Manaaki Whenua
Landcare Research

A review of control strategies and tools for feral pigs

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Project and client

- Northland Regional Council aims to improve management of feral pig (*Sus scrofa*) populations and thereby reduce their potential role in spreading kauri (*Agathis australis*) dieback disease caused by the agent *Phytophthora* taxon Agathis. Manaaki Whenua – Landcare Research was commissioned by Northland Regional Council to review control methodology for feral pigs and recommend a broad strategy for ongoing sustained control of feral pigs in Northland Region. The project was carried out between October 2019 and February 2020.

Objectives

- Review the strategic options for managing feral pigs.
- Review the control methodology for feral pigs, with emphasis on new or emerging methods.
- Recommend a broad strategy, and suitable control tools for achieving that strategy, for control of feral pigs in Northland Region.

Strategic options for managing feral pigs

In order to reduce or eliminate the impacts of a pest species, managers generally have five options to select from, listed here in decreasing order of benefit:

1 Stop the pest arriving in the first place

2 Eradicate all pests present

3 Apply a single control or management action with a long-term benefit (e.g. biocontrol or exclusion fencing)

4 Sustained control to keep animals at a lower level

5 Do nothing (which although an option, does not reduce or eliminate the impacts caused by the pest).

Targeted sustained control of feral pig populations that threaten kauri (or other conservation or production system assets) is the only viable management option currently available for Northland. Doing nothing will not reduce the risks pigs pose to kauri or other assets, and eradication is currently not technically feasible and lacks social licence to operate.

Control methods for feral pigs

- Habitat modification may be useful in some areas, but is unlikely to be a useful broad-scale tool for managing feral pigs in Northland. Fencing may be useful for protecting small areas of high conservation value, or, as a last resort, to prevent feral pigs from entering kauri forests.

- The only vertebrate toxic agent currently registered for feral pigs in New Zealand is sodium nitrite in Bait-Rite Paste®, but there is little information on the field efficacy of this bait for controlling pigs in New Zealand.
- Recreational hunters are used as a control tool, especially by landholders in production landscapes, but their effort may not be sufficient to markedly reduce damage in areas affected by pigs. The motivation of recreational hunters will probably be too low for effective control of feral pigs when pig numbers are low, and therefore they should not be used as a primary control method in areas of high conservation concern.
- Professional ground and aerial hunters using thermal imaging technology and trapping are likely to be most successful at achieving population reductions of feral pigs in areas listed as high priority for kauri (or potentially some other conservation asset), especially if professional hunters are on performance-based contracts.

Take home messages for managing feral pigs in Northland

- Feral pigs are believed to be important vectors of kauri dieback disease and therefore populations near important kauri forests should be controlled.
- In the absence of quantitative data about the population reduction required to prevent or limit the risk of pigs spreading kauri dieback disease, we recommend reducing populations to 'low levels'. However, due to the lack of data, we cannot define a threshold for pig abundance.
- A combination of professional ground and aerial hunting, including using thermal imaging technology, and trapping should be used to achieve population reductions of feral pigs in areas listed as high priority for kauri (or potentially some other conservation asset).
- A community awareness and engagement programme should educate stakeholders about the probable risks feral pigs pose to kauri in some areas, and dissuade them from the practice of liberating pigs to bolster hunting opportunities in areas where risks to kauri are highest.
- Recreational hunters should be used as the primary method for 'controlling' feral pigs in areas where kauri conservation is not a priority, e.g. farmland pasture that is being damaged by pig rooting. Management (effort and funding) of feral pigs by agencies should only focus on critical areas for conservation, especially of kauri.
- Control operations should be monitored using numbers of pigs harvested annually, including hunter effort, and/or camera trap surveys.
- Future research needs to elucidate the role pigs play in dispersing kauri dieback disease and the population reduction needed to mitigate that risk.
- Fencing is not recommended for broad-scale management of feral pigs in Northland, but may ultimately be needed to fence off important kauri forests to exclude pigs (and errant livestock), especially if the required density to prevent the spread of kauri dieback disease is zero.

1 Introduction

Feral pigs (*Sus scrofa*) are widespread in Northland region. They are believed to be important vectors of kauri (*Agathis australis*) dieback disease caused by the agent *Phytophthora* taxon Agathis and they damage production systems. Northland Regional Council aims to conduct sustained control to mitigate the unwanted impacts caused by feral pigs. Manaaki Whenua – Landcare Research (MWLR) was commissioned by Northland Regional Council to review control methodology for feral pigs and recommend a broad strategy for ongoing targeted sustained control of feral pigs in Northland Region. The project was carried out between October 2019 and February 2020.

2 Background

Feral pigs are widespread in Northland region (McIlroy 2005). They are an important game species for hunters (Nugent 1992), but they also have unwanted impacts on indigenous species and ecosystems, and they damage production systems, especially agriculture (Parkes et al. 2004; Latham et al. 2017, 2020).

A key concern in Northland is the potential role of feral pigs as vectors of kauri dieback disease, caused by the agent *Phytophthora* taxon Agathis (PTA) (Beever et al. 2009; Waipara et al. 2013). PTA has been confirmed from forests in Northland, e.g. Russell and Waipoua forests, and together with people and cattle (*Bos taurus*), pigs are thought to be the primary vectors of the disease (Beauchamp & Waipara 2014). Controlling feral pig populations to low numbers in and around kauri forests may mitigate the role that pigs have as vectors of PTA.

In addition to the negative impacts they can have on indigenous species, feral pigs also affect production systems by damaging pasture and grain crops, and, more rarely, killing and eating lambs (Rowley 1970; McIlroy 2005; Latham et al. 2020). In some parts of New Zealand, they are also spillover hosts (or, more rarely, maintenance hosts) of bovine tuberculosis (TB; Nugent 2011). Effective control of feral pig populations would mitigate the damage they have on assets in production systems and their potential role as vectors of TB in Northland.

Localised agricultural damage caused by feral pigs is often dealt with by farmers using recreational pig hunters with their dogs (NPCA 2018). Sometimes, however, feral pig numbers and the damage they cause are greater than recreational pig hunters can manage and the few pigs they remove are insufficient to mitigate their unwanted impacts (McIlroy 2005). In these instances, professional control staff using a range of control tools may be required to adequately reduce pig numbers to mitigate their impacts (e.g. Choquenot et al. 1996; Hone 2007).

Although professionals are sometimes used to control feral pigs in Northland, Northland Regional Council has primarily depended on recreational pig hunters for control and damage reduction. However, while recreational hunters may be effective at controlling feral pigs in some areas, pigs are valued more as a resource than a pest by many people, including Māori (Nugent et al. 1995). This means recreational hunters and other people who view feral pigs as a resource do not want to control pig numbers to low levels, and often translocate pigs to new areas (or subsidise existing populations) to increase hunting opportunities (McIlroy 2005; Baird 2018). If feral pig populations in Northland are to be effectively managed, this potential source of conflict will need to be managed by Northland Regional Council through a community awareness, engagement, and support programme.

Given that feral pigs are an important hunting resource in Northland, eradication is not an option – it is not currently technically feasible or supported by enough of the community. Therefore, we base this report on a strategy of sustained control targeted at areas where the risks associated with the spread of kauri dieback disease and damage to agricultural production assets are greatest.

3 Objectives

- Review the strategic options for managing feral pigs.
- Review the control methodology for feral pigs, with emphasis on new or emerging methods.
- Recommend a broad strategy, and control tools for achieving that strategy, for control of feral pigs in Northland Region.

4 Strategic options for managing feral pigs

In order to reduce or eliminate the impacts of a pest species, managers generally have five options to select from, listed here in decreasing order of benefit (Parkes 2003):

1 Stop the pest arriving in the first place

2 Eradicate all pests present

3 Apply a single control or management action with a long-term benefit (e.g. biocontrol or exclusion fencing)

4 Sustained control to keep animals at a lower level

5 Do nothing (which although an option, does not reduce or eliminate the impacts caused by the pest).

If *eradication* is the chosen management strategy, three criteria *must* be met. These are (*sensu* Parkes 1990; Bomford & O'Brien 1995):

1 All feral pigs must be put at risk – this would be difficult to achieve in New Zealand because of the terrain, vegetation, financial resources, lack of a suitable toxin, and social licence to operate (i.e. pigs are valued as a hunting resource and hunters would be against eradication)

2 There must be no risk of immigration – unless the pig population considered for eradication is in a geographic 'island' of habitat, there is usually some form of immigration – and there must be no human-assisted liberations

3 Pigs must be killed at rates faster than they can replace their losses at all densities.

At least two of these key criteria are not met: not all pigs can be put at risk and there is a risk of immigration. Human-assisted liberations in Northland are also common (Baird 2018). Therefore, eradication is not currently feasible.

Option three (apply a single control or management action with a long-term benefit) is also unlikely to be technically possible at present. First, there is no known biocontrol agent for pigs. Second, pigs already occupy many indigenous forests and production landscapes in Northland, and they would need to be eradicated from these areas before a strategy of exclusion fencing could be used. Exclusion fencing may be a possibility to protect some valuable assets, such as small remnant patches of indigenous forest, if feral pigs are absent from these areas but could disperse into them. However, the construction and maintenance of fences is expensive, especially given the destructive capability of feral pigs (see 5.2.2 Exclusion fences below, where we also discuss the Te Paki feral pig fence), and therefore is unlikely to have much utility for feral pig management in Northland.

The two remaining management choices, sustained control or do nothing, need to be carefully considered. If the cost of control exceeds the benefits, then the best option is to do nothing. In Northland, the economic aspect of this argument may be applicable to assets in production landscapes, i.e. the cost of control may be higher than the cost of their damage. However, given kauri are an important taonga for Māori and New Zealanders more generally, doing nothing is not an option and, irrespective of their exact role as vectors of PTA, the precautionary principle should be applied to mitigate the risk (or potential risk) of pigs to kauri.

Sustained control requires that target pig populations are reduced to some low density in an initial operation and then held there by maintenance control applied at either some set frequency or as the need (i.e. increasing trend in numbers or damage) arises. We argue that this strategy is the most appropriate for managing feral pigs in Northland, with the caveats that as pigs are also an important game species, populations targeted for control will need to be a high risk to kauri (or possibly some other indigenous or production asset) and control staff must have social licence to operate.

5 A review of control methods for feral pigs

5.1 Choice of control methods

Although no widespread official control of feral pigs has been carried out for many years in New Zealand (McIlroy 2005), the National Pest Control Agencies have recently updated their national guidelines for monitoring and control methods for this species (NPCA 2018). In that document, they note that "feral pig management is once again becoming more of an issue, with both Regional Councils and the Department of Conservation giving increasing attention to the impacts feral pigs have on biodiversity values." To date however, control of feral pigs by these agencies has been limited (NPCA 2018). Similarly, although pigs can have a high prevalence of TB, they are generally not targeted for control by OSPRI, although they have recently killed c. 1,000 feral pigs annually for surveillance of TB in New Zealand.

As stated, most farmers rely on recreational hunters with dogs (McIlroy 2005). However, there are a number of other potentially suitable control methods for pigs and we detail these below. The appropriateness of a particular method will depend on the strategic aim of the control programme and the ecological and social context in which control is to be undertaken. In some circumstances it may be appropriate to use two or more control methods at the same location. Alternatively, some methods, such as trapping, might be most efficacious if the pigs in the area are not disturbed by other methods, such as ground or aerial hunting.

There is currently only a single registered vertebrate toxic agent in New Zealand for controlling pigs: sodium nitrite in Bait-Rite Paste® Connovation Ltd. Nevertheless, multiple vertebrate toxic agents have been used with success in Australia and elsewhere (Hone 2002; Cruz et al. 2005), and therefore we provide further details below. We also use research and management examples from overseas to assess the potential efficacy of other control methods for the Northland context.

5.2 Control methods

5.2.1 Habitat modification

Feral pigs, like other wild animals, need to have areas of safe harbourage (refugia), where young can be safely raised and where all pigs can retreat when pursued by dogs and/or hunters. Removing refuges like patches of scrub and remnant forest will make control easier, thereby enabling pig numbers to be reduced, and help restrict their distribution.

It is believed that the progressive clearance of scrub and forest during European settlement of New Zealand contributed to the gradual reduction in feral pig populations that were once pervasive (Holden 1994). Clearing indigenous scrub and forest is less acceptable today and it will not be effective if neighbouring patches of scrub can also be used as refuges, as pigs will simply move from one area to another. Removing large areas dominated by scrubby, introduced species like gorse (*Ulex europaeus*) may be useful for

managing feral pigs in some locations in Northland. In most parts of the region, however, there are ample refugia that cannot be removed, and pigs will use these.

Habitat modification, such as planting production forests, is also likely to have an effect on pig numbers. For example, if production forests are young, poorly thinned, and/or have a dense understorey, they will likely create good refuges for pigs from ground and aerial hunters, and therefore pig numbers are likely to be comparatively high in these habitats. Conversely, well-thinned adult pines with little undergrowth will provide less refuge from ground hunters and dogs and, depending on canopy closure, aerial hunters.

5.2.2 Exclusion fences

Fences can assist with the control of feral pigs in three ways. They can be used strategically to prevent or at least slow the immigration of pigs into new areas and thereby prevent (or minimise) damage in uninvaded areas. They can be used tactically to reduce the effective size (by partitioning) an area in which feral pigs are to be controlled. This means managers can focus on one portion of the control area at a time, without having to continually return to previously cleared areas to remove individuals that have reinvaded it. Fences also permit clear separation of management objectives between adjoining lands of different tenure or use. Even though fences do not reduce the numbers of feral pigs, these three facets have made fencing the cornerstone of successful and progressive elimination of feral pigs from some areas, e.g. protected natural areas in Hawai'i (Hone & Stone 1989).

The principal drawbacks with fencing are the high initial expense, and the need for ongoing monitoring and maintenance of the fences to ensure their integrity (e.g. Reidy et al. 2008; NPCA 2018). The cost of non-electric fences is particularly high, e.g. it cost about 2019 NZ $16,800–$47,600 per km to build exclusion fencing for pigs in Hawai'i (Polhemus 2003; note: as the date the fence was constructed is often not reported, all inflation conversions are based on the year of report publication). In contrast, the cost of electric fencing is generally much lower, e.g. it cost approximately 2019 NZ $5,200 per km to erect electric fencing in the USA, but this was for white-tailed deer (*Odocoileus virginianus*, Miller et al. 1992), which are less destructive than feral pigs but can jump higher. The NPCA (2018) states that feral pig-specific fences can be constructed at less cost than a multi-pest species exclusion fence.

Non-electric fences must be of hinge joint fence (e.g. 15 cm wide × 8 cm high) or diamond mesh construction with a mesh size of not more than about 15 cm (Hone & Atkinson 1983). They must be at least 80 cm tall, with the bottom wire pulled tightly down into dips in the ground. In Hawai'i, iron standards are used as posts, with 2-m spacing between posts and with all components triple-dipped galvanised. Fences need to be inspected at regular intervals, and after any major storms. They can also be sabotaged by pig hunters to increase hunting opportunities.

For Northland, and in New Zealand more generally, fences are likely to be most valuable for protecting small areas of high conservation value within a larger area of continuous pig habitat. For example, the Te Paki pig-proof electric fence in Northland was built to protect threatened flax snail, *Placostylus ambagiosus*, colonies (Aviss & Roberts 1994). This fence cost c. 2019 NZ $25.00 per m (c. 2019 NZ $25,000 per km) for construction material only

(Aviss & Roberts 1994). The cost of building the fence would add substantially to the total cost of this fence, again, suggesting that this management option is only practicable and affordable for protecting small areas of high conservation value.

5.2.3 Vertebrate toxic agents and baits

Several types of toxic baits have been trialled for feral pigs and used operationally to control them, e.g. in Australia (Hone & Stone 1989; Saunders et al. 1990; Choquenot et al. 1996) and Santiago Island, Galàpagos (Cruz et al. 2005). These trials have included testing a variety of vertebrate toxic agents (Table 1), bait types (e.g. cereal, fishmeal, meat, carcasses), and bait application methods (e.g. aerial sowing, ground-laying, bait stations). Operations using toxic baits for feral pig control have achieved high kills, but poisoning alone has never achieved eradication.

Before toxic baits can permissibly be used for control of feral pigs in New Zealand, the issues of non-target risks through primary or secondary poisoning, residues and environmental contamination, and public/hunter opposition need to be addressed, and then the toxic bait needs to be registered.

At present there is only a single registered product for control of feral pigs in New Zealand, Bait-Rite Paste®, an encapsulated sodium nitrite toxin manufactured by Connovation Ltd (Shapiro et al. 2016; www.connovation.co.nz/; accessed 10 February 2020). Although registered, however, little is known about the effectiveness of this product for free-ranging feral pigs in New Zealand. The advantages and disadvantages of current vertebrate toxic agents and our ranking for their potential usefulness in Northland are shown in Table 1.

Table 1. Advantages and disadvantages of prospective vertebrate toxic agents for control of feral pigs in New Zealand (adapted from Choquenot et al. 1996). Only one bait, Bait-Rite Paste® (containing the vertebrate toxic agent, sodium nitrite), is currently registered for feral pig control in New Zealand. We rank potential use in New Zealand assuming registration is readily achievable. If it is not, all options except Bait-Rite Paste® have low potential for use in New Zealand

Vertebrate toxic agent	Advantages	Disadvantages	Potential for use in NZ
Sodium nitrite ($NaNO_2$, used in Bait-Rite Paste®)	Currently the only registered toxin for feral pigs in New Zealand Can be used in bait stations to limit non-target access Has an antidote, methylene blue No licence is required to purchase and use it	Efficacy in the field poorly understood	High
1080	Can be effective against pigs Can be applied to grains, cereal baits, or meal Comparatively cheap	Non-target impacts (specifically, high risk of primary and secondary poisoning of dogs) Hunter concerns about residues in carcasses Users must be licensed	Low
Cyanide	Pen efficacy established against pigs Fast acting and the most humane of toxin options Feratox® formulation available	Preliminary field results (Australia) not successful Possibility of pigs developing bait shyness Requires user licence	High
Cholecalciferol	Delayed action may reduce risk of bait shyness Lower risk of secondary poisoning non-targets	Acute toxicity to pigs not known Humaneness unknown Requires user licence	High
Anticoagulants (especially Warfarin)	Delayed action may reduce risk of bait shyness Effective against pigs in Australia	Animal welfare concerns Concerns about residues in carcasses and environment	Low
Zinc phosphide	Residues/secondary risk probably comparatively low	Unknown efficacy against pigs Animal welfare unknown Licence requirements unknown	Low–medium
Phosphorus	Effective in carcass baits (efficacy of other bait types unknown)	Unacceptable animal welfare Secondary risks and residues not well researched Risks to human handlers Requires user licence	Low

5.2.4 Trapping

Live capture cage traps are an effective technique for controlling feral pigs, providing sustained effort is put into baiting and checking traps. Results from Australia suggest capture efficacy of traps is moderate to high. In Kosciusko National Park, New South Wales, 62% of feral pigs exposed to traps were captured (Saunders et al. 1993), and in Central Tablelands, New South Wales, trapping resulted in an 81% reduction of feral pigs, based on spotlight counts (Choquenot et al. 1996).

There are several advantages of trapping compared to poisoning (Lukins 1989; Choquenot et al. 1996), including:

- Landowner effort can be maintained as they can see the results of their effort
- Trapped pigs can be used for their meat
- Trapped pigs can be radio-collared and used as Judas pigs (see below)
- It does not noticeably change pig behaviour (c.f. dogging and shooting)
- It is a flexible method that can be carried out in conjunction with on-farm activities, thereby reducing labour costs associated with control
- Traps are portable and can be moved and reused in a variety of habitats and seasons, allowing trappers to target pigs as they shift their activity ranges
- It is comparatively humane (so long as traps are checked regularly, which, by law, needs to be done daily)
- No non-targets in New Zealand
- No residue problems
- Pig numbers can be monitored to assess changes in catch per unit effort.

Trapping can be expensive depending on the type of traps used and the number that need to be built (or bought) and maintained to control the local pig population (Choquenot et al. 1996). In Australia, poisoning and helicopter shooting are often preferred to traps. Nevertheless, where pig densities make recreational hunting with dogs inefficient, and cover makes aerial hunting inefficient, trapping can be a useful method for controlling pig numbers, e.g. it was the primary removal method for a successful feral pig control programme in Alabama, USA (Foster & Pinkston 2017).

There are two types of traps commonly used for capturing feral pigs: the portable box trap and the weld-mesh-panel trap. The portable box trap is designed as an efficient and environmentally acceptable method for capturing feral pigs, and the traps are easily relocatable so that seasonal movement and availability of food can be fully exploited. A local engineering shop or welder should be able to build this type of trap at reasonable cost from the structure shown in Figure 1. There are also commercially available collapsible traps such as the Outdoor Outfitters Pig Trap available from Gun City (www.guncity.com/outdoor-outfitters-pig-trap-345858; accessed 10 February 2020) with a retail price of approximately 2019 NZ $1,000.

The weld-mesh-panel trap (Fig. 2) is a little less portable, but nevertheless is reasonably quick to erect (around 45 minutes). This trap has a one-way swinging door welded into one of the weld-mesh panels and, other than that modification, it is simply four sides of

straight weld-mesh panel (120 cm height, 240 cm width, with 5-cm squares). The door is 75 cm wide and 100 cm high. Eight waratah posts and lacing wire are used to hold it together (Fig. 2). It is important that the weld-mesh panels are spliced together with the waratahs on the outside of the trap. An extra precaution when trapping large pigs is to use a tight, large-gauge, outrigger wire all the way around the inside top of the trap (extending out about 25 cm), as this prevents them from clambering over the top of the trap and escaping. The cost for this type of weld-mesh trap is approximately c. 2019 NZ $450 plus the welding costs for each door.

If reliable cell phone coverage is available within the trapping area the trap could be fitted with a remote triggering device and/or alert via cellular text to indicate that the trap has been triggered. A large corral dropdown trap with this technology has been developed and marketed by BoarBuster (www.boarbuster.com/; accessed 10 February 2020). The trap is comparatively cumbersome and expensive (c. 2019 NZ $11,000–$12,500, plus shipping costs), especially as more than one trap would likely be needed for effective pig control in Northland. However, a potential benefit of this type of trap is that camera footage conveyed to the operator through the cellular network can indicate when all (or most) pigs in a mob have entered into the trappable zone, allowing the operator to trigger the trap when it is likely to maximise captures.

Figure 1. Portable box trap for feral pigs. These types of traps are commonly used for feral pig management in Australia and USA (Credit: J. Lewis, Arizona State University; Wight & Boughton 2018).

Figure 2. Weld-mesh-panel trap set with the door wired open and a trail of fermented barley leading into the trap (Credit: I. Yockney).

Feral pigs can be extremely wary of new foods and objects in their environment, i.e. they can be neophobic. Therefore, it is essential to allow pigs to get used to the trap and bait type before setting it. Wiring a trap's door open for at least 10–12 days is usually recommended.

There are several different bait types that can be used, but ideally they should be easily transported by a four-wheel drive vehicle, readily available, and cheap. Animal carcasses are often used but are not ideal as they are not user-friendly, not always readily available or easily transported. Grains such as maize or barley are more user-friendly and can be particularly attractive to pigs if fermented (Choquenot et al. 1996; I. Yockney, unpubl. data). To ferment grains, place the barley in a large black container with water added and leave in direct sunlight during summer for 10–12 days or until the barley has a pungent, fermented odour. Maize is also a good bait, either fermented or unfermented. It can be used dry in automatic feeders or a mini-silo-type operation for pre-feeding. Pre-feeding is also a useful method for bringing pigs into an area where they can be targeted by night shooting with the aid of a spotlight or thermal imaging equipment (Kessler 2002; Schuyler et. al. 2002).

The trapping methodology recommended by Hone (1984), and used successfully by MWLR, is based on the use of fermented barley as a bait type and is outlined below:

- Locate areas of significant pig activity to pre-feed
- Pre-feed the area with fermented barley placed in small clumps of approximately 1-kg piles (fermented barley works best if it does not dry out too much)

- Once the pigs have found and are eating the bait at the chosen site, construct or place the trap unset (wired open)
- Pre-feed in and around the unset trap until all the bait is eaten (bait for at least 2 consecutive nights)
- Set the trap, rebait and check daily (killing and removing all captured pigs from the trap) until there is no more bait take
- Start pre-feeding another area of high pig activity and move the trap to it (as described above)

Other points to consider for trapping include:

- Try to locate pre-feed sites and traps in a circuit to make checking them more efficient
- Do not be discouraged if the pigs do not immediately start to take bait or enter the traps, as with time they should overcome neophobia
- Keep activity in the area to a minimum and stop using hunting dogs, as disturbed pigs will be more likely to leave the area or be untrappable
- Trapping will likely take a larger proportion of pigs from a large group than will ground hunting with dogs
- Kill the pigs in the trap humanely (shoot them in the head with a centrefire rifle) and remove the carcasses from the area

5.2.5 Aerial shooting

Shooting feral pigs from a helicopter can be very successful in open and semi-open habitat. This method has been used to achieve rapid population knockdown (Choquenot et al. 1996), e.g. a knockdown of 80% was achieved in the first year of aerial control in western New South Wales (Saunders 1993). The efficacy of aerial hunting of feral pigs in New Zealand has not been well studied, however, one trial compared the efficacy of aerial shooting with and without Judas pigs (Yockney & Nugent 2006; see Judas pigs section below).

The most cost-effective helicopters for aerial control operations are the two-seater Robinson R22 or the Guimbal Cabri G2 at a cost of about 2019 NZ $750 per hour, excluding the cost of the shooter and ammunition (I. Yockney, unpubl. data). The use of thermal imaging technology can increase pig detections, especially in open and semi-open habitat (e.g. Focardi et al. 2001), potentially increasing kill rates relative to aerial shooting without thermal imaging technology. If a thermal imaging camera and operator are used, a larger machine (R44, H500) will probably be needed (unless the shooter also operates the camera) and this will be much more expensive per hour of flight time (2019 NZ $1300–$1800 per hr).

The suitability and effectiveness of aerial shooting in Northland will depend on the locations chosen for management, the type of habitat at chosen locations, and the visibility of pigs in those habitats. Efficacy is likely to be highest for areas with open and semi-open habitats and in seasons when vegetation is likely to be shorter or less dense, as this will make it easier for aerial cullers to see and shoot them.

5.2.6 Judas pigs

Judas animals are used to track down and kill conspecific survivors of eradication or control operations and have most often been used for feral goats *Capra hircus* (e.g. Parkes 1993). The method involves having one (or more) of the target species radio-collared, and then tracking this individual to re-locate it in the hope that it will betray the location of other individuals of the same species that it has teamed up with.

Judas goats have been effective mainly because goats are gregarious. Studies using Judas pigs in New Zealand and Australia have been more variable than for goats. However, it was a highly effective method for locating sparsely distributed pigs in expansive open areas in Otago (Knowles 1994). The technique was also effective for shooting pigs in areas of dense vegetation on Molesworth Station, Marlborough district, that would normally have been flown over with no (or rare) sightings of pigs (Yockney & Nugent 2006).

The Judas technique for feral pigs has been most successful when adult sows are used that are familiar with the area, and therefore trapping and radio-collaring sows from the area intended for control is recommended (Yockney et al. 2005). The Judas pig technique can work in conjunction with trapping operations, as sows caught in traps can be radio-collared and released (permits are required under the Wild Animal Control Act). A simple radio-transmitter collar (or tag) developed by Lotek NZ is convenient and easy to use and can be readily deployed by managers or landowners (www.lotek.com/; accessed 11 February 2020). The cost per radio-collar is approximately 2019 NZ $400 and these can be reused on other pigs, if the Judas pig is mistakenly shot or dies naturally. The cost of telemetry equipment (aerial and receiver) would be additional if the helicopter or ground hunters contracted to do the work do not have this equipment.

Some key recommendations for maximising the efficacy of Judas pigs:

- Radio-mark sows caught in traps and release them at the site of capture, do not translocate them
- Radio-tags or radio-collars can be used, but radio-collars, clearly marked with bright or reflective paint (e.g. dazzle), are likely to be more visible (large reflective ear tags may also be useful for identifying Judas animals)
- Given the low cost of radio-collars relative to capture costs, radio-collar more than one Judas sow in each area targeted for control to maximise the chance of encounters with conspecifics in the affected area
- If aerial shooting, ensure the pilot and shooter are experienced with radio-telemetry work and aerial shooting techniques
- Maximise efficacy and cost effectiveness by having as many Judas pigs to track as practical *before* hiring the helicopter and shooter
- Radio-collars and ear tags will probably not be noticeable using thermal imaging (although the collar may show up as a dark band relative to the heat signature of the pig), and Judas pigs and their collars could be covered in mud. The pilot and shooter should carefully identify target animals to avoid shooting Judas individuals
- Before releasing radio-collared pigs, coordinate with the Department of Conservation about radiofrequencies and permitting requirements

5.2.7 Ground hunting with dogs

Ground hunting with 'pig dogs' is the traditional method of recreational pig hunting in New Zealand (Holden 1994). Pig hunting with dogs for control of feral pig populations is likely to be most effective if hunters are experienced and use well-trained dogs, and the hunters have adopted a focus of control, as opposed to recreational hunting. That is, they do not only target big boars, or let small pigs go so that they can get bigger for future hunting opportunities.

Ground hunting with dogs is likely to be less effective for population control as the habitat becomes more demanding (steep and overgrown). There is also evidence that the effectiveness of hunting dogs declines as pig group size increases (Caley & Ottley 1995). This is because the dogs and hunters can only capture and kill a small proportion of the pigs in a group. If the hunters and their dogs are highly motivated to reduce pig numbers, they may be able to have a measurable effect on pig numbers, if they frequently target the population for control. If they do not, it is likely that pigs will replace their losses more quickly than they are killed, especially as they can have large litters (mean in New Zealand is about six piglets, but sows can have as many as 11; McIlroy 2005).

If pig numbers are high, or the required density to mitigate their unwanted impacts is low, recreational pig hunting with dogs by itself will likely have low efficacy as a control method in Northland. However, recreational pig hunters may be useful for removing problem feral pigs from production landscapes and they may be able to be used in concert with professional ground or aerial hunters and trapping to reduce pig numbers. It is also likely that recreational pig hunters could prevent a low-density pig population from increasing, but as they tend to view feral pigs as a resource rather than a pest (Nugent 1992), they may not be motivated to do this. Using professional hunters on performance-based contracts is more likely to keep pig densities and therefore their impacts, low.

5.2.8 Ground hunting without dogs

Traditionally, ground hunting without dogs has not been an effective method for controlling feral pigs. For example, Tisdell (1982) estimated that recreational hunters in Australia killed about 15–20% of the feral pig population annually. This level of harvest would not be sufficient to prevent pigs replacing their losses more quickly than they are killed (McIlroy 2005). Landholders familiar with properties are thought to be more effective, e.g. landholders in New South Wales shot 33% more feral pigs than recreational hunters (Benson 1980). Professional shooters who are familiar with properties are likely to be at least as effective as landholders, probably more so, given their level of training and experience.

Recent advances in thermal imaging technology for night shooting, such as handheld thermal imaging units and riflescopes, are likely to increase the effectiveness of ground shooting as a method for controlling feral pigs. However, although this technology is purported to increase detection and kill rates, there are currently sparse data to support this (Bengsen et al. in press). Anecdotally, it has been effective for night shooting dama wallaby (*Notamacropus eugenii*), parma wallaby (*N. parma*), and swamp wallaby (*Wallabia bicolor*) on Kawau Island, Auckland Region (Gardiner 2015) and white-tailed deer in the

USA (Williams et al. 2013). It has also been successfully used in concert with trapping to control feral pigs in Alabama, USA (Foster & Pinkston 2017). It is likely that it will have high applicability for controlling feral pigs in Northland, especially in open or semi-open areas used by pigs, such as where farms border production or native forests and scrub.

Discharging firearms at night is not legal on Public Conservation Land, but it is permissible with landholder permission on private land. Ground hunting at night may be effective in areas that are naturally good habitat for pigs, or where pigs have been baited/pre-fed specifically with this technique in mind. A thermal handheld unit and a thermal scope mounted on a centrefire rifle can be used to successfully target these specific areas.

6 A strategy for managing feral pigs in Northland

The strategy in this report is based on the precautionary principle, i.e. it assumes that feral pigs are an important vector of kauri dieback disease and any detectable reduction in pig numbers will also reduce the spread of PTA to unaffected areas. However, the exact role pigs play as vectors of this disease is unknown. Equally important from a manager's perspective is, what reduction in pig numbers is needed to prevent (or substantially reduce) the spread of kauri dieback disease by feral pigs? That is, data are needed to estimate a density–impact function for feral pigs and the spread of kauri dieback disease. It is possible, for example, that if pigs are an important vector, the required density to prevent them spreading kauri dieback disease is zero. This density reduction is not technically feasible, and it is likely to lack social licence to operate in Northland. Similarly, if control of feral pigs is not also being done to mitigate damage to other assets (indigenous or production system), it could be questioned why sentient animals are being killed when the outcomes of that control are unknown and may not even be measurable. Nevertheless, following the precautionary principle, we recommend a strategy (below) for controlling feral pigs in Northland, assuming the primary aim of that control is to reduce the spread of kauri dieback disease.

Professional control in Northland should only target pig populations of key concern to kauri forests or other indigenous assets. These populations may already be in kauri forests, or found adjacent to them and therefore pose a high risk to unaffected areas through geographic spread. Adjacent populations requiring control may be on production landscapes, such as farmland, and Northland Regional Council and its partners should insofar as is possible coordinate with landholders to reduce the densities of these potentially problematic populations. It will be critical to promote community awareness about the control of feral pig populations for the mitigation of kauri dieback disease, and to actively engage with local communities and stakeholders. If this does not happen, the control programme will be unlikely to have social licence to operate.

We do not recommend habitat modification or vertebrate toxic agents for controlling feral pigs in Northland. While Bait-Rite Paste® may be useful, there is little evidence to support its efficacy in New Zealand. If future control operations or research demonstrate high efficacy of this bait, it may be worth including it as a tool for pig control in Northland. Although it does not permit harvest rates or catch per unit effort to be estimated (as

carcasses are unlikely to be found), trends in the relative abundance of feral pigs could be estimated from camera traps, for example.

We also do not recommend fences as a primary control method for feral pigs. However, similar to the Te Paki fence, it may be a useful option for protecting small areas of high conservation value. We have one key caveat about the use of fences as a control tool for feral pigs and this relates to the uncertainty about the necessary reduction in pig numbers to reduce the spread of kauri dieback disease. If future research demonstrates that pig numbers have to be at or near zero density to substantially reduce or eliminate the spread of this disease, fences may prove to be the best (or only) method of protecting kauri. This may require eradicating pigs from within the fenced area and, if this is the case, it is critical that the criteria necessary for achieving eradication (listed above) are met. It may also be necessary to prevent the other vectors of PTA, humans and livestock, from accessing high priority forests, and the Department of Conservation has already "permanently closed" walking tracks to the public in some forests in Northland to prevent further spread of kauri dieback disease (https://www.doc.govt.nz/parks-and-recreation/places-to-go/northland/places/russell-forest-and-ngaiotonga-scenic-reserve/; accessed 12 February 2020).

For high priority pig populations, we recommend using a combination of ground and aerial shooting and traps with the work done by professional control staff. For low to moderate pig numbers, portable box or weld-mesh-panel traps may be enough to substantially reduce the population, e.g. by 50–80%, as estimated from operations in Australia (Saunders et al. 1993; Choquenot et al. 1996). Dropdown corral traps, like BoarBuster, are likely to capture a greater proportion of pigs from a group than are the aforementioned traps, but they are more expensive and need to be imported from the USA. However, we reiterate that it is not known whether a reduction of 50–80% is sufficient to reduce the risks of pigs spreading kauri dieback disease.

Populations targeted for trapping should not be disturbed by dogging or shooting prior to trapping, and the trapping methodology should follow the prescription in the trapping section above. Once traps stop catching pigs, professional ground or aerial hunters may be useful for further reducing the population, especially if camera trap or informal sign surveys suggest that pigs are still common in the area. For areas with known or suspected high numbers of pigs, ground or aerial hunting, potentially using thermal imaging technology, could be used for initial knockdown of the population and, following some period where the pigs were not disturbed, trapping could be used to further reduce the population. Most recreational hunters will not be sufficiently motivated to contribute to effective pig control when numbers are already very low, and therefore we do not recommend using them for high priority pig populations.

However, recreational hunters should be the primary 'control' method for pig populations in non-priority areas on Public Conservation Land. Private landholders with feral pigs that are not a threat to kauri can choose to do nothing (perhaps because damage is minor), or they can use tools such as recreational hunters with dogs or thermal imaging equipment for shooting at night, traps, or a combination of these control methods.

7 Take home messages

- Feral pigs are believed to be important vectors of kauri dieback disease and therefore populations near important kauri forests should be controlled.
- In the absence of quantitative data about the population reduction required to prevent or limit the risk of pigs spreading kauri dieback disease, we recommend reducing populations to 'low levels'. However, due to the lack of data, we cannot define a threshold for pig abundance.
- A combination of professional ground and aerial hunting, including using thermal imaging technology, and trapping should be used to achieve population reductions of feral pigs in areas listed as high priority for kauri (or potentially some other conservation asset).
- A community awareness and engagement programme should educate stakeholders about the probable risks feral pigs pose to kauri in some areas, and dissuade them from the practice of liberating pigs to bolster hunting opportunities in areas where risks to kauri are highest.
- Recreational hunters should be used as the primary method for 'controlling' feral pigs in areas where kauri conservation is not a priority, e.g. farmland pasture that is being damaged by pig rooting. Management (effort and funding) of feral pigs by agencies should only focus on critical areas for conservation, especially of kauri.
- Control operations should be monitored using numbers of pigs harvested annually, including hunter effort, and/or camera trap surveys.
- Future research needs to elucidate the role pigs play in dispersing kauri dieback disease and the population reduction needed to mitigate that risk.
- Fencing is not recommended for broad-scale management of feral pigs in Northland, but may ultimately be needed to fence off important kauri forests to exclude pigs and livestock, especially if the required density to prevent the spread of kauri dieback disease is zero.

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