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Authors

Bengsen, Andrew J.
Gentle, Matthew N.
Mitchell, James L.
et al.

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Feral Pig Management in Australia: Current Trends and Future Directions

Andrew J. Bengsen

Department of Primary Industries, Orange, New South Wales, Australia

Matthew N. Gentle

Department of Agriculture, Fisheries and Forestry, Toowoomba, Queensland, Australia

James L. Mitchell

FeralFix, Charters Towers, Queensland, Australia

Hayley E. Pearson

University of Sydney, Faculty of Veterinary Science, Sydney, South Wales, Australia

Glen R. Saunders

Department of Primary Industries, Orange, New South Wales, Australia

ABSTRACT: Feral or free-ranging pigs have been a problem in Australia since the first years of European settlement, and they now occur in a wide range of habitat types throughout much of the continent. Feral pigs impact environmental, agricultural, and cultural resources, but they can also have commercial value from harvesting and recreational or subsistence hunting. It has been difficult to quantify many of the adverse impacts of feral pigs. Consequently, most management programs aim to mitigate actual, potential, or perceived impacts that have been inferred from observational studies and anecdotes, untested retroductive hypotheses, or observations generated from outside of Australia. Lethal control to reduce population density is the most common form of management, and it is often applied as a form of insurance, rather than to mitigate specific, measurable impacts. We suggest that future management programs should aim to quantify the effects of management actions on pig populations and the vulnerable resources that are the basis of real management objectives. There are important ethical and practical reasons for this approach, which should in turn enhance the efficiency and efficacy of management programs and help to ensure continued public and government support for ongoing mitigation of the feral pig problem.

KEY WORDS: control methods, damage, population control, strategies, *Sus scrofa*, wild pigs

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INTRODUCTION

Pigs (*Sus scrofa*) arrived in Australia with the first European settlers in 1788. Within 7 years, free-ranging pigs were recognised as a threat to the colony's food and water supply and became the subject of one of the colony's first animal control proclamations (Robertson 1932). Feral pigs now occur across about 45% of the Australian continent in a diverse range of habitats including alpine regions, tropical rainforests, and semi-arid rangelands (West 2008). They are most widespread and abundant in the tropical north-east (Figure 1). As in the U.S., states are able to set their own laws regarding the management of feral pigs. However, unlike the U.S., feral pigs are a declared pest animal in all Australian states and territories. All land managers are required to take action to reduce the impacts and presence of feral pigs on their land and it is illegal to feed, transport, release, or otherwise facilitate establishment or persistence of feral pig populations.

Despite the relatively long history of active management in Australia, and the best intentions of different organisations with an interest in their control, feral pigs remain a persistent and serious problem throughout much of the country. There have been few examples of demonstrably effective large-scale damage mitigation programs. This paper examines the current state of feral pig management and control in Australia and suggests ways to improve the efficacy and efficiency of feral pig management in a future environment where re-

Figure 1. Relative abundance of feral pigs in Australia, as assessed from a survey of institutional knowledge (adapted from West 2008).

sources and political support for pig control may be scarce.

IMPACTS

Environmental impacts typically occur through predation, habitat modification, and competition. For

example, heavy predation on snake-necked turtles (*Chelodina rugosa*) is expected to lead to localized population extinctions in northern Australia if the feral pig threat is not mitigated (Fordham et al. 2008). At present, 179 other threatened plant and animal species have been recognised as being affected by feral pigs (Department of the Environment 2009). Economic impacts are typically incurred through damage to crops such as cereals and sugarcane (e.g., Mitchell and Dorney 2002, Gentle et al. 2010); through disease transmission to livestock or people (e.g., Eales et al. 2010); or through predation on lambs (e.g., Choquenot et al. 1997). There has also been substantial concern among researchers, managers, and administrators over the potential for feral pig populations to harbor exotic pathogens, such as the foot and mouth disease virus, that could have major impacts on the national economy (e.g., Productivity Commission 2002). Social impacts have not been well-explored, but can include the destruction of important Aboriginal cultural or subsistence resources such as rock art sites and bush foods (e.g., Koichi et al. 2012). Positive values of pigs arise from their role as game for recreational hunters (Meurk 2011), food and cultural resources for Aboriginal communities (Koichi et al. 2012), and as an export product for commercial harvesters servicing the European game meat market (Gentle and Pople 2013).

MANAGEMENT RESPONSIBILITIES AND STRATEGIES

Because of their broad distribution and diverse impacts, many different organisations are actively involved in feral pig management, including agencies from all levels of government, non-government organisations such as Indigenous land management councils and conservation groups, corporations with land management responsibilities, and private landholders. An increasing appreciation of the importance of strategic pest management (*sensu* Braysher 1993) in recent decades has seen many of these organisations develop management strategies and plans incorporating actions to mitigate the impacts of pigs. These range in scale and focus from a national Threat Abatement Plan to reduce the impacts of feral pigs on threatened species and communities (Braysher 2005), to resource management plans for specific properties in which the impacts of feral pigs are considered along with other management issues such as fire, infrastructure maintenance, and the impacts of other invasive species (e.g., Anonymous 2000).

Funding for large-scale management programs typically comes from state or federal government grants that are linked to broad resource management goals, such as reducing the impact of invasive species in northern and remote Australia. These programs usually involve numerous stakeholders coordinating action and investment across property boundaries. It has recently been suggested that further funding for feral pig control, and for increasing employment in remote communities, might be sourced from the generation of carbon credits to offset greenhouse gas emissions (e.g., Farrow and Winer 2011). This is theoretically possible under the current carbon accounting system in Australia, which allows for the

crediting of emissions avoidance arising from the control of invasive herbivores (e.g., reduced leakage of greenhouse gases from wetland soils disturbed by pigs). However, a great deal of research would be needed before feral pig control could be accepted as a verifiable and accountable means of reducing emissions and generating tradeable credits (Bengsen and Cox 2014).

Strategic pest management principles dictate that management actions should aim to reduce specific impacts, rather than just the number of pests (Braysher 1993). However, the distribution and nature of some types of damage can be highly variable and difficult to predict, being influenced by variability in climate, weather or land management practices. The diversity and sporadic nature of many feral pig impacts, and the difficulties in measuring those impacts (particularly over large areas and time scales), means that many pig management programs focus on reducing pig densities in the expectation that this will reduce their actual or potential impacts. Relationships between pig density and damage have been demonstrated in the cases of ground-rooting in sub-alpine areas (Hone 1988), predation on lambs in semi-arid rangelands (Choquenot et al. 1997), and rooting damage to seasonal tropical lagoons (Mitchell 2010). However, a direct relationship between damage and pig density may not always be apparent, so reducing pig density *per se* may not always be the most effective or efficient way of reducing damage. For example, a recent study of predation on marine turtle nests found that predation by pigs was the dominant cause of nest mortality, but most predation events were spatially clustered and likely attributable to a small number of pigs (Whytlaw et al. 2013). The authors suggested that targeted removals of pigs at specific sites might be a more efficient means of reducing predation on turtle nests than the current broadscale population reduction program, although it would do little to reduce other pig impacts in the area.

CONTROL METHODS

Most feral pig control programs use lethal methods to reduce the densities of pigs where they are perceived to threaten valued resources. Non-lethal methods have not been widely used. Fencing has been useful to protect some high value resources (e.g., lambing paddocks) at relatively small geographic scales, but methods such as habitat manipulation are rarely applicable and no feasible/practical fertility control agents are currently available.

Estimates of population growth rates suggest that around 55 to 70% of a population needs to be removed annually to prevent rapid recovery in numbers (Giles 1980, Caley 1993, Gentle and Pople 2013). Re-invasion from surrounding, untreated areas is also problematic, contributing to post-control recovery (e.g., Spencer et al. 2005). Consequently, lethal control programs should generally strive to remove a large proportion of the population over a broad geographic area, ideally encompassing distinct populations. Smaller scale programs may need to operate near-continuously to counter re-invasion (Bengsen et al. 2014).

Available lethal control methods to achieve these aims include trapping, poison baiting, and shooting. It is

widely recognised that control programs should use a combination of these methods, but this is not often applied (Reddiex et al. 2006). In reality, the choice of control methods available for any given situation is limited by a range of technical, environmental, social, economic, and logistical constraints. For example, many feral pig populations occur in remote areas that can be logistically difficult and expensive to access, and this can greatly reduce the feasibility of the more labour-intensive control methods.

Live trapping has been one of the most common forms of feral pig control used by conservation organisations, government bodies, and private landholders (Reddiex et al. 2006, West and Saunders 2007). Unlike the U.S., neck snares are not permissible in Australia. Intensive trapping programs can achieve substantial local population reductions (e.g., Vernes et al. 2001, Bengsen et al. 2011b) but require substantial investment in labour and resources over large areas (e.g., Saunders et al. 1993). Consequently, strategic trapping programs tend to focus on the protection of specific resources and often run continuously or at high frequency to counter local population recovery through immigration (e.g., Dorrington 2001).

Shooting is conducted from the ground or air. Aerial shooting from helicopters is particularly valuable for its ability to produce a large and rapid population reduction over a broad area (Saunders 1993). Hunting from the ground is often used by private landholders on individual properties, commonly in conjunction with hunting dogs, but there is little evidence to suggest that it is effective at achieving useful population reductions (e.g., Saunders and Bryant 1988, Caley and Otterley 1995). Recreational hunting is also permissible on public lands in some states, but its effectiveness in reducing pest densities or impacts has not yet been assessed.

Poison baiting is also widely used in Australia, where most areas with important feral pig populations support few native omnivores that might also be imperilled by taking baits (c.f. Bengsen et al. 2011a). This contrasts with the U.S. experience, where non-target species such as raccoons (*Procyon lotor*) and collared peccaries (*Tayassu tajacu*) can take a large proportion of baits (e.g., Campbell et al. 2006). In Australia, baiting can provide an efficient means of producing a large and rapid population reduction over a broad area (e.g., Mitchell 1998). Baiting programs are heavily reliant on the toxin 1080. This dependency has recently been viewed as problematic due to concerns about animal welfare with alternative toxins; yellow phosphorous is not permitted in most states, and warfarin has already been withdrawn from use for pig control for this reason (see Sharp and Saunders 2012). Many of these concerns might be overcome with the development of a new toxin, sodium nitrite (Lapidge et al. 2012). Poison baits are usually deployed by ground, but some bait types can also be dropped from the air in some areas, which provides a more cost-effective means of covering large and inaccessible tracts of land (Mitchell 1998, Fleming et al. 2000).

Ground-based shooting and trapping are also used to harvest feral pigs for export, mainly to European game meat markets. However, commercial harvesting opera-

tions are restricted to the vicinity of refrigeration depots, known as 'chillers,' which are only economically viable in limited areas, and demand for pig carcasses is highly volatile (Gentle and Pople 2013). Moreover, commercial harvesting has not been effective at maintaining population reductions, even in areas well serviced by chillers (Gentle and Pople 2013).

DISCUSSION

The recognition of feral pigs as an important pest animal in all states and territories of Australia has provided consistent legislation across the country to support the mitigation of feral pig impacts and to prevent illegal introductions. There are also federal and state level strategies and action plans that specify a broad range of management objectives aiming to reduce pig impacts, such as preventing the establishment of new populations, integrating planning and investment for pig management across different levels of government, and increasing community awareness and ownership of the feral pig problem (e.g., Anonymous 2004, Braysher 2005).

This high-level planning and prioritisation has facilitated research that has described the distribution and relative abundance of feral pigs at national and regional scales (e.g., West and Saunders 2007), identified and mapped high-value sites where feral pigs co-occur with susceptible species or ecosystems at national and state-wide scales (Anonymous 2010), improved our understanding of some of their impacts (e.g., Mitchell 2010), broadened the range of control methods available to reduce pig impacts and numbers (e.g., Lapidge et al. 2012), and elucidated the roles of different social and economic factors that can influence the efficacy of feral pig management (e.g., Gentle and Pople 2013, Koichi et al. 2013). Importantly, it has also provided targeted funding for on-ground management and control programs to reduce specific, high-priority threats, such as aerial shooting programs to reduce predation on marine turtle nests.

Despite this wide recognition of feral pigs as a significant pest, and the expenditure of substantial administrative and practical effort to reduce their abundances or impacts, few of their impacts have been well described or estimated (c.f. Caley 1993, Fordham et al. 2006). For example, pigs are thought to adversely affect the persistence of many plant and animal species, but these attributions have often been based on anecdote, casual observations, untested retroductive hypotheses, or observations generated outside of Australia (Bengsen et al. 2014). Similarly, the benefits of reducing pig populations have rarely been effectively estimated in terms of impact reduction (c.f. Melzer et al. 2009), and pig control objectives in local scale management plans are sometimes vague, impossible to assess, or missing altogether. Consequently, information to help prioritise investment in the on-ground management of feral pigs is scarce, and much public investment in control works is allocated through bottom-up processes such as grant applications, rather than being directed to protect the most vulnerable and high-value resources. Furthermore, scrutiny of both public spending and ethical issues relating to the treatment of animals are increasing in Australia, and lethal control programs lacking important and measurable

environmental, economic, or social benefits may be increasingly open to challenge.

In an effort to overcome some of these problems, the federal government commissioned a project to develop generic monitoring frameworks for assessing the impacts of pest herbivores, including pigs, on vegetation condition (Lethbridge et al. 2013a,b). It is likely that major herbivore control programs receiving federal funding will be required to evaluate their efficacy, in terms of impact reduction, using a species-specific monitoring framework. The 7-step process proposed for assessing pig impacts may be broadly applicable to a wide range of vegetation types. However, it would not help estimate other, less obvious impacts such as the effects of predation, competition, or disease transmission on native fauna. Furthermore, it does not specify the collection and analysis of information that could be used for bio-economic modelling to assess the relative cost-effectiveness of different control programs.

We suggest that large-scale management programs aiming to mitigate the impacts of feral pigs should make greater effort to estimate their efficacy, in terms of achieving meaningful outcomes. Ideally, they should attempt to quantify the relationships between management costs, inputs (flying hours, trap nights, bait density), outputs (reduction in pig abundance or density), and outcomes (recovery or avoided decline of threatened resource) (e.g., Walsh et al. 2012). Additionally, researchers studying the impacts of pigs should aim to broaden the scope of their investigations beyond the immediate impacts on a specific resource, such as rate of predation on a vulnerable species, to examine the likely population-level impacts (e.g., Fordham et al. 2008). More effective estimation of feral pig impacts and the benefits of pig control programs would have four important advantages: 1) it would help ensure that pig control programs are only undertaken where significant, manageable impacts are occurring; 2) it would allow the use of adaptive management approaches that can improve the efficacy and efficiency of control programs over time; 3) it would increase the strength and depth of our understanding of pig impacts and management more generally; and 4) it would provide greater justification for ongoing investment in the reduction of feral pig impacts.

In reality, the outputs and outcomes of management actions are often very difficult to detect or estimate, due to high variability and interactions with other processes such as climate, fire, other invasive species, and commodity prices (Bengsen et al. 2014). New monitoring approaches, such as population surveys using camera traps (Bengsen et al. 2011b) or airborne forward looking infra-red imaging (Edwards et al. 2004), may improve abundance or density estimates, whereas methods such as using satellite remote-sensing data to assess damage to crops or other vegetation may be useful for estimating some impacts (Gentle et al. 2010). However, many organisations with responsibilities for feral pig management are likely to lack the technical or logistical capacity to conduct such work. We suggest that managers and researchers should strive to cooperate in the development, implementation, and analysis of pig control programs that

can be conducted in an experimental or quasi-experimental way to test specific, important hypotheses.

CONCLUSION

Despite the relatively long history of active feral pig management in Australia, and recent advances in approaches to understanding and managing the impacts of pigs, there is much room for improvement. Each year, many feral pig control programs are conducted for different purposes across the continent (Reddiex et al. 2006). Greater integration of research goals and methods into some of these programs could improve our ability to identify impacts and act efficiently to mitigate them. It could also help secure ongoing investment for feral pig management in an increasingly challenging and competitive environment. We urge researchers and managers to collaborate closely in the design and implementation of management programs to achieve demonstrable, important benefits, both in terms of impact reduction and knowledge generation.

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