.67	3.20	5	98.60	87	111	9.53
	6/17	Tow Net	6	3	2.00	1.00	6	85.50	79	89	4.04
	6/18	Tow Net	2	3	0.67	1.15	2	92.50	89	96	4.95
	6/20	Tow Net	3	5	1.20	1.10	3	91.67	83	98	7.77
	6/22	Tow Net	2	3	0.67	0.58	2	90.50	83	98	10.61
	6/24	Tow Net	8	3	2.67	3.79	8	89.38	82	95	4.69
	6/26	Tow Net	9	3	3.00	2.65	4	93.50	85	110	11.39

APPENDIXB (Continued)

Station	Date	Gear	catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Len gth	SD Len gth
	7/12	Tow Net	3	3	1.00	1.73	3	106.67	96	116	10.07
14	6/01	Tow Net	3	7	0.43	G. 53	3	105.67	79	128	24.79
15	5/31	Tow Net	78	1			78	94.65	73	117	11.63
	6/02	Tow Net	69	3	23.00	16.37	19	94.00	71	126	19.39
16	5/31	Tow Net	27	1	27.00		27	97.78	85	116	8.57
17	6/05	Tow Net	40	15	5.13	4.97	25	100.08	83	118	9.51
	6/07	Tow Net	5	3	1.67	0.58	5	93.00	78	112	12.77
	6/08	Tow Net	1	3	0.33	0.58	1	96.00	96		
	6/09	Tow Net	11	3	3.67	1.15	11	89.00	72	1::	10.88
	6/10	Tow Net	5	3	1.67	1.15	5	91.40	75	110	12.93
	6/11	Tow Net	4	3	1.33	1.15	4	100.25	94	107	5.85
	6/14	Tow Net	4	3	1.33	1.53	4	92.75	83	110	12.28
	6/17	Tow Net	42	3	14.00	1.00	15	94.80	85	119	9.99
	6/18	Tow Net	67	3	22.33	2.52	31	95.48	78	114	8.91
	6/20	Tow Net	7	3	2.33	2.52	7	95.71	80	117	13.36
	6/22	Tow Net	10	3	3.33	1.15	10	92.80	83	108	7.32
	6/24	Tow Net	55	3	18.33	5.69	34	93.50	84	123	7.83
	6/26	Tow Net	53	3	17.67	1.53	52	93.21	81	109	6.93
	7/10	Tow Net	26	3	8.67	14.15	1	113.00	113	113	
	7/12	Tow Net	20	3	6.67	5.13	19	101.89	87	123	12.46
	7/13	Tow Net	24	3	8.00	2.65	24	99.83	82	117	8.60
	8/05	Tow Net	4	3	1.33	0.58	4	101.00	85	115	12.33
	8/07	Tow Net	2	3	0.67	0.58	2	112.50	110	115	3.54
	8/08	Tow Net	2	4	0.50	0.58	2	112.00	111	113	1.41
41	6/04	Tow Net	1	2	0.50	0.71	1	112.00	112	112	
51	6/06	Tow Net	1	2	0.50	0.71	1	103.00	103	103	
						CHUM SALMON					
1	6/12	Tow Net	57	3	19.00	8.89	56	38.70	35	46	2.43
	6/15	Tow Net	181	3	60.33	35.13	68	40.00	33	52	4.33
	6/19	I"ow Net	148	3	49.33	34.44	45	41.64	36	55	4.23
	7/14	Tow Net	4	3	1.33	1.53	4	49.50	40	62	10.02

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
2	6/12	Tow Net	63	3	21.00	19.29	62	39.74	35	61	5.60
	6/15	Tow Net	92	3	30.67	5.03	41	40.83	36	53	4.36
	6/19	Tow Net	98	3	32.67	3.79	68	41.66	36	56	3.46
	7/14	Tow Net	1	3	0.33	0.58	1	57.00	57		
	8/06	Tow Net	2	3	0.67	0.58	2	83.00	59	1:;	33.94
3	6/12	Tow Net	16	3	5.33	2.08	16	37.44	35	40	1.93
	6/15	Tow Net	11	3	3.67	3.79	11	43.64	36	61	7.13
	6/19	Tow Net	87	3	29.00	29.44	63	40.38	36	48	2.96
	7/11	Tow Net	25	3	8.33	8.02	25	47.72	36	68	7.21
	7/14	Tow Net	1	3	0.33	0.58	1	43.00	43	43	
4	6/12	Tow Net	42	3	14.00	9.85	41	39.15	34	51	3.42
	6/15	Tow Net	18	3	6.00	2.65	18	44.00	37	85	11.27
	6/19	Tow Net	87	3	29.00	5:57	41	40.20	34	47	3.04
	7/11	Tow Net	1	2	0.50	0.71	1	46.00	46	46	
	7/14	Tow Net	1	3	0.33	0.58	1	51.00	51	51	
5	6/12	Tow Net	39	3	13.00	6.24	39	40.03	35	54	4.68
	6/15	Tow Net	105	3	35.00	16.09	50	42.88	35	55	5.63
	6/19	Tow Net	191	3	63.67	7.09	54	40.93	35	48	3.37
6	6/12	Tow Net	3	3	1.00	1.00	3	38.67	38	40	1.15
	6/15	Tow Net	135	3	45.00	6.08	38	41.45	35	50	4.12
	6/19	Tow Net	60	3	20.00	4.36	60	41.82	35	52	3.68
	7/14	Tow Net	4	3	1.33	0.58	4	46.00	42	53	4.97
	8/06	Tow Net	1	3	0.33	0.58	1	33.00	33	33	
8	6/10	Beach Seine-150	3	2	1.50	0.71	3	36.67	34	38	2.31
	6/14	Beach Seine-150	4	2	2.00	2.83	4	38.50	38	39	0.58
	6/24	Beach Seine-150	1	2	0.50	0.71	1	42.00	42	42	
11	6/10	Beach Seine-75	9	2	4.50	0.71	9	37.00	32	39	2.18
	6/14	Beach Seine-75	197	2	98.50	55.86	40	39.70	36	43	1.79
13	6/04	Tow Net	16	3	5.33	2.89	16	39.38	33	62	8.88
	6/05	Tow Net	15	3	5.00	1.00	15	36.40	35	38	0.74
	6/09	Tow Net	158	3	52.67	10.02	46	39.93	34	69	6.10
	6/13	Tow Net	122	3	40.67	13.65					
	6/14	Tow Net	195	6	65.00	6.29	36	41.89	35	53	4.21

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
	6/17	Tow Net	150	3	50.00	17.35	47	45.51	38	70	5.96
	6/18	Tow Net	66	3	22.00	4.36	49	44.76	36	52	3.57
	6/20	Tow Net	171	5	68.40	30.31	32	43.25	36	57	5.21
	6/22	Tow Net	165	3	55.00	7.00	55	45.64	38	6(.I	4.66
	6/24	Tow Net	53	3	17.67	12.22	53	45.43	35	56	4.51
	6/26	Tow Net	44	3	14.67	2.31	44	48.91	39	57	4.33
	7/12	Tow Net	3	3	1.00	1.00	3	51.00	42	59	8.54
	8/05	Tow Net	2	3	0.67	0.58	2	46.50	36	57	14.85
	8/07	Tow Net	1	3	0.33	0.58	1	49.00	49	49	
	8/08	Tow Net	2	5	0.40	0.55	2	41.50	38	45	4.95
14	6/01	Tow Net	12	7	1.71	1.70	12	37.50	29	61	9.49
15	6/02	Tow Net	43	3	14.33	13.58	43	37.14	35	40	1.19
16	5/31	Tow Net	5	1	5.00		5	36.00	34	37	1.22
17	4/05	Tow Net	103	15	12.87	7.62	30	40.90	34	66	9.84
	6/07	Tow Net	35	3	11.67	7.51	35	37.46	33	42	2.28
	6/08	Tow Net	67	3	22.33	5.13	67	37.58	33	42	1.86
	6/09	Tow Net	324	3	108.00	12.53	45	37.36	34	48	2.39
	6/10	Tow Net	22	3	7.33	3.06	22	38.77	34	50	3.41
	6/11	Tow Net	21	3	7.00	3.61	21	42.33	35	52	5.08
	6/13	Tow Net	45	3	15.00	8.54					
	6/14	Tow Net	49	3	16.33	5.13	49	42.41	35	53	5.31
	6/17	Tow Net	187	3	62.33	20.60	55	44.16	36	55	4.76
	6/18	Tow Net	336	3	112.00	26.00	61	42.54	32	55	4.27
	6/20	Tow Net	95	3	31.67	7.77	47	42.98	35	62	4.58
	6/22	Tow Net	83	3	27.67	10.60	56	46.07	37	59	4.94
	6/24	Tow Net	115	3	38.33	12.10	63	45.54	35	58	5.55
	6/26	Tow Net	326	3	108.67	4.73	93	45.84	37	59	4.84
	7/10	Tow Net	13	3	4.33	2.52	13	47.92	41	57	5.@
	7/12	Tow Net	25	3	8.33	4.04	25	47.80	37	71	7.52
	7/13	Tow Net	30	3	10.00	3.46	30	48.57	38	65	6.28
	8/(.)5	Tow Net	18	3	6.00	1.00	18	47.28	35	60	7.09
	8/07	Tow Net	6	3	2.00	1.73	6	43.50	37	55	6.09
	8/08	Tow Net	16	4	4.00	2.45	16	43.75	35	59	7.65

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
21	6/06	Tow Net	3	3	1.00	0.00	3	34.33	34	35	0.58
41	6/04	Tow Net	1	2	0.50	0.71	1	37.00	37	37	
	6/06	Tow Net	3	2	1.50	2.12	3	56.00	36	93	32.08
51	6/06	Tow Net	2	2	1.00	0.00	2	35.50	34	37	2.12

PINK SALMON

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
15	6/02	Tow Net	1	3	0.33	0.58	1	34.00	34	34	
17	6/05	Tow Net	1	15	0.13	0.52	1	37.00	37	37	
	7/12	Tow Net	2	3	0.67	0.58	2	420.00	410	430	14.14

ARCTIC CHAR

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
15	6/02	Tow Net	1	3	0.33	0.58	1	142.00	142	142	
17	6/05	Tow Net	1	15	0.13	0.52	1	175.00	175	175	
41	6/04	Tow Net	1	2	0.50	0.71					

SHEEFISH

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
3	7/14	Tow Net	1	3	0.33	0.58					
4	7/11	Tow Net	1	2	0.50	0.71					
	7/14	Tow Net	1	3	0.33	0.58					
5	7/14	Tow Net	3	3	1.00	1.00					
6	7/11	Tow Net	1	2	0.50	0.71					
	7/14	Tow Net	10	3	3.33	3.21					
8	6/10	Beach Seine-150	1	2	0.50	0.71					
	6/14	Beach Seine-150	5	2	2.50	0.71					
	6/17	Beach Seine-150	2	2	1.00	0.00					
	6/22	Beach Seine-150	6	2	3.00	1.41					
	6/24	Beach Seine-150	1	2	0.50	0.71					
	7/12	Beach Seine-150	3	2	1.50	2.12					
9	6/25	Beach Seine-150	1	2	0.50	0.71					
	7/13	Beach Seine-150	4	2	2.00	2.83					
	8/04	Beach Seine-150	29	2	14.50	3.54					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
11	6/17	Beach Seine-75	1	2	0.50	0.71					
	8/04	Beach Seine-75	4	2	2.00	1.41					
13	7/12	Tow Net	3	3	1.00	1.00					
	8/05	Tow Net	2	3	0.67	0.58					
	8/07	Tow Net	5	3	1.67	0.58					
	8/08	Tow Net	4	5	0.80	0.84					
17	7/10	Tow Net	10	3	3.33	1.15					
	7/12	Tow Net	69	3	23.00	9.85					
	7/13	Tow Net	116	3	38.67	8.96					
	8/05	Tow Net	21	3	7.00	1.73					
	8/07	Tow Net	8	3	2.67	2.89					
	8/08	Tow Net	19	4	4.75	2.75					
41	6/04	Tow Net	1	2	0.50	0.71					
				HUMPBACK WHITEFISH							
8	6/10	Beach Seine-150	4	2	2.00	1.41					
	6/14	Beach Seine-150	7	2	3.50	2.12					
	6/22	Beach Seine-150	4	2	2.00	0.00					
9	6/25	Beach Seine-150	39	2	19.50	21.92					
	7/13	Beach Seine-150	2	2	1.00	1.41					
	8/04	Beach Seine-150	17	2	8.50	10.61					
11	6/17	Beach Seine-75	4	2	2.00	1.41					
	6/22	Beach Seine-75	2	2	1.00	0.00					
	8/04		10	2	5.00	2.83					
12	6/25		5	2	2.50	0.71					
	7/13		5	2	2.50	0.71					
	8/04		1	2	0.50	0.71					
17	6/05	Tow Net	4	15	0.53	1.60					
41	6/04		3	2	1.50	2.12					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
		BROAD WHITEFISH									
8	6/10	Beach Seine-150	14	2	7.00	9.90					
11	6/10	Beach Seine-75	6	2	3.00	4.24					
41	6/04	Tow Net	2	2	1.00	1.41					
		WHITEFISH SP.									
3	7/11	Tow Net	4	3	1.33	2.31					
4	7/14	Tow Net	1	3	0.33	0.58					
8	6/14	Beach Seine-150	4	2	2.00	0.00					
	6/17	Beach Seine-150	4	2	2.00	1.41					
	6/22	Beach Seine-150	7	2	3.50	4.95					
	6/24	Beach Seine-150	17	2	8.50	7.78					
	7/12	Beach Seine-150	24	2	12.00	1.41					
	8/04	Beach Seine-150	16	2	8.00	5.66					
9	6/25	Beach Seine-150	4	2	2.00	0.00					
	7/13	Beach Seine-150	2	2	1.00	1.41					
	8/04	Beach Seine-150	51	2	25.50	23.33					
10	8/05	Beach Seine-75	39	2	19.50	4.95					
11	6/17	Beach Seine-75	6	2	3.00	1.41					
	6/22	Beach Seine-75	1	2	0:50	0.71					
	6/24	Beach Seine-75	4	2	2.00	1.41					
	7/12	Beach Seine-75	4	2	2.00	0.00					
	8/04	Beach Seine-75	13	2	6.50	0.71					
12	6/2 5	Beach Seine-75	61	2	30.50	43.13					
	7/13	Beach Seine-75	3	2	1.50	0.71					
	8/04	Beach Seine-75	2	2	1.00	1.41					
13	6/04	Purse Seine	1	2	0.50	0.71	1	112.00	112	112	
	6/05	Purse Seine	1	2	0.50	0.71					
	6/18	Tow Net	2	3	0.67	0.58					
	7/12	Tow Net	8	3	2.67	1.53					
	8/08	Tow Net	1	5	0.20	0.45					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
17	6/17	Tow Net	2	3	0.67	1.15					
	6/22	Tow Net	3	3	1.00	0.00					
	6/26	Tow Net	1	3	0.33	0.58					
	7/10	Tow Net	25	3	8.33	1.15					
	7/12	Tow Net	101	3	33.67	24.66					
	7/13	Tow Net	101	3	33.67	19.43					
	8/05	Tow Net	9	3	3.00	0.00					
	8/07	Tow Net	4	3	1.33	0.58					
41	6/06	Tow Net	19	2	9.50	3.54					

BERING CISCO

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
9	6/25	Beach Seine-150	22	2	11.00	15.56					
	7/13	Beach Seine-150	2	2	1.00	1.41					
	8/04	Beach Seine-150	2	2	1.00	1.41					
10	8/05	Beach Seine-75	1	2	0.50	0.71					
11	6/22	Beach Seine-75	1	2	0.50	0.71					
12	8/04	Beach Seine-75	1	2	0.50	0.71					
41	6/06	Tow Net	15	2	7.50	10.61					

LEAST CISCO

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
1	8/06	Tow Net	1	3	0.33	0.58					
2	7/14	Tow Net	4	3	1.33	1.15					
	8/06	Tow Net	1	3	0.33	0.58					
3	6/19	Tow Net	2	3	0.67	0.58					
	8/06	Tow Net	1	3	0.33	0.58					
5	6/12	Tow Net	2	3	0.67	1.15					
	6/15	Tow Net	1	3	0.33	0.58					
	8/06	Tow Net	11	3	3.67	0.58					
6	6/12	Tow Net	11	3	3.67	3.21					
	6/15	Tow Net	23	3	7.67	10.02					
	6/19	Tow Net	1	3	0.33	0.58					
	8/06	Tow Net	2	3	0.67	0.58					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
8	6/10	Beach Seine-150	12	2	6.00	4.24					
	6/14	Beach Seine-150	6	2	3.00	1.41					
	6/17	Beach Seine-15(1	2	2	1.00	1.41					
	6/22	Beach Seine-150	6	2	3.00	0.00					
	6/24	Beach Seine-150	7	2	3.50	0.71					
9	6/25	Beach Seine-150	2	2	1.00	0.00					
	7/13	Beach Seine-150	4	2	2.00	0.00					
11	6/10	Beach Seine-75	1	2	0.50	0.71					
	6/17	Beach Seine-75	6	2	3.00	0.00					
	6/22	Beach Seine-75	5	2	2.50	3.54					
12	7/13	Beach Seine-75	11	2	5.50	7.78					
13	6/04	Purse Seine	8	2	4.00	5.66	8	221.50	73	297	68.37
	6/05	Purse Seine	13	2	6.50	6.36					
	6/09	Tow Net	1	3	0.33	0.58					
	6/13	Tow Net	1	3	0.33	0.58					
	6/14	Tow Net	1	6	0.33	0.82					
	8/07	Tow Net	5	3	1.67	2.89					
15	6/02	Tow Net	4	3	1.33	2.31					
16	5/31	Tow Net	2	1	2.00		2	92.50	74	111	26.16
17	6/05	Tow Net	1	15	0.13	0.52					
	6/09	Tow Net	5	3	1.67	2.08					
	6/24	Tow Net	2	3	0.67	0.58					
	8/07	Tow Net	7	3	2.33	1.53					
41	6/04	Tow Net	40	2	20.00	0.00					
	6/06	Tow Net	39	2	19.50	9.19					
					CISCO SP.						
1	7/11	Tow Net	34	2	17.00	8.49					
	7/14	Tow Net	38	3	12.67	2.08					
2	7/14	low Net	82	3	27.33	12.50					
3	7/11	Tow Net	449	3	149.67	49.66					
	7/14	Tow Net	26	3	8.67	3.21					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
4	7/11	Tow Net	55	2	27.50	9.19					
	7/14	Tow Net	91	3	30.33	9.29					
5	7/14	Tow Net	89	3	29.67	12.10					
6	7/11	Tow Net	601	2	300.50	113.84					
	7/14	Tow Net	61	3	20.33	3.51					
8	7/12	Beach Seine-150	1	2	0.50	0.71					
9	7/13	Beach Seine-150	3	2	1.50	2.12					
	8/04	Beach Seine-150	19	2	9.50	2.12					
11	6/14	Beach Seine-75	12	2	6.00	7.07					
	6/17	Beach Seine-75	1	2	0.50	0.71					
	6/22	Beach Seine-75	2	2	1.00	1.41					
	7/12	Beach Seine-75	4	2	2.00	0.00					
	8/04	Beach Seine-75	2	2	1.00	1.41					
12	7/13	Beach Seine-75	13	2	6.50	4.95					
	8/04	Beach Seine-75	1	2	0.50	0.71					
13	6/26	Tow Net	5	3	1.67	2.89					
	7/12	Tow Net	393	3	131.00	35.38					
	8/05	Tow Net	2	3	0.67	1.15					
	8/08	Tow Net	4	5	0.80	0.84					
17	6/24	Tow Net	8	3	2.67	1.53					
	6/26	Tow Net	7	3	2.33	4.04					
	7/10	Tow Net	104	3	34.67	9.87					
	7/12	Tow Net	397	3	132.33	48.64					
	7/13	Tow Net	353	3	117.67	24.95					
	8/05	Tow Net	7	3	2.33	1.15					
	8/08	Tow Net	12	4	3.00	0.82					
					WHITEFISH AND CISCO						
11	6/24	Beach Seine-75	13	2	6.50	3.54					
17	6/24	Tow Net	2	3	0.67	1.15					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
					BOREAL SMELT						
1	6/12	Tow Net	1	3	0.33	0.58					
	6/15	Tow Net	1	3	0.33	0.58					
	6/19	Tow Net	335	3	111.67	52.32					
2	6/15	Tow Net		3	0.67	0.58					
	6/19	Tow Net	14:	3	48.67	45.83					
3	6/19	Tow Net	24	3	8.00	8.54					
4	6/19	Tow Net	408	3	136.00	28.16					
5	6/12	Tow Net	2	3	0.67	1.15					
	6/15	Tow Net	4	3	1.33	0.58					
	6/19	Tow Net	633	3	211.00	43.14					
6	6/12	Tow Net	240	3	80.00	61.58					
	6/19	Tow Net	853	3	284.33	140.20					
13	6/05	Purse Seine	2	2	1.00	0.00					
	6/09	Tow Net	2	3	0.67	0.58					
	6/13	Tow Net	1	3	0.33	0.58					
41	6/04	Tow Net	129	2	64.50	34.65					
	6/06	Tow Net	286	2	143.00	4.24					
51	6/06	Tow Net	9	2	4.50	2.12					
					SMELT SP.						
1	6/06	Tow Net	15	2	7.50	0.71					
	7/11	Tow Net	1	2	912.50	95.46					
	7/14	Tow Net	151	3	50.33	26.41					
	8/06	Tow Net	235	3	78.33	46.46					
2	7/14	Tow Net	710	3	236.67	45.96					
	8/06	Tow Net	165	3	55.00	21.79					
3	7/11	Tow Net	233	3	77.67	69.76					
	7/14	Tow Net	565	3	188.33	37.53					
	8/06	Tow Net	315	3	105.00	21.79					
4	7/11	Tow Net	1	2	630.00	346.48					
	7/14	Tow Net	1	3	518.33	140.12					

APPENDIX B (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
5	7/14	Tow Net	475	3	158.33	59.23					
	8/06	Tow Net	180	3	60.00	26.46					
6	6/15	Tow Net	184	3	61.33	51.78					
	7/11	Tow Net	793	2	396.50	178.90					
	7/14	Tow Net	320	3	107.00	2.88					
	8/06	Tow Net	23	3	7.67	2.31					
8	6/14	Beach Seine-150	1	2	0.50	0.71					

THREESPINE STICKLEBACK

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
12	7/13	Beach Seine-75	12	2	6.00	7.07					
	8/04	Beach Seine-75	2	2	1.00	1.41					

NINESPINE STICKLEBACK

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
1	6/06	Tow Net	106	2	53.00	38.18					
	6/12	Tow Net	1	3	346.67	92.22					
	6/15	Tow Net	457	3	152.33	32.59					
	6/19	Tow Net	1	3	356.67	141.45					
	7/11	Tow Net	23	2	11.50	0.71					
	7/14	Tow Net	274	3	91.33	23.07					
	8/06	Tow Net	165	3	55.00	22.91					
2	6/12	Tow Net	974	3	324.67	239.06					
	6/15	Tow Net	805	3	268.33	110.95					
	6/19	Tow Net	1	3	548.00	266.57					
	7/14	Tow Net	256	3	85.33	91.53					
	8/06	Tow Net	115	3	38.33	10.41					
3	6/12	Tow Net	409	3	136.33	158.34					
	6/15	Tow Net	12	3	4.00	1.00					
	6/19	Tow Net	1	3	423.33	248.71					
	7/11	Tow Net	292	3	97.33	57.13					
	7/14	Tow Net	57	3	19.00	4.58					
	8/06	Tow Net	140	3	46.67	16.07					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
4	6/12	Tow Net	746	3	248.67	69.01					
	6/15	Tow Net	115	3	38.33	11.72					
	6/19	Tow Net	237	3	79.00	61.51					
	7/11	Tow Net	2	2	1.00	0.00					
	7/14	Tow Net	3	3	1.00	1.00					
5	6/12	Tow Net	1	3	470.67	412.85					
	6/15	Tow Net	489	3	163.00	41.90					
	6/19	Tow Net		3	343.33	335.31					
	7/14	Tow Net	20;	3	69.00	104.85					
	8/06	Tow Net	90	3	30.00	30.41					
6	6/12	Tow Net	21	3	7.00	3.46					
	6/15	Tow Net	85	3	28.33	18.90					
	6/19	Tow Net	373	3	124.33	5.51					
	7/11	Tow Net	163	2	81.50	45.96					
	8/06	Tow Net	20	3	6.67	0.58					
8	6/10	Beach Seine-150	18	2	9.00	5.66					
	6/14	Beach Seine-150	7	2	3.50	3.54					
	6/17	Beach Seine-150	3	2	1.50	0.71					
	6/22	Beach Seine-150	4	2	2.00	2.83					
	6/24	Beach Seine-150	2	2	1.00	0.00					
	8/04	Beach Seine-150	1	2	0.50	0.71					
9	6/25	Beach Seine-150	1	2	0.50	0.71					
	8/04	Beach Seine-15(1	8	2	4.00	5.66					
10	8/05	Beach Seine-75	840	2	420.00	113.14					
10	8/05	Beach Seine-75	840	2	420.00	113.14					
11	6/10		9	2	4.50	2.12					
	6/14		15	2	7.50	0.71					
	6/17		6	2	3.00	1.41					
	6/24		3	2	1.50	2.12					
	8/04		1	2	0.50	0.71					
12	6/25		1	2	0.50	0.71					
	7/13		4	2	2.00	2.83					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
	8/04		736	2	368.00	45.25					
21	6/06	Tow Net	8	3	2.67	0.58					
41	6/04		42	2	21.00	9.90					
	6/06		452	2	226.00	96.17					
51	6/06		13	2	6.50	0.71					
				ARCTIC LAMPREY							
1	6/12		12	3	4.00	3.61					
	6/15		17	3	5.67	3.06					
	6/19		49	3	16.33	10.02					
	7/14		3	3	1.00	1.00					
2	6/12		11	3	3.67	3.21					
	6/15		41	3	13.67	2.89					
	6/19		53	3	17.67	1.53					
	7/14		2	3	0.67	1.15					
3	6/19		9	3	3.00	0.00					
	7/11		14	3	4.67	2.08					
4	6/12		14	3	4.67	4.04					
	6/15		16	3	5.33	3.06					
	6/19		25	3	8.33	1.53					
	7/11		1	2	0.50	0.71					
5	6/12		14	3	4.67	1.53					
	6/15		32	3	10.67	4.04					
	6/19		38	3	12.67	2.31					
	7/14		1	3	0.33	0.58					
6	6/12		3	3	1.00	1.00					
	6/19		11	3	3.67	1.15					
13	6/09		9	3	3.00	3.00					
	6/13		13	3	4.33	5.86					
	6/14		35	6	11.67	6.86					
	6/17		234	3	78.00	14.00					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
	6/18		121	3	40.33	18.34					
	6/20		41	5	16.40	3.58					
	6/22		42	3	14.00	5.20					
	6/24		48	3	16.00	4.36					
	6/26		29	3	9.67	11.24					
17	6/08		3	3	1.00	0.00					
	6/13		1	3	0.33	0.58					
	6/14		5	3	1.67	1.53					
	6/17		9	3	3.00	2.65					
	6/18		16	3	5.33	5.03					
	6/20		14	3	4.67	3.06					
	6/22		5	3	1.67	1.53					
	6/24		1	3	0.33	0.58					
	6/26		4	3	1.33	1.53					
41	6/06		1	2	0.50	0.71					

LAMPREY Sp.

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
4	7/14		1	3	0.33	0.58					
13	6/04		2	3	0.67	0.58					
	6/05		2	3	0.67	1.15					
14	6/01		22	7	3.14	2.67					
17	6/05		1	15	0.07	0.26					

LONGNOSE SUCKER

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
8	6/17	Beach Seine-150	11	2	5.50	4.95					
	6/22		6	2	3.00	2.83					
13	6/05	Purse Seine	1	2	0.50	0.71					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
					NORTHERN PIKE						
11	6/17	Beach Seine-75	1	2	0.50	0.71					
					BURBOT						
1	7/14	Tow Net	1	3	0.33	0.58					
2	6/12		1	3	0.33	0.58					
8	6/10	Beach Seine-150	2	2	1.00	1.41					
	6/14		1	2	0.50	0.71					
	6/17		4	2	2.00	1.41					
	7/12		3	2	1.50	0.71					
	8/04		1	2	0.50	0.71					
9	6/25		4	2	2.00	0.00					
11	6/10	Beach Seine-75	5	2	2.50	0.71					
	6/14		16	2	8.00	1.41					
	6/17		1	2	0.50	0.71					
	6/22		2	2	1.00	1.41					
	6/24		2	2	1.00	1.41					
	7/12		3	2	1.50	0.71					
	8/04		7	2	3.50	0.71					
12	6/25		3	2	1.50	0.71					
	7/13		5	2	2.50	2.12					
	8/04		4	2	2.00	1.41					
13	6/04	Tow Net	1	3	0.33	0.58					
	6/04	Purse Seine	6	2	3.00	1.41	6	137.67	70	245	71.59
	6/05	Tow Net	1	3	0.33	0.58					
	6/05	Purse Seine	1	2	0.50	0.71					
	7/12	Tow Net	5	3	1.67	2.08					
14	6/01		8	7	1.14	1.46					
17	6/05		9	15	1.20	1.82					
	7/10		4	3	1.33	1.15					
	7/13		5	3	1.67	1.53					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
	8/05		1	3	0.33	0.58					
	8/07		1	3	0.33	0.58					
21	6/06		2	3	0.67	0.58					
41	6/04		54	2	27.00	11.31					
	6/06		116	2	58.00	7.07					
					STARRY FLOUNDER						
1	6/19		1	3	0.33	0.58					
2	7/14		1	3	0.33	0.58					
	8/06		1	3	0.33	0.58					
4	6/15		1	3	0.33	0.58					
6	7/14		1	3	0.33	0.58					
9	6/25	Beach Seine-150	1	2	0.50	0.71					
	8/04		42	2	21.00	1.41					
41	6/06	Tow Net	5	2	2.50	0.71					
					ARCTIC FLOUNDER						
1	7/11		1	2	0.50	0.71					
	8/06		1	3	0.33	0.58					
2	8/06		1	3	0.33	0.58					
3	6/19		4	3	1.33	1.53					
4	6/15		4	3	1.33	0.58					
	6/19		15	3	5.00	0.00					
	7/11		7	2	3.50	0.71					
5	7/14		2	3	0.67	0.58					
6	6/19		1	3	0.33	0.58					
	7/11		18	2	9.00	9.90					
9	6/25	Beach Seine-150	7	2	3.50	0.71					
	8/04		18	2	9.00	0.00					
10	8/05	Beach Seine-75	176	2	88.00	66.47					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
					SAFFRON COD						
1	6/19	Tow Net	50	3	16.67	3.51					
	7/14		3	3	1.00	1.73					
	8/06		25	3	8.33	7.02					
2	6/19		57	3	19.00	3.00					
	7/14		1	3	0.33	0.58					
	8/06		6	3	2.00	2.65					
3	6/12		2	3	0.67	1.15					
	6/19		18	3	6.00	1.73					
	7/11		11	3	3.67	4.04					
4	6/19		4	3	1.33	0.58					
	7/-14		2	3	0.67	0.58					
5	6/12		1	3	0.33	0.58					
	6/19		4	3	1.33	1.15					
	8/06		1	3	0.33	0.58					
6	6/12		3	3	1.00	1.00					
	6/19		6	3	2.00	1.73					
	7/11		2	2	1.00	0.00					
9	6/25	Beach Seine-150	1	2	0.50	0.71					
					ARCTIC COD						
1	6/15	Tow Net	1	3	0.33	0.58					
2	6/15		1	3	0.33	0.58					
4	6/15		1	3	0.33	0.58					
5	6/15		7	3	2.33	2.08					
41	6/06		19	2	9.50	13.44					
.51	6/06		1	2	0.50	0.71					

APPENDIXB (Continued)

Station	Date	Gear	Catch	Reps	CPUE	SD Catch	N	Mean Length	Minimum Length	Maximum Length	SD Length
FOURHORN SCULPIN											
1	8/06		1	3	0.33	0.58					
2	7/14		1	3	0.33	0.58					
3	7/11		2	3	0.67	1.15					
4	6/19		4	3	1.33	0.58					
5	6/19		1	3	0.33	0.58					
	7/14		1	3	0.33	0.58					
6	7/14		1	3	0.33	0.58					
10	8/05	Beach Seine-75	7	2	3.50	0.71					
SCULPIN Sp.											
2	7/14	Tow Net	1	3	0.33	0.58					
4	6/12		1	3	0.33	0.58					
PACIFIC HERRING											
1	6/19		11	3	3.67	3.51					
	7/11		46	2	23.00	5.66					
	7/14		140	3	46.67	20.11					
	8/06		1	3	0.33	0.58					
2	6/15		7	3	2.33	1.53					
	6/19		56	3	18.67	2.08					
	7/14		91	3	30.33	19.86					
	8/06		11	3	3.67	2.52					
3	6/12		1	3	0.33	0.58					
	6/19		9	3	3.00	2.65					
	7/11		70	3	23.33	26.41					
	7/14		14	3	4.67	4.16					
	8/06		25	3	8.33	7.57					
4	6/12		1	3	0.33	0.58					

APPENDIXB (Continued]

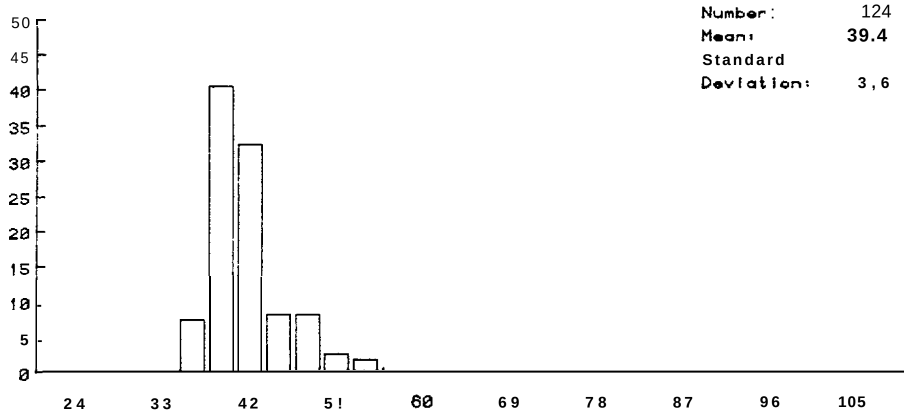
Station	Date	Gear	Catch	Reps	CPUE	SD' Catch	N	Mean Len gth	Minimum Length	Maximum Len gth	SD Length
	7/11		7	2	3.50	0.71					
	7/14		2	3	0.67	0.58					
5	6/12		6	3	2.00	1.73					
	6/15		24	3	8.00	3.61					
	6/19		2	3	0.67	0.58					
	8/06		1	3	0.33	0.58					
6	6/12		22	3	7.33	6.66					
	6/15		53	3	17.67	18.90					
21	6/06		16	3	5.33	4.04					
51	6/06		1	2	0.50	0.71					
					POACHER SP.						
3	8/06		1	1	1.00						
					PRICKLEBACK Sp.						
2	6/15		1	3	0.33	0.58					
3	6/19		1	3	0.33	0.58					
	7/11		1	3	0.33	0.58					
5	8/06		1	3	0.33	0.58					
6	8/06		1	3	0.33	0.58					
					GREENLING						
1	8/06		1	3	0.33	0.58					
2	8/06		1	3	0.33	0.58					
3	8/06		1	3	0.33	0.58					
					SANDLANCE						
2	6/19		1	3	0.33	0.58					
3	8/06		2	3	0.67	0.58					

APPENDIX C

LENGTH FREQUENCY OF JUVENILE CHUM SALMON
BY STATION AND TIME PERIOD DURING SUMMER 1986

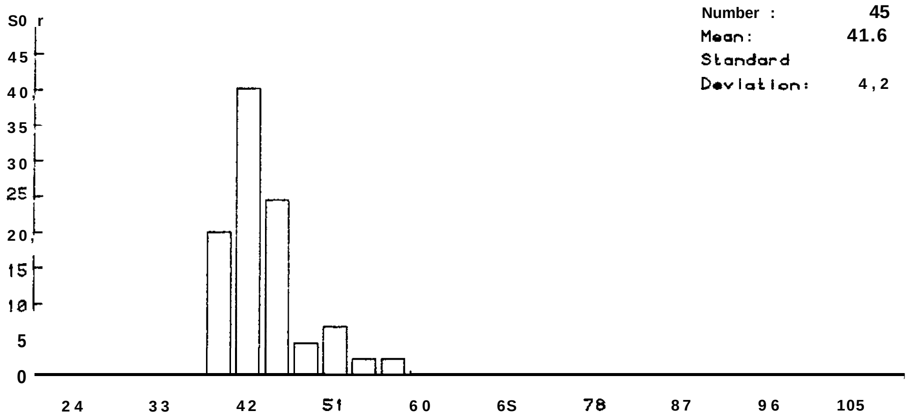
STATION 1
CHUM SALMON

6/12/86 TO 6/15/86

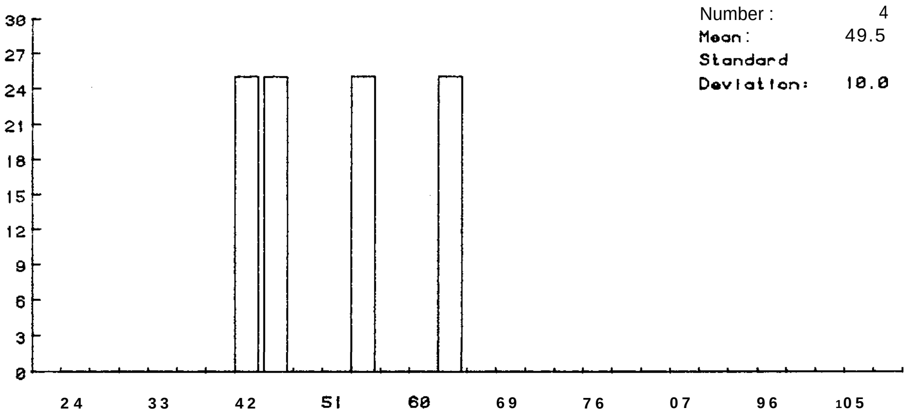


PERCENT

6/17/86 To 6/20/86



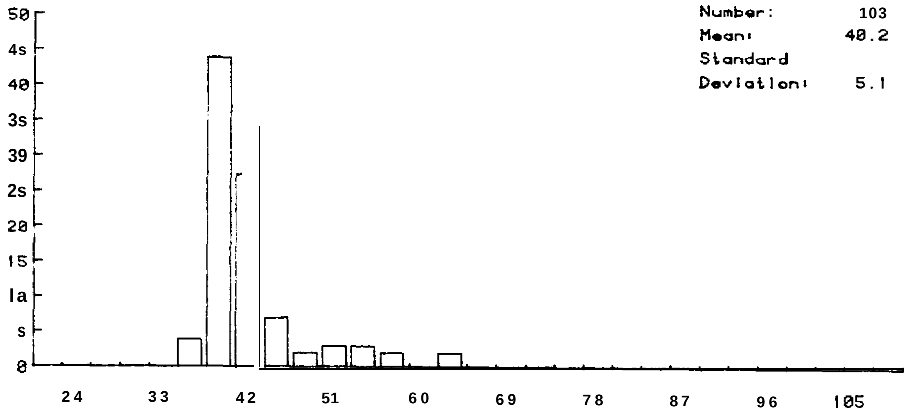
7/10/86 TO 7/14/86



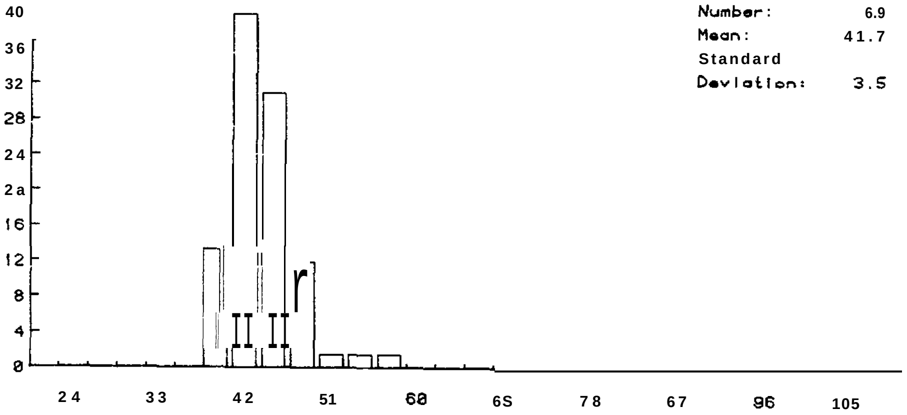
FORK LENGTH IN 3 MM GROUPS

STATION 2
CHUM SALMON

6/ 12/s6 TO 6/ 15/86



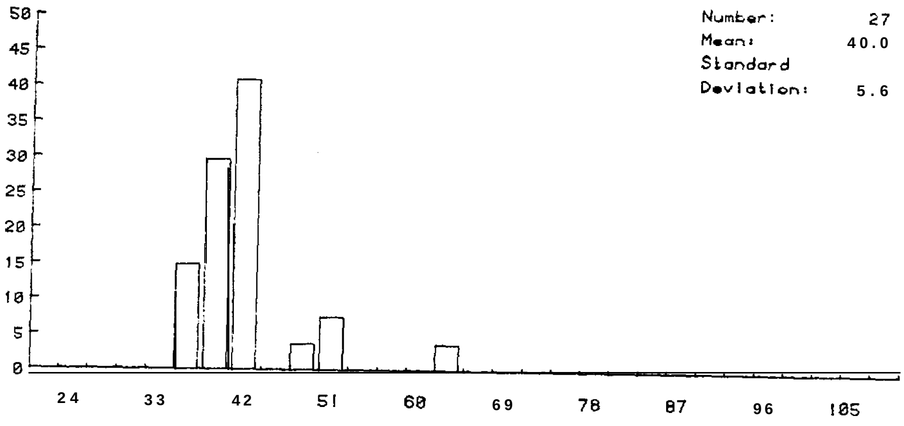
6/ 17/86 TO 6/20/86



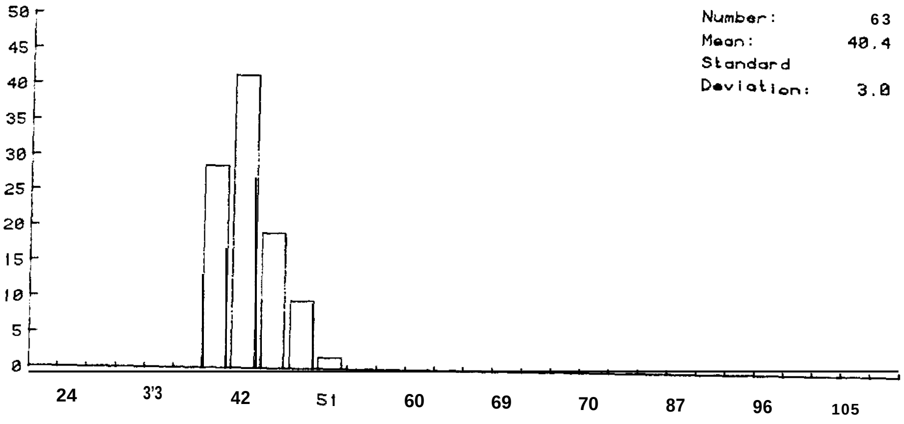
FORK LENGTH IN 3 MM GROUPS

STATION 3
CHUM SALMON

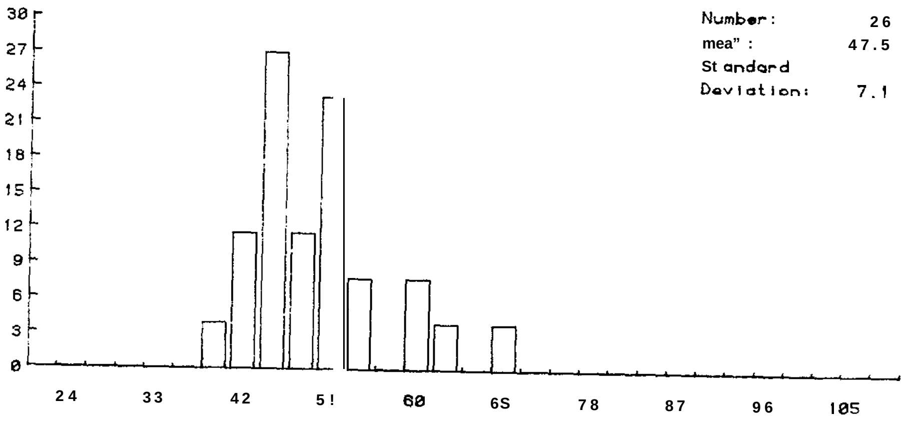
6/12/86 TO 6/15/86



6/17/86 TO 6/20/86

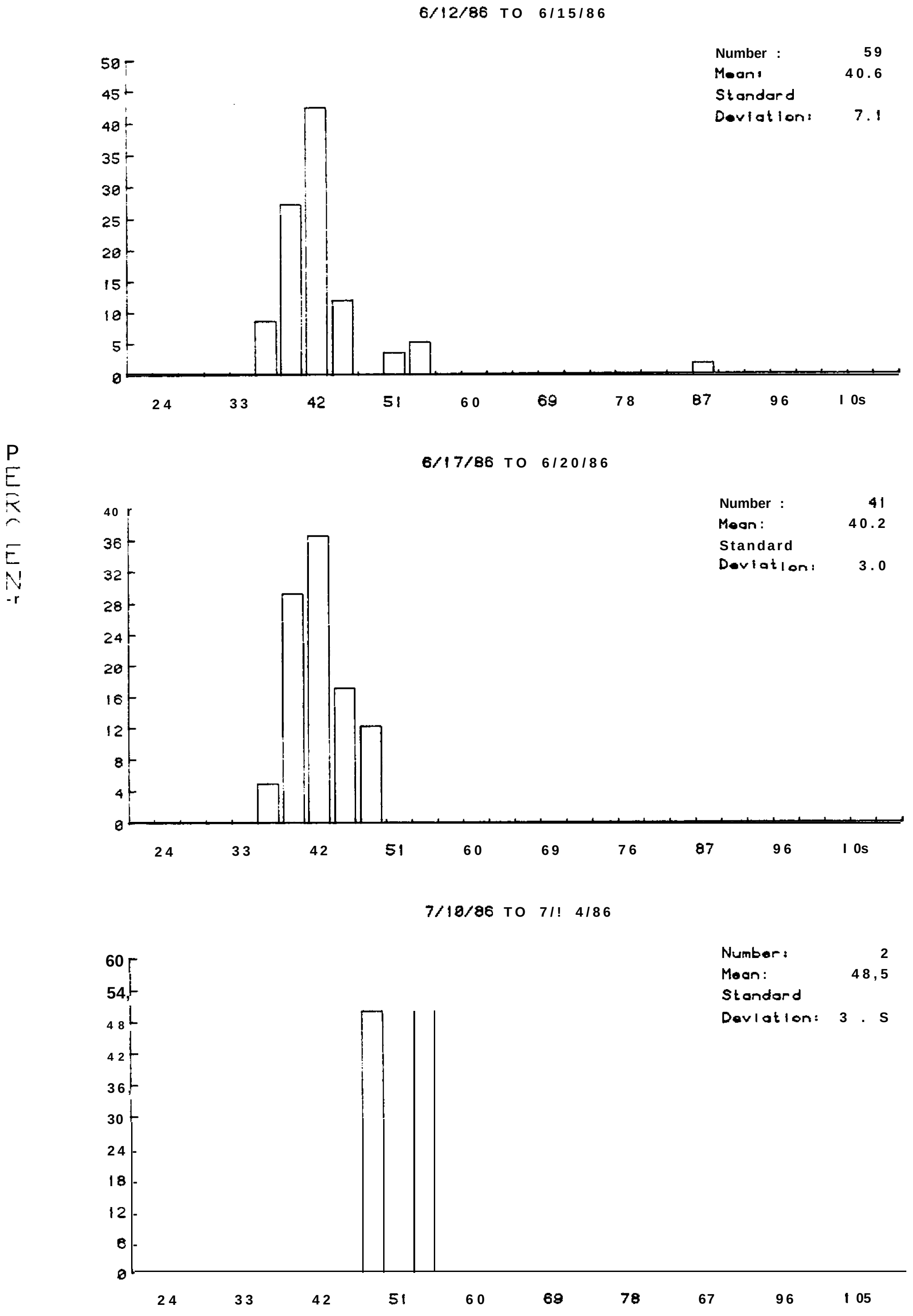


7/10/86 TO 7/14/86



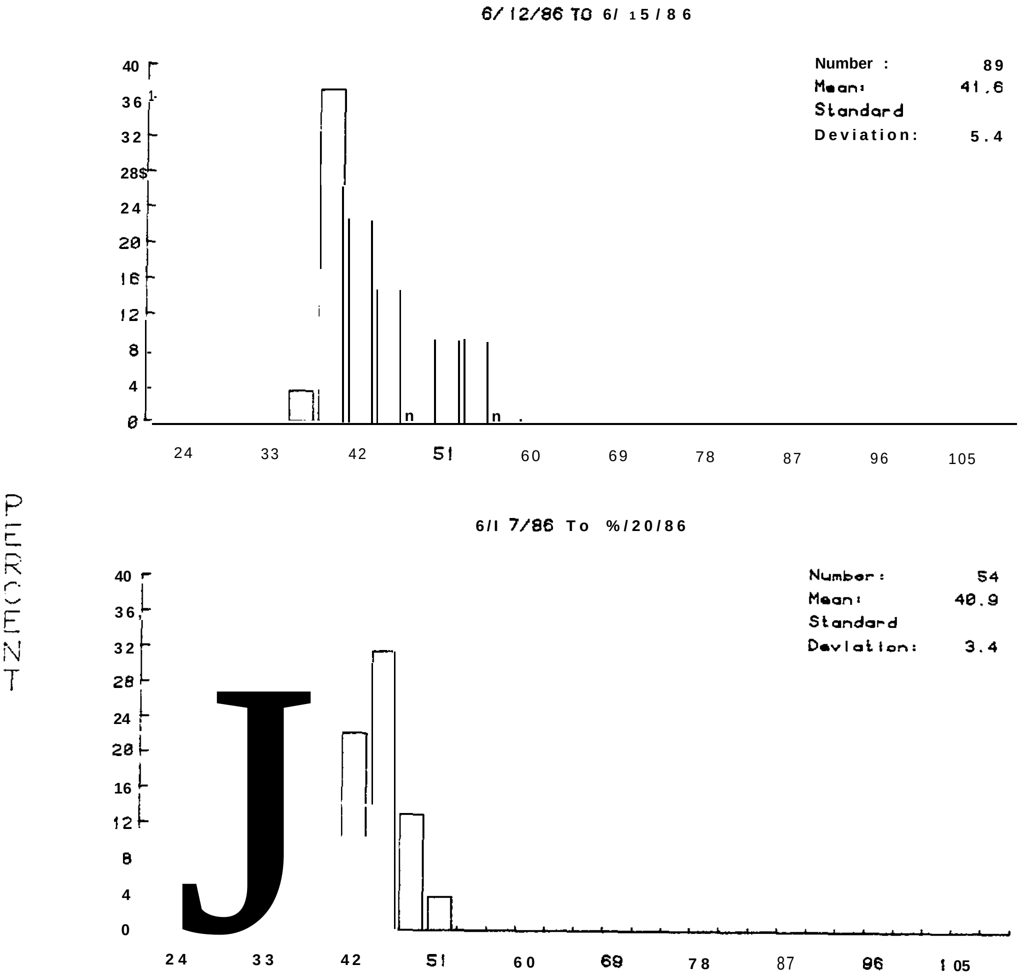
FORK LENGTH IN 3 MM GROUPS

STATION 4
CHUM SALMON



FORK LENGTH IN 3 MM GROUPS

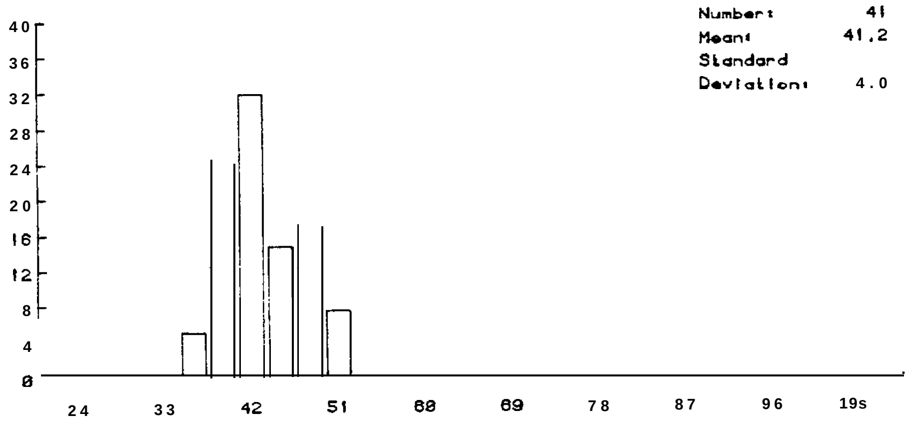
STATION 5
CHUM SALMON



FORK LENGTH IN 3 MM GROUPS

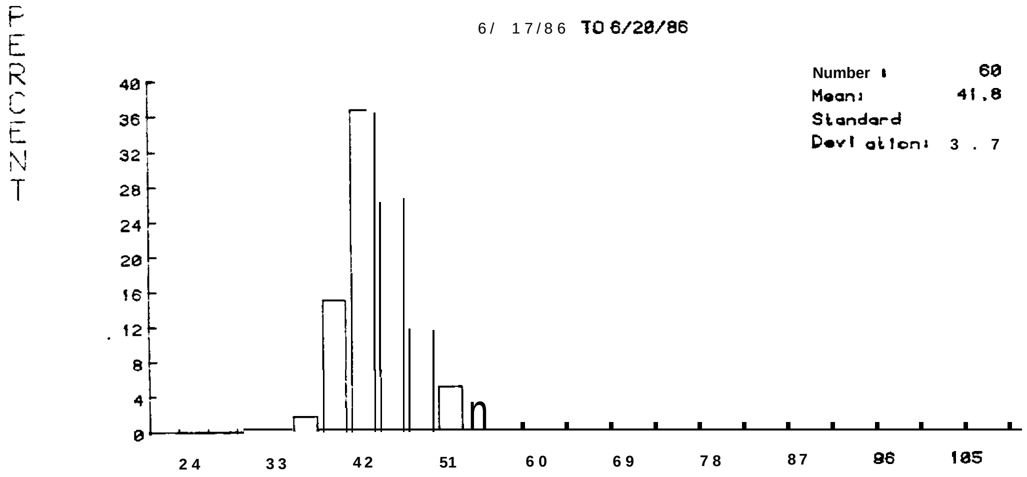
STATION 6
CHUM SALMON

6/12/86 TO 6/15/86



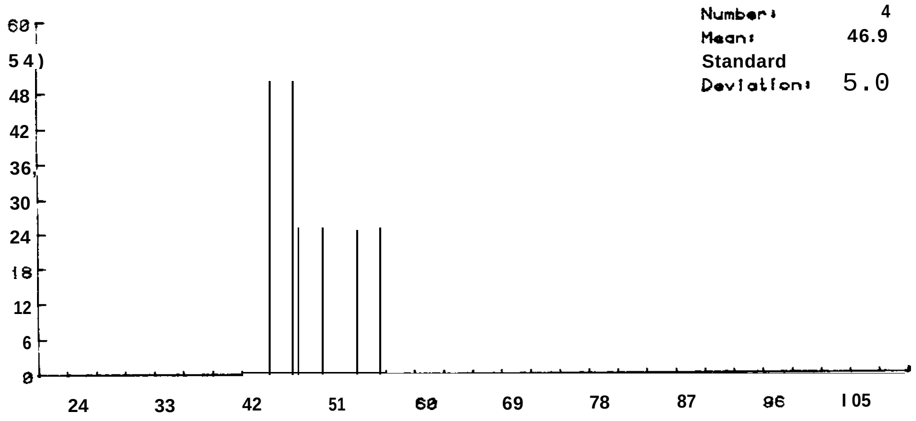
Number: 41
Mean: 41.2
Standard Deviation: 4.0

6/17/86 TO 6/20/86



Number: 60
Mean: 41.8
Standard Deviation: 3.7

7/10/86 TO 7/14/86



Number: 4
Mean: 46.9
Standard Deviation: 5.0

FORK LENGTH IN 3 MM GROUPS