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Data-Based Decision-Making is Essential for Effective Feral Pig Management in Australia

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ABSTRACT: Australia's *National Feral Pig Action Plan 2021-2031* is the first national strategy to reduce the extensive and diverse impacts caused by feral pigs to Australia's environmental, agricultural, cultural and social assets by actively suppressing feral pig populations over time. Its development was instigated in response to growing threats of an exotic disease incursion, particularly African swine fever to the Australian pork industry. It provides a national framework for alignment of state, regional and local strategic feral pig management plans. The Plan was endorsed by Australia's National Biosecurity Committee in October 2021 and aims to encourage land managers to work together in coordinated groups on a landscape scale, cross tenure basis, and strategically apply the most appropriate combinations of best practice management methods for their region (National Feral Pig Action Plan 2021). Its 10-year time frame reflects the long time required to reduce impacts from feral pigs, and their populations, as well as the enormity of the task. Many stakeholders, including governments, agricultural industries, natural resource management organisations, universities, Indigenous organisations, private land managers and not for profit environmental conservation managers are being engaged to support the Plan's implementation. In Australia, how feral pig management is being undertaken needs to shift from being fragmented, *ad hoc* and reactive to be more coordinated, collaborative, strategic, and proactive; with activities supported by strong and trusted partnerships between all land managers. This paper discusses several initiatives being undertaken to support the implementation of the *National Feral Pig Action Plan 2021-2031*. These initiatives are principally directed at improving the efficacy and efficiency of on-ground best practice management actions by land managers by influencing practice and behaviour change and undertaking monitoring to fill significant data and knowledge gaps.

KEY WORDS: Australia, coordination, feral pigs, impacts, land managers, management, monitoring, *Sus scrofa*

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INTRODUCTION

In all Australian states and territories, all land managers are legally required to manage feral pigs present on their land as they are classified as an established pest animal. This means all land managers, both public and private, must take all reasonable steps to remove feral pigs on their land to minimise biosecurity threats to comply with Australian state and territory legislation. The most successful feral pig control programs involve long term efforts of many people working together conducting planned activities at the same time across a large area, rather than just on individual properties.

In many instances, land manager's engagement in coordinated groups and their management efforts are being hampered by a lack of knowledge of feral pig impacts, population size and distribution, preferred locations, and/or spatial and temporal movement in the landscape. Addressing the human dimension element is equally important. The management of feral pigs at a landscape scale can be significantly hampered by limited participation of land managers in community-led groups (Marshall et al. 2023).

Strong communication, program longevity, information sharing and trusted relationships between land managers, supported by a local facilitator, are integral to running successful programs, maintaining land manager engagement, and achieving sustained reductions in feral pig populations. Increasingly, technology is being used to

capture information to support adaptive feral pig management and continuous improvement in reducing feral pig impacts. Difficulties in knowing how and what to measure so that changes in feral pig impacts to different asset classes can be monitored over time are real and need to be addressed.

In January 2020, the Australian Government's Department of Agriculture, Fisheries and Forestry provided funding for the National Feral Pig Management Coordination Program to Australian Pork Limited (the producer owned body for the Australian pork industry). This initiative was in response to the ongoing threat of African swine fever entering into Australia. The key goals of the National Feral Pig Management Coordination Program, together with those of the *National Feral Pig Action Plan 2021-2031*, reflect the myriad of changes that are needed to make long term reductions in feral pig impacts (National Feral Pig Action Plan 2021).

Australia's Feral Pig Problem - Population Distribution and Density

Australia's feral pig problem is not new. It originates from the First Fleet in 1788 when pigs were first brought to Australia, escaping fencing and going feral not long after their introduction (Choquenot et al. 1995). It has been estimated that up to 45% of Australia's land mass, or 3.43 million square kilometers, is inhabited by feral pigs (West, 2008). Feral pigs are most abundant near wetlands, flood

plains and associated watercourses due to supporting thermoregulation. Their reliance on water and suitable vegetation for food and shelter has limited their expansion into Australia's arid interior. Feral pig populations are widely distributed throughout northern and eastern Australia, as well as in southern Western Australia. Population distribution and density maps are being updated by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES).

The abundance of feral pigs was re-estimated in 2020 using data from 30 published studies (Hone 2019) and estimated to vary from 2.4 million to 4.4 million, with an average population of 3.2 million and a density of 1.03 pigs per square kilometer. The impact of favourable weather conditions that have been experienced in many regions across Australia has led to a surge in feral pig populations. Whilst the size of the change in population densities are not known, many land managers continue to experience (and report) significant impacts from feral pigs.

Feral pigs are mobile in their home range and disregard fencelines and property boundaries. It's critical that feral pig control programs are conducted at a landscape scale and on an ongoing basis, rather than just on individual properties. Land managers working together in coordinated ways on a landscape scale has been shown to be most effective way of managing vertebrate pests and their impacts, including wild dog management in Australia (National Wild Dog Action Plan 2020). Burgeoning feral pig populations in many regions across Australia over the past three years in response to La Nina weather events have emphasised that consistent and collective feral pig management by land managers, supported by solid communication between them, is crucial to overcome the intelligence, adaptiveness and resilience of the feral pig.

Feral Pig Ecology and Behaviour

As pigs cannot sweat, they are dependent on water to regulate their body temperature. In Australia, very few pigs are therefore found more than two kilometers from water, particularly during dry periods (Hone and Atkinson, 1983). Sows become sexually mature at around 25 kg liveweight at around six months of age and can produce two weaned litters every 12-15 months. Litter size can be 4-10 piglets depending on age, weight, and food supply of the sow. Feral pigs generally live less than five years. The mortality of piglets is relatively high during their first year, particularly during drought. Feral pigs can increase their population size by more than 85% under favourable seasonal conditions (Choquenot et al. 1996).

The diet of feral pigs is varied, highly flexible and opportunistic as they are generalist omnivores. Their varied and flexible diet results in sporadic, often seasonal, impacts as they identify and utilise different available food sources. The majority of their diet has been shown to be comprised of vegetative material (Gentle et al. 2015) including cereal and pulse crops, fruits, nuts and seeds, bulbs, yams, rhizomes and tubers, fungus, flowers, foliage and stems, as well as invertebrates (e.g., earthworms, insects, and crustaceans) and vertebrates (e.g. lambs, kid goats and calves, amphibians, native mammals, marine and freshwater turtles and their eggs, and ground nesting birds and their eggs). This behaviour means that it is very difficult to

monitor impacts on specific assets in particular areas over time.

Feral Pig Impacts

Feral pig impacts to Australia's environmental, agricultural, cultural, and social assets are broad and significant (National Feral Pig Action Plan 2021). Sheep meat, wool, beef, horticulture, sugar, banana, cotton, grain and pulse industries are the major agricultural sectors in Australia affected by feral pigs. In relation to livestock industries, feral pigs may predate lambs and calves, and cause productivity and profitability losses through disease transmission, contamination of water sources and pasture destruction. Crop destruction, yield loss and land degradation are major issues experienced by grain, cotton and horticultural producers. Infrastructure including fencing, water troughs and dams can be damaged through their behavioural activity. From an environmental perspective, they threaten, and impact, native ecosystems, biodiversity, water quality, and can spread weeds and diseases. Culturally, feral pigs can damage Indigenous artifacts, rock art, places of cultural significance and heritage through their rubbing, wallowing, digging and feeding behaviours (Perry et al. 2021). The National Threat Abatement Plan for predation, habitat degradation, competition, and disease transmission by feral pigs (Commonwealth of Australia 2017) identified 148 species of threatened flora and fauna and eight threatened ecological communities as being adversely affected by feral pigs.

Additionally, feral pigs may play a role in the transmission of exotic diseases (including foot and mouth disease and African swine fever), endemic diseases, and zoonotic diseases to other livestock, plants, wildlife, and humans. Feral pigs can be implicated in the spread of zoonotic diseases to domestic livestock and humans in Australia, including Q fever, leptospirosis, brucellosis, melioidosis, tuberculosis, salmonella, porcine parvovirus, Japanese encephalitis, Murray Valley encephalitis and sparganosis (Choquenot et al. 1996, Heymann 2008). A large multi-state incursion of foot and mouth disease (across the beef, sheepmeat, pork, wool, and dairy industries) has been estimated to cost in excess of A\$80 billion to the Australian economy (in 2020-21 with a 3% discount rate) (Hone et al. 2022). Furthermore, a large outbreak of African swine fever could cost the Australian pork industry alone more than A\$2 billion under a high spread scenario over five years (ACIL Allen Consulting 2019). To better predict the potential role of the feral pig in the transmission of African swine fever, feral pig population and disease spread pathway information is being incorporated into the Australian Animal Disease Spread Model (Bradhurst et al. 2021) and work is underway through the Center of Excellence in Biosecurity Risk Analysis for FMD (Richard Bradhurst, pers. comm.). Feral pigs may complicate disease eradication and proof of freedom surveillance in the event of an exotic disease outbreak in Australia for which feral pigs may be susceptible. The involvement of feral pigs in an outbreak could delay detection of the disease and increase the rate or the extent of the spread of the outbreak. Feral pig populations acting as a reservoir could make disease eradication measures expensive, time-consuming, and potentially impossible. Feral pigs are also implicated in the

transmission of both Panama Disease tropical race 4 in bananas in Queensland and *Phytophthora cinnamomi* that causes dieback in a range of native, forestry, ornamental, and horticultural plants, threatening Australian biodiversity, ecosystems and agricultural industries (Li et al. 2014).

Management and Monitoring Challenges Faced by Land Managers

As stated by Bengsen et al. (2014), published annual maximum rates of population growth estimates (r_{max}) indicate that between 55-70% of feral pig populations need to be removed annually just to keep it stable. Further to this, Gentle and Pople (2013) considered that population reductions of at least 70% must be achieved to suppress populations, prevent rapid population recovery and achieve sustained reductions in impacts on assets. Due to constraints with surveillance methodologies and their costs, the majority of programs do not involve pre- and post- cull monitoring of populations to measure population change over time. It is therefore not possible to determine whether management programs achieved desired outcomes and effort from land managers was worthwhile.

Management is significantly constrained by lack of local intelligence on feral pig populations present, where they are and the extent of their impacts (Gentle et al. 2019). The lack of practical, meaningful, and reliable data that can be used to inform management programs is an enormous shortcoming that exists for the majority of feral pig management programs in Australia (Perry et al. 2021). It is not possible to manage what is not being measured. Data collected by most programs is poor, primarily focussed on numbers removed (rather than impact reduction), and not generally shared.

When preparing management plans, land managers are actively encouraged to consider what can be monitored (Koichi et al. 2020). It is clear that land managers cannot keep doing the same things and expect different results. Collectively, the group needs to decide on what the key assets being damaged by pigs are, what could be measured to assess change over time, and whether technology could be usefully applied to collect, record and report data.

Economic Costs of Feral Pig Impacts to Australian Agriculture

The cost of feral pigs to Australian agriculture (including infrastructure costs) was recently estimated by ABARES (Hafi et al. 2023). Based on private landholder responses to the ABARES 2019 Pest Animal and Weed Management Survey, private expenditure on feral pig management was estimated at A\$110 million whilst the average residual agricultural losses to major production systems over five years was estimated at A\$46 million (in 2020-21 dollars). While this national estimate represented the best high-level estimates currently available, there is considerable uncertainty in the results due to a significant lack of reliable data. This recent estimate is only A\$50 million higher than the A\$106.5 million estimate determined by Bomford and Hart (2002).

The national pest animal and weeds survey conducted by ABARES aims to understand problems, impacts and management actions used on agricultural properties and in their local area (Stenekes et al. 2023). In 2022, 26% of land

managers (n=5,380 from the horticulture, broadacre) stated that they experienced minor or major problems with feral pigs on their properties. A total of 16% of land managers surveyed spent an average of \$3,758 on feral pig management during 2022, an increase of \$1,700 compared with 2016.

Information detailing specific benefits from effective feral pig management across different assets is key to engaging and motivating private and public land managers, communities and wider stakeholders to work proactively together (National Feral Pig Action Plan 2023a). Economic costs of damage caused by feral pigs are not being routinely or consistently collected by most management programs. For this to change, a number of major impediments will need to be overcome. Firstly, simple and meaningful performance measures to collect feral pig impact data do not exist reflecting the sporadic and diverse nature of damage, different land uses, and the ability to definitely identify feral pig activity as the cause of the impact(s). Secondly, methodologies that enable data to be easily, consistently and simply collected, recorded and reported over time need to be developed. Thirdly, a centralised reporting system to capture, store and analyse aggregated management data does not exist and will need to be developed, together with agreed governance/business rules in place that describes the conditions of use, access and ownership. These actions have been identified as key priorities of the *National Feral Pig Action Plan 2021-2031* but will require significant investment to achieve and time to maximise the adoption of these systems.

In addition to this national estimate, only two known studies since 2020 have estimated costs of economic damage caused by feral pigs - in the Whitsunday Regional Council area in north Queensland (Synergies Economic Consulting 2020) and North West New South Wales (NSW; Powell 2024). For the Whitsunday study, economic losses from feral pigs across sugarcane, grazing and horticultural land use was estimated at A\$12.5 million per year in 2020/21. Annual losses to beef producers alone from feral pigs in the Whitsunday Regional Council region were estimated to be between A\$1.7-\$4.2 million, resulting from reduced sale weights and weaning rates, loss of pasture and water infrastructure, and vaccination costs for leptospirosis (Synergies Economic Consulting 2020). An analysis commissioned by NSW North West Local Land Services (Powell 2024) identified that agricultural businesses in this region lost A\$62 million due to feral pig activity, an increase of 32% compared with 2020/21. Compared with 2021/22, anticipated damage by feral pigs (as a percentage of yield) were higher for barley, chickpeas, faba beans, maize, sorghum, sheep and wheat. Losses to sheep enterprises due to lamb losses were estimated at just over A\$10 million, using a 12% lamb loss rate and an opportunity cost of A\$171/head for each lamb lost.

Earlier published studies estimated production losses caused by feral pigs. For example, Tisdell (1982) estimated production losses of 3% in wheat, 5% sorghum, 1% barley and 3% in maize due to feral pigs. The damage in NSW and Queensland from wheat and barley crops was estimated to be 1% in medium impact areas and 3% in high impact areas. Production losses to the grain sector were estimated by Gong et al. (2009) to be 1% at low pig

densities, 2% at medium pig densities and 3% at high pig densities, that equated to an annual total loss of A\$5.7 million. Caley (1993) determined that feral pig losses in sorghum and maize crops in the Northern Territory ranged between 7% and 50%. Yield in sugarcane and banana in north Queensland were estimated to be reduced by 6% and 1% (Mitchell and Dorney 2002).

Further studies to demonstrate economic impacts of feral pigs to different agricultural enterprises are required. Such information is needed for different land managers to be able to answer the ‘what’s in it for me?’ question in relation to being involved in local community-led feral pig management programs. Estimating current costs of feral pig damage is required to quantify return on investment resulting from feral pig management activities to land managers, motivate land managers to work together on a sustained basis, and stimulate continued investment to reduce risks from feral pigs over time. Further, the potential economic cost of feral pigs to the Australian live-stock industry and human health as a carrier and amplifier of diseases is substantial and greatly exceeds these current estimates.

Best Practice Management and Monitoring of Feral Pigs in Australia

At the local/regional level, management efforts by land managers are typically applied using a risk-based approach and directed on areas identified as having the highest likelihood of feral pig impacts. The *Code of Practice for the humane control of feral pigs* (COP, Sharp 2012) provides information and guidance to vertebrate pest managers involved in controlling feral pigs to reduce their negative impacts using the most humane, target specific, cost effective and efficacious techniques available. The COP has been adopted nationally and allows for state and territory jurisdictions to apply more stringent requirements as long as the principles set out in the COP are retained.

The suite of best practice management methods approved for use in Australia (Sharp and Saunders 2011) need to be effectively, humanely and strategically used by land managers, in the right order, at the right time and at the right scale (Wilson and Gentle 2022). These methods include the following: baiting with sodium fluoroacetate (1080) or microencapsulated sodium nitrite (i.e. HOGGONE™), aerial shooting, aerial baiting (with 1080-treated meat baits for selected local government areas in Queensland), trapping, ground shooting and exclusion fencing. The order, timing of control activities, and combinations of tools used vary in response to local conditions and are important considerations for land managers. To achieve effective and efficient management, it is important that land managers first consider, and apply, those methods that are capable of removing whole group(s) of pigs. Land managers need to be ready to take advantage of seasonal conditions to knock populations down. The best time is during dry conditions when they congregate around water. However, once it is determined that management actions are necessary, these should not stop; a long-term vision is crucial to long term positive outcomes. Consistent ongoing effort is necessary - short term action will waste time, money, resources and effort.

When ground baiting and/or trapping are chosen as the management tool, it is very important that feral pigs are fed ad libitum for long enough that as many pigs as possible are attracted to the feed site(s). This requires patience on behalf of the land manager, and it can be very tempting to go too early. If the ad libitum period is insufficient, there is a high risk that pigs may become trap or bait shy. This will make their control more time consuming, frustrating, and difficult. Management activities can also be disrupted by outside sources such as recreational hunters or neighbours bait feeding feral pigs too close to existing activities. Managing feral pigs is challenging and mentally straining to land managers, and can be overwhelming due to the time, effort and cost to maintain consistent control efforts.

What Success Looks Like

The implementation of the *National Feral Pig Action Plan 2021-2031* is supported by strong governance arrangements. Its Implementation Committee was established in May 2021, with its membership drawn from government, conservation/environmental management, agricultural industries, Indigenous organisations, and research, development, and extension technical specialists. The Implementation Committee is independently chaired to ensure balanced engagement of all stakeholders and oversee the Plan’s efficient execution.

The purpose of the Committee is to drive the Plan’s implementation, set strategic direction and its annual priorities, advocate the Plan’s purpose and vision to stakeholders and identify and attract long term investment and collaboration to support best practice feral pig management programs. Several sub-committees have been established to provide independent advice to the Implementation Committee: the Scientific Advisory Panel, Indigenous Advisory Panel and Investment Advisory Panel. These Panels have provided significant contributions and input to inform the development of the Plan’s Prospectus (National Feral Pig Action Plan 2023a) and its Research, Development and Extension Plan (National Feral Pig Action Plan 2023b).

Cooperation, coordination, and collaboration between geographically disparate land managers is enabled through activities to implement the Plan. This is creating new relationships and networks, new insights and approaches to feral pig management, and monitoring to be unearthed, and knowledge to be shared. For the Plan to be successful and deliver lasting reductions in feral pig impacts, the key priorities needing to be addressed and resolved are:

- Longevity in resourcing and operations of coordinated community-led feral pig management groups, enabling ongoing land manager participation.
- Engaged local communities and sustained collaborations between public and private land managers in coordinated, community-led groups.
- Quantification of impacts and net benefits from feral pig best practice management programs to land managers, informed by consistent monitoring and reporting.
- Increased effectiveness of control programs reducing feral pig impacts and populations.

- Better local information to target where, when, and how to control feral pigs in the landscape, informed through effective use of existing and new technologies.

This will be enabled through trusted partnerships, effective communication, connected supported and engaged communities, coordinated action over large land areas on a nil tenure basis, population and/or impact monitoring embedded into management programs, and sharing of knowledge and data between different groups of land managers.

Applying Science-Based Data to Inform Feral Pig Management Programs

Marshall et al. (2023) outlined how GPS collars fitted to feral pigs are being used to encourage land manager participation in regional scale feral pig management programs operating across land owned and managed by different types of land managers, both public and private. This is being done by demonstrating the need for collective and coordinated action to land managers as the home ranges of feral pigs within their local area are extending across different land holdings and tenures. Data from collaring studies has been aggregated and analysed to better understand feral pig movement and habitat preferences in different landscapes (Wilson et al. 2023a, b). Wilson et al. (2023a) reported that male pigs have larger home ranges than females, likely due to their reproductive drive, as well as between different seasons. Home range size was positively scaled to body mass, with larger animals having a larger home range size. Overall, 91% of pigs demonstrated preference for habitat between 11-50% canopy cover. Interestingly, habitat with between 20-40% foliage protective cover was preferred, whilst areas with vegetative cover of >50% was generally avoided. Their use of very open landscapes with 1-10% foliage protective cover was also avoided but was dependent on site.

Further analysis identified that proximity to creeks, dams, cultivation, and the interface between open and dense vegetation were key factors influencing revisitation of sites by feral pigs (Wilson et al. 2023b). Across these four sites, Wilson et al. (2023b) found that 51% of all highly-revisited locations were within 150m of a water-course (e.g. creek) and 89% of all highly-revisited sites within wooded vegetation were within 150m of the border with open vegetation. Female pigs preferred habitat that was closely located to cultivation, while males did not. This is in contradiction with earlier Australian studies that showed a preference of feral pigs to thicker habitat. Methodological differences may have influenced these results.

The ability to analyse feral pig movement data has yielded important insights, and identified criteria, that can be used to optimise the effectiveness and efficiency of feral pig management programs. These findings indicate that land managers should prioritise areas for control with habitats with convenient access to shelter, water, and food – characteristics preferred by feral pigs. By doing this, the likelihood of encountering feral pigs will be increased, thereby improving control programs and contributing to a reduction in feral pig impact on targeted assets.

Within a study site, analysis of the movement data identified that feral pigs occupy different regions of their

home range during different seasons. At the local level, this type of information would be very useful to inform both the timing and location of management activities. If this information was available for every area, it could then be used to better target areas for feral pig control and improve the efficiency of management programs. Understanding what feral pigs are consuming in different areas at different times of the year requires more detailed and localised investigations.

Feral pig movement data is also being compiled and analysed to improve understanding of potential disease transmission dynamics in feral pig populations (Smith et al. 2023). Data is being aggregated from Australia-wide surveillance programs where GPS collars are monitoring feral pig movement. This data will be used to inform disease transmission and evaluate the effectiveness of different control strategies in the event of an exotic disease outbreak. It is expected that insights generated will be used to inform decision-making for feral pig management, emergency disease preparedness and planning control at a national level.

Building Trust, Networks and Partnerships

Peers and neighbours are the single most important source of vertebrate pest information and advice to other land managers, not technical specialists (Steneke et al. 2023). Land managers value and trust other land managers to learn about new land management practices and rely on peer networks to learn and innovate. With this in mind, the Plan's Implementation Committee selected six existing coordinated feral pig management programs from around Australia to become the first set of demonstration sites for the National Feral Pig Action Plan in December 2021. These demonstration sites were selected based on their leadership, community engagement, integrated best practice management strategies being used to control feral pig populations and how outcomes from their actions are being monitored to enable continuous improvement in their programs (Figure 1). The demonstration sites for the Plan are:

- Carpentaria Land Council Aboriginal Corporation, Queensland
- Cape York Coastal Catchments demonstration site, Far North Queensland
- Kangaroo Island Feral Pig Eradication Program, South Australia
- MidWest Feral Pig Demonstration Site, Western Australia
- Western Riverina Pest Program, New South Wales
- Whitsunday Regional Management Program, Queensland

Each of these sites differ in their objectives, scale, facilitation, levels of stakeholder involvement, types of land managers involved, land uses and tenures, habitats affected, feral pig impacts, and resourcing and support available in addition to the best practice management and monitoring methods being used. This presents extensive opportunities for land managers to learn from one another and to test and adopt different management and monitoring strategies to protect targeted assets from feral pigs. Importantly, these programs do not profess to have all the answers, but are striving to share what they have learnt

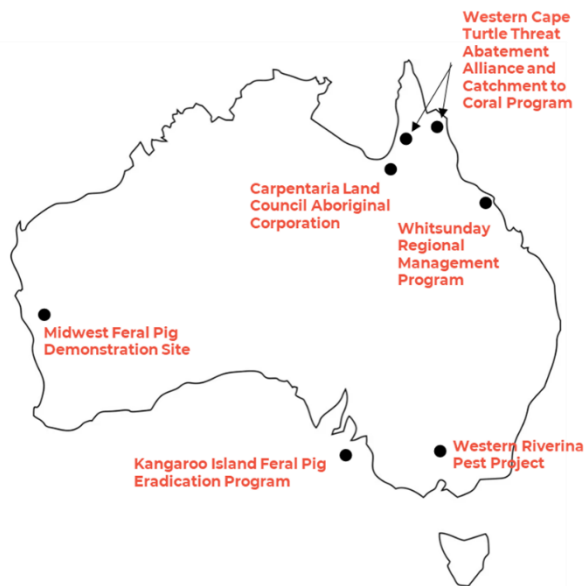


Figure 1. Locations of the six National Feral Pig Action Plan's demonstration sites in Australia.

(including what has and hasn't worked for them). Whilst the approaches and tools used may not be directly transferrable to all other programs, different aspects can be very useful. One component that each site has in common is that they are all locally facilitated - this is essential to bring land managers together, plan and coordinate program activities and report outcomes to group members.

The demonstration sites have been intentionally featured in stakeholder forums, monthly newsletters, and feature articles to provide information on the innovative management, monitoring and community engagement approaches being used. Importantly, this has initiated the establishment of networks and partnerships between different community-led groups dealing with feral pig impacts.

CONCLUSION

In conclusion, feral pig management can be informed by data but it is all about people. To achieve successful outcomes, people need to be patient, proactive, and consistent in how management approaches are applied and recorded, and not take short cuts. All management programs being conducted should be in a state of continuous improvement, with monitoring insights used to adapt their design and influence behaviour and practice change of land managers so that they work more closely together on a landscape-scale, nil tenure basis. This is all needed to optimise outcomes from the extensive efforts being applied by land managers to control feral pig populations to reduce their impacts to Australia's unique environment, agricultural industries, cultural heritage and values and social assets.

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