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Animal pest monitoring and control methods for Waingake Bush

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Animal pest monitoring and control methods for Waingake Bush

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Summary

Project and client

- In order to effectively manage introduced mammals and their impacts, suitable monitoring and control methods are needed. Gisborne District Council (GDC) contracted Landcare Research to develop a work plan to manage introduced mammals and monitor biodiversity outcomes in the ecologically important Waingake Waterworks Bush, Gisborne District. The work plan was developed between July and August 2017.

Objectives

- To develop a plan for managing brushtail possums, ship rats, stoats and feral goats in Waingake Waterworks Bush, including:
  - methods for monitoring trends in the populations of these pest mammals
  - suitable methods (tactics) for controlling them
  - methods for monitoring the outcomes of pest control
  - spatial maps showing example networks for monitoring locations and control sites.

Establishing management objectives

- The goal of managing pest mammals in Waingake is to protect indigenous biodiversity.
- There are four possible strategies for managing mammal pests in Waingake. We recommend sustained control as the best option for managing possums, ship rats, stoats and feral goats, and their unwanted impacts.
- Sustained control assumes there is some relationship between pest density and the condition of the asset being protected (i.e. a density–impact relationship). Although sparse data are available for Waingake, information on density–impact relationships for some of the key pests is available from other areas. Based on these data, pest densities in Waingake should be kept at low levels (i.e. comparable to 5% trap catch for possums and 5% tracking rate for ship rats, and c. 0.2–0.5 goats per square kilometre). Appropriate levels for stoats are unknown, but trapping should attempt to maintain them at low numbers.
- To ensure that pest control is sufficient but not excessive (which may be unaffordable for long-term management), to achieve the defined outcomes we recommend adopting an adaptive management approach to monitoring and control in Waingake.

Monitoring pest mammals

- A combination of the following four methods may be suitable for long-term monitoring of pest mammals in Waingake:

- camera traps for annual trends and population indices (before versus after control) for all four species of pest mammals
- chewcards for possums and rats
- annual kill rates of stoats from trapping data (i.e. trap catch per unit effort)
- an analysis of annual catch-per-unit-effort for goats, with data provided by professional ground-based hunters.

Controlling pest mammals

- Possums and rats are likely to be a greater threat than stoats to the native birds present in Waingake. If funding is insufficient to control all predator species, we suggest the initial focus should be on possums and ship rats.
- Poisoning will be the most effective method of controlling possums and ship rats. Depending on regulatory restrictions, we recommend using a pre-fed aerial 1080 operation conducted in winter for initial knockdown (using a toxic sowing rate of c. 1 kg of cereal bait per hectare). Alternatively, the non-toxic pre-feed could be spread by aircraft, followed by a ground-laid application of toxic baits. We recommend using cyanide (e.g. paste) and bait stations containing permissible anticoagulant baits (e.g. diphacinone) for maintenance control. This latter approach will also kill stoats by secondary poisoning. Pest monitoring will guide the frequency of aerial control, but it is likely that operations will need to be repeated every 3–5 years.
- If GDC does decide to target stoats directly, we recommend establishing trapping lines using DOC 150, DOC 200 and/or Modified Victor traps. Traps should be about 500 m apart and baited using Erayz dried mustelid and rat blocks as bait. Critically, trapping effort must be standardised, as this will enable trap catch to be reliably estimated to assess trends in the numbers of stoats caught over time.
- Ground-shooting by professional hunters (preferably using indicator dogs) is likely to be the best method for controlling feral goats. To reduce the likelihood that goats from adjacent areas move into Waingake, we recommend, insofar as it is possible, shooting goats within a 1 km buffer around Waingake. In addition to ground-shooting, it is possible that some combination of aerial shooting from a helicopter, use of thermal imaging equipment, and Judas individuals may be suitable in Waingake, and these may help to reduce the costs of per capita kill rates at low goat densities.

Outcome monitoring

- Once control of the pest populations has occurred, it is critical that the responses of the assets be monitored to determine if the management objectives have been achieved. In Waingake the objective is to increase indigenous dominance.
- The responses of two broad ecosystem components to pest control in Waingake should be monitored: forest birds and vegetation. Five-minute bird counts and 20 m × 20 m plots and seedling ratio plots are well-established methods for monitoring forest birds and vegetation, respectively, and will probably be suitable for monitoring outcomes in Waingake.

- Although bats have not been recorded in Waingake, we recommend that surveys for them be conducted, as pest control may enable them to establish a viable population, or an undetected population already present to increase in numbers.
- If monitoring shows that defined outcomes have not been achieved, pest control should be adjusted adaptively to further reduce the numbers of pests.

Recommendations

- Pest mammal populations should be monitored using four methods: camera traps, chewcards, trap catch, and catch-per-unit-effort.
- A camera trap monitoring programme will require about 60 cameras in order to be sensitive to any changes in pest populations following control. Camera traps should be deployed randomly about 300–500 m apart, using a passive survey design. If there are sufficient cameras, a subset of cameras should be deployed along game trails to target goats. Cameras should be set to take photos continuously if an animal is detected.
- We recommend deploying baited chewcards every second year using standard methodology to determine how post-control densities of possums and rats, as indexed by cameras, compare to the recommended 5% trap catch required for an adequate reduction of predation pressure on native birds and browse pressure on flora.
- Trapping protocols for stoats and ground-shooting methodology for feral goats should be standardised to allow trap catch and catch per unit effort to be estimated.
- If there is insufficient funding to control all predator pests, we recommend that possums and ship rats be the priority, with stoats controlled thereafter. Possum and ship rat populations should be knocked down using a pre-fed aerial 1080 operation conducted in winter. Bait stations containing cyanide and a first-generation anticoagulant (e.g. diphacinone) should be used for maintenance control of possums and rats, respectively. Rat control will probably need to start in late winter–early spring, and monitoring will help determine the appropriateness of this.
- A trapping grid should be established to maintain stoats at low numbers. Centrally located traps and perimeter traps should be c. 500 m and 250 m apart, respectively.
- Feral goats should be controlled using shooting conducted by ground-based hunters with indicator dogs. Also, some combination of aerial shooting, thermal infrared imaging and Judas goats may improve efficacy. If possible, goats should be controlled in a 1 km buffer around Waingake to prevent reinvasion.
- Five-minute bird counts should be undertaken every 2–4 years using the same 150–200 count stations.
- At least 8–10 permanent 20 m × 20 m plots should be established in tawa–rimu forest to monitor change in vegetation structure and composition. Measurement of seedling subplots should be prioritised if all components of the standard method cannot be measured.
- Automatic bat detectors should be used to survey for long-tailed bats.

1 Introduction

Enhancing native biodiversity in Waingake Waterworks Bush is an important goal for Gisborne District Council (GDC). However, as in other parts of the country, native forest birds in that area are probably limited by predation by introduced mammalian predators (Innes et al. 2010). Similarly, introduced mammalian herbivores can have a negative impact on native vegetation and ecosystems, which can subsequently affect habitat quality for native birds (Wardle et al. 2001; Innes et al. 2010; Gormley et al. 2012). To effectively manage these introduced mammals and their impacts, suitable monitoring and control methods are needed. GDC contracted Landcare Research to develop a work plan to manage introduced mammals and monitor biodiversity outcomes in the ecologically important Waingake Waterworks Bush, Gisborne District. The work plan was developed between July and August 2017.

2 Background

Waingake Waterworks Bush (hereafter Waingake) is a 1,104 ha area owned by GDC. It is situated in the Tiniroto Ecological District and is the largest and most intact podocarp–broadleaved–beech forest remaining in the eastern soft-rock lowlands of the North Island. The forest is dominated by rimu (*Dacrydium cupressinum*) and tawa (*Beilschmiedia tawa*), with black beech (*Fuscospora solandri*) forest on ridges and spurs at lower altitudes and red beech (*F. fusca*) and silver beech (*Lophozonia menziesii*) on higher-altitude ridges (Whaley et al. 2001).

The size and diversity of the forest provide important habitat for many native forest birds. On 24 July 2017 N. Fitzgerald visited Waingake with GDC and Department of Conservation (DOC) staff and recorded the presence of whitehead (*Mohoua albicilla*), rifleman (*Acanthisitta chloris*), tomtit (*Petroica macrocephala*), grey warbler (*Gerygone igata*), tūī (*Prosthemadera novaeseelandiae*), bellbird (*Anthornis melanura*) and kererū/New Zealand pigeon (*Hemiphaga novaeseelandiae*). Compared to most of the Gisborne District, Waingake has a high indigenous biodiversity, and it is an important source of clean freshwater for Gisborne City. However, Waingake's indigenous biodiversity and ecosystem services are threatened by invasive alien species, and this led GDC and other stakeholders (DOC, QEII Natural Trust and local iwi) to request technical expertise to develop a management plan for the control of pest mammals in the area.

The primary mammal pests in Waingake include brushtail possum (*Trichosurus vulpecula*), ship rat (*Rattus rattus*), stoat (*Mustela erminea*) and feral goat (*Capra hircus*). The negative impacts of these species have been well documented in New Zealand and elsewhere (Innes et al. 2010; Latham et al. 2017b; Parkes et al. 2017). Brushtail possums are primarily herbivorous and their selective browsing can damage indigenous and exotic plants and cause widespread and progressive mortality of some forest canopies (Cowan 2005 and references therein). However, when presented with the opportunity, they readily eat meat, such as birds and their eggs, and land snails (Brown et al. 1993; Walker 2003; Innes et al. 2015). They are also the primary wildlife maintenance host for bovine tuberculosis in New Zealand (Warburton & Livingstone 2015).

Ship rats are omnivores and important predators of seeds and inflorescences, invertebrates, skinks and birds (Towns et al. 2006). Stoats and other mustelids introduced into New Zealand are obligate carnivores and important predators of insects, skinks and birds, as well as other introduced mammals like rodents and rabbits (*Oryctolagus cuniculus*) (King & Murphy 2005). Selective browsing by feral goats can significantly reduce the abundance of preferred species of plants and change the composition of forests, such that they become dominated by the least palatable plant species (Forsyth et al. 2002; Parkes et al. 2017).

With the exception of feral goats, the damage caused by the mammal pests listed above has not been quantified in Waingake. However, the damage caused by these species in similar habitats elsewhere in New Zealand has been well studied, and based on the information from these studies these pests have been included in the Proposed Gisborne Regional Pest Management Plan 2016–2026 as species of concern that need to be managed to mitigate their unwanted impacts (Gisborne District Council 2016). For goats, exclosure plots established in Waingake in the 1960s to 1980s demonstrated similar negative impacts to studies conducted elsewhere in New Zealand; i.e. their selective feeding was deemed to have negatively changed the structure and composition of plants outside of the exclusion plots relative to that inside the plots (Knowlton 1982). Based on these results, goat control was started in Waingake in the 1960s and has been carried out periodically since then, initially by the New Zealand Forest Service and then by DOC (Whiting 1994). The latest goat control programme led by DOC started in 2014/15 (S. Hustler, Department of Conservation, pers. comm.). Possums were also controlled by DOC in 1994 using ground-based trapping (Department of Conservation 1994).

3 Objectives

The ultimate objective of management intervention in Waingake is to increase indigenous dominance so that ecosystem processes such as predation, herbivory and pollination are performed by indigenous rather than exotic species. Also, if mammalian predation can be sufficiently reduced, reintroduction of some locally extinct taxa may be feasible and would further enhance indigenous dominance.

To assist GDC and their stakeholders to achieve these objectives, we developed a management plan for Waingake, which includes:

- suitable monitoring methods for assessing trends in the populations of possums, ship rats, stoats and feral goats before and after control, and over time
- suitable vertebrate pest control methods (tactics) for managing pest mammals
- methods for quantifying the responses of the assets of value to pest control (i.e. outcome monitoring)
- spatial maps showing example networks of monitoring locations and control sites (trap lines and bait stations).

4 Management strategies

The *goal* of managing pest mammals is ultimately to protect some biodiversity or productive asset of value. In areas where the pest and the asset already overlap, and the damage caused by the pest is significant, management of the pest population is needed to mitigate their unwanted impacts. Clearly identifying these goals is important because it allows managers to justify and defend their actions against the pest populations. This is particularly important (a) for pest species that are of value (i.e. for hunting or fur) to some people; (b) when the strategies, tactics and costs of any management are contentious; and (c) because it is unethical to kill sentient animals without good cause (Parkes et al. 2017).

The *asset of value* may be a rare or threatened indigenous species affected by the pest, a particular ecosystem affected by the pest, or some process that is being disrupted by the pest. In Waingake the assets of value are likely to be related to indigenous biodiversity and clean freshwater, as opposed to assets in production landscapes that are affected by the pests. For example, goats in Waingake may selectively feed on highly palatable *Coprosma grandifolia*, and goats may need to be controlled to prevent this species being removed from the understorey. Similarly, possums, ship rats and stoats may have to be controlled to maintain a viable population of North Island rifleman, or to enable extirpated indigenous species to be reintroduced to the area (if that is a goal).

There are four key *strategies* for managing mammal pests in Waingake. The first is to prevent the spread of a new mammal pest into Waingake, either via natural spread, illegal translocations, or escapes from captive species. This report focuses on four pest species already present and widespread in Waingake, so we do not discuss this strategy further. Second, it may be possible to eradicate (i.e. permanently remove) the target pest population from the area. Given how widespread and abundant possums, ship rats, stoats and feral goats are in Gisborne District, this strategy is unlikely to be feasible, because even if the target population could be eradicated, reinvasion from neighbouring populations is highly probable. A third strategy is to conduct sustained control on the pest population to keep their numbers below threshold densities in order to ameliorate their damage. A fourth strategy is to do nothing. This is a deliberate decision not to manage the pest, either because it falls below a priority threshold when budgets are limited, or because its unwanted impacts are not significant.

For the pest species in this management plan we focus on *sustained control* to reduce the pest population to a threshold density that is sufficiently low to ameliorate the damage to the asset/s. For irruptive pests (like ship rats) that have acute (possibly brief, but severe) impacts, pulse control (a type of sustained control) needs to be done every time the pest is predicted to increase in numbers, as this is likely to minimise the damage to the asset. It is essential to monitor outcomes (benefits) under sustained control strategies.

Sustained control is a complex strategy, which assumes that there is some relationship between pest density and the condition of the asset being protected (i.e. a *density–impact relationship*). It is often considered that the lower the pest density, the better the ecological outcome. While this pattern holds for some density–impact relationships, it does not always hold, and the same outcome may be achievable with substantially less control effort (this has implications for the long-term affordability of a management plan). For some density–

impact relationships there may be threshold levels of pest abundance below which a positive response in the asset is observed (Norbury et al. 2015).

Density–impact relationships have been assessed for some pests and assets in New Zealand, and these probably provide a good starting point for guiding pest control in Waingake. For example, a linear negative relationship has been reported for ship rat abundance and some demographic rates of North Island robins (*Petroica longipes*) (Armstrong et al. 2006). Similarly, there was a linear negative relationship between stoat abundance and predation of mohua (*Mohoua ochrocephala*) nests in New Zealand beech forest (Elliott et al. 1996). These studies suggest that even a small reduction in the density of ship rats and stoats can allow some nests of robins and mohua to escape predation.

Conversely, North Island brown kiwi (*Apteryx mantelli*), whio (*Hymenolaimus malacorhynchos*), yellow-crowned kākāriki (*Cyanoramphus auriceps*) and kōkako (*Callaeas wilsoni*) are highly vulnerable to predation by possums, ship rats and/or stoats (Elliott et al. 1996; Basse et al. 1999; Innes et al. 1999; Whitehead et al. 2008). Similarly, heketara (*Olearia rani*) and patē (*Schefflera digitata*) are highly preferred by possums and show increased survival only at very low possum densities (Gormley et al. 2012).

For species that are highly vulnerable to predation or herbivory, pest densities will need to be kept low (e.g. equivalent to about 5% trap catch for possums and 5% tracking rate for ship rats; Innes et al. 1999). Parkes et al. (2017) recommend that goats be kept at very low densities (c. 0.2–0.5 goats per square kilometre) to protect highly vulnerable environmental assets in Victoria, Australia, and this probably holds for goats in Waingake.

There are a number of uncertainties around density–impact relationships, but these details should not be a reason for delaying action, because there will always be uncertainties (Parkes et al. 2017). A solution to a lack of information is to take an *adaptive management* approach by collecting data about the pest population being controlled and the response of the asset to pest control. If the predicted response of the asset to pest control is not observed, the intensity of control may need to be increased. A further source of complication in density–impact relationships is determining pest target densities if there are one or more sympatric pest species present (e.g. possums, ship rats and stoats negatively affecting the breeding success of indigenous birds). Again, an adaptive management approach may help to solve this complexity.

5 Monitoring pest mammals

Effective monitoring of the pest population being controlled is a vital component for demonstrating that the defined outcomes of control have been achieved (Clayton & Cowan 2010). It is seldom possible to make a complete count of an entire population, especially for rare and cryptic species (Edwards et al. 2000; Ball et al. 2005). Instead, it is necessary to make inferences about the relative trends (relative abundance) of a subset of the pest population being controlled (Caughley 1977). A number of survey methods, some species-specific, have been developed to provide these indices. In New Zealand, wildlife managers often obtain these data using spotlight transects, hair traps, tracking tunnels, scat surveys, chewcards, WaxTags®, leg-hold traps, camera traps, and catch-per-unit-effort (CPUE) obtained from hunting data (Fraser & Nugent 2003; Ball et al. 2005; Latham et al. 2012). Similarly, kill rates following control operations have been estimated using radio-tags deployed on a subset of the population (e.g. possums; Nugent et al. 2017).

Camera traps are emerging as a useful and affordable tool for monitoring cryptic species (Cutler & Swann 1999) and show considerable promise for monitoring the effectiveness of pest mammal control operations (Latham et al. 2012; Glen et al. 2013). They are also increasingly being used to provide wildlife inventories and monitor trends of multiple species simultaneously (i.e. in the same area, during the same survey period), thereby doing away with the need to have multiple species-specific monitoring tools (De Bondi et al. 2010; O'Connell et al. 2011). Camera traps are capable of detecting all the mammal pests that cause damage in Waingake (De Bondi et al. 2010; Glen et al. 2013), and they have been successfully used to monitor operations conducted to control possum and rabbit populations (e.g. Latham et al. 2012; Nugent et al. 2017). Note that best practice for camera trap set-up, deployment, image analysis, and how the number of detections (images) relates to biodiversity outcomes is evolving quickly. Accordingly, GDC may need to periodically review methodology if camera traps are adopted for monitoring mammal pests in Waingake.

We recommend deploying baited *chewcards* in Waingake every second year, using standard methodology (and stratified by habitat, as required) to determine how post-control densities of possums and rats, as indexed by cameras, compare to the recommended 5% trap catch required for reduced predation pressure on native birds or browse on flora. This needs to be done, because although camera traps are becoming increasingly used for these types of monitoring programmes, the relationship between the density of the pest (camera trap index) and the asset being protected remains poorly understood, and research assessing this is ongoing. Chewcard surveys should be done in winter (note: we recommend using camera traps to monitor for a potential increase in ship rat numbers in late winter or early spring; see section 5.1 'Monitoring design for camera traps', below).

It is possible that camera traps will yield few detections of stoats (low sensitivity), resulting in an inability to confidently identify a trend in stoat numbers, if one exists. This problem is not uncommon for stoats, irrespective of the sampling method (e.g. Glen et al. 2014). However, camera traps will provide data on the *presence* of stoats, and this may be sufficient information to warrant control effort being maintained or increased. Moreover, because we recommend using traps to kill stoats (see section 6, 'Controlling pest mammals'), trends in stoat numbers may also be identifiable from trapping data (i.e. *trap catch per unit effort*). Importantly, trapping effort must be standardised by using the same trap types, trapping sites and bait types, and standardising the number of days traps are set between checks (Latham et al. 2017a).

Robust trends in goat numbers are probably obtainable from camera traps. However, if goat numbers in Waingake are already low (our understanding is that they are not) because of previous control by ground-based shooters (Whiting 1994; S. Hustler, Department of Conservation, pers. comm.), the sensitivity to detect trends in their numbers using camera traps may also be low.

An alternative or complementary method to using camera traps for goats is to use *catch-per-unit-effort*. This analytical method requires hunters to collect information on time spent hunting (easily obtained using a GPS unit and saving time-stamped track files), number of goats shot, and (ideally) number of goats seen but not shot. These analyses have previously been used in Waingake (Whiting 1994; S. Hustler, Department of Conservation, unpubl. data), and Brennan et al. (1993) found that kill rates of goats recorded by DOC in Marlborough provided linear indices of goat population size.

In summary, we recommend using a combination of four methods for long-term monitoring of pest mammals in Waingake:

- **camera traps** for annual trends and population indices from before versus after control for all four species of pest mammals, as well as other mammal pests like hedgehogs (*Erinaceus europaeus*) and feral cats (*Felis catus*), should they be present (see proposed survey design and camera setup below)
- **chewcards** for possums and rats
- annual kill rates of stoats from trapping data (i.e. **trap catch per unit effort**)
- an analysis of annual **catch-per-unit-effort** for goats, with data provided by professional ground-based hunters.

5.1 Monitoring design for camera traps

It is difficult at this stage to recommend a suitable number of cameras to deploy in Waingake, primarily because of uncertainties relating to rates of detection for each species and unknown effect sizes of control (i.e. the magnitude of the change in population sizes caused by control). However, we suggest that c. 60 camera traps is a good starting point. Appendix 1, based on Landcare Research's standard operating procedure for the use of trail cameras (Morriss 2017), provides details about what makes and models of cameras may be suitable, and their functions and care.

The spatial placement of camera traps for obtaining data on population trends of pests in Waingake is less critical than that used for studies looking to estimate actual population size (Meek et al. 2014). For some wide-ranging species like stoats, feral cats and feral goats, camera traps will be more likely to detect an individual at multiple sites than for species that range less widely, such as ship rats or hedgehogs (Bengsen et al. 2012). We recommend that camera traps be placed 300–500 m apart. We predict that this will allow for a sample size of cameras that is adequate to detect any trends in relative abundance of each pest species, as well as a design that is affordable to deploy and service. We further recommend that, unless pest mammals can be controlled in a buffer outside of Waingake, camera traps not be erected within a buffer of 250 m from the edge of Waingake (see Figure 1 for an example layout, which GDC should refine as required based on factors such as access and topography). This is because pest mammals detected at camera traps situated at the perimeter may be individuals living on land adjacent to Waingake where control has not occurred. Ideally, the buffer would be larger than 250 m for the widest-ranging pest species, but increasing this buffer is likely to reduce the camera trap sample size to a level where trends are not detectable or statistically robust.

We recommend deploying camera traps randomly within Waingake (Figure 1). If cameras are not a limiting factor, we suggest that a subset of cameras have deliberately biased placement to target animals, particularly goats, using game trails (these locations will need to be identified following a site assessment by appropriate staff).

Camera traps can be deployed to create active or passive survey designs (Meek et al. 2012). An active survey design uses a bait or attractant to lure individuals into the camera trap's detection zone, increasing the probability of detecting an animal if it is present. Unlike active designs, a passive design does not use a bait or attractant, and these designs are used if it is critical that the animal's behaviour not be changed. Both approaches have pros and cons. However, we suggest using a passive design because we do not want to unduly influence animal behaviour, as this could significantly affect detection rates and therefore population trends (as has been shown for possums using baited chewcards at camera traps; Nugent et al. 2017).

A single animal can spend a lot of time in the detection zone of a camera trap (even in the absence of a lure), potentially resulting in a large number of images of the same individual in a short period. This can be overcome by setting cameras to take 3–5 (or more) photos, followed by a down period of, for example, 5 min, when the camera cannot take any more photos. Alternatively, cameras can be set for continuous rapid fire (i.e. no period when the camera cannot take photos), and repeat images of the same individual taken within a short period can be managed after the Secure Digital Memory (SD) cards are downloaded. The latter approach can provide additional observations of multiple individuals in the same image, different individuals, or different species visiting the camera trap in quick succession, which may not have been acquired if camera traps were set with a down period. Therefore, we recommend that GDC set cameras to continuous rapid fire (i.e. no down period) and manage images after downloading them. Landcare Research can assist with image and metadata management and analysis, if required.

Cameras do not need to be deployed all the time. Rather, they should be deployed strategically at times of the year that correspond best with the species of interest and/or control programmes. For example, to assess the outcome of an aerial 1080 operation conducted in winter to control possums, camera traps should be deployed and active for 2–3 weeks before the operation, then re-activated 2 weeks after the operation for another 2–3 weeks. Note: in this case, camera traps are left in the same location before and after control. A similar design may be suitable for detecting an increase in rat numbers in late winter or spring and then monitoring the outcome of subsequent control (e.g. using bait stations). It is probable that these sampling periods will also provide required data for goats, and possibly stoats.

See Appendix 1 for details of how to mount and set-up/aim cameras at the detection zone, and refer to the instruction manual of the chosen make and model of cameras for programming details.

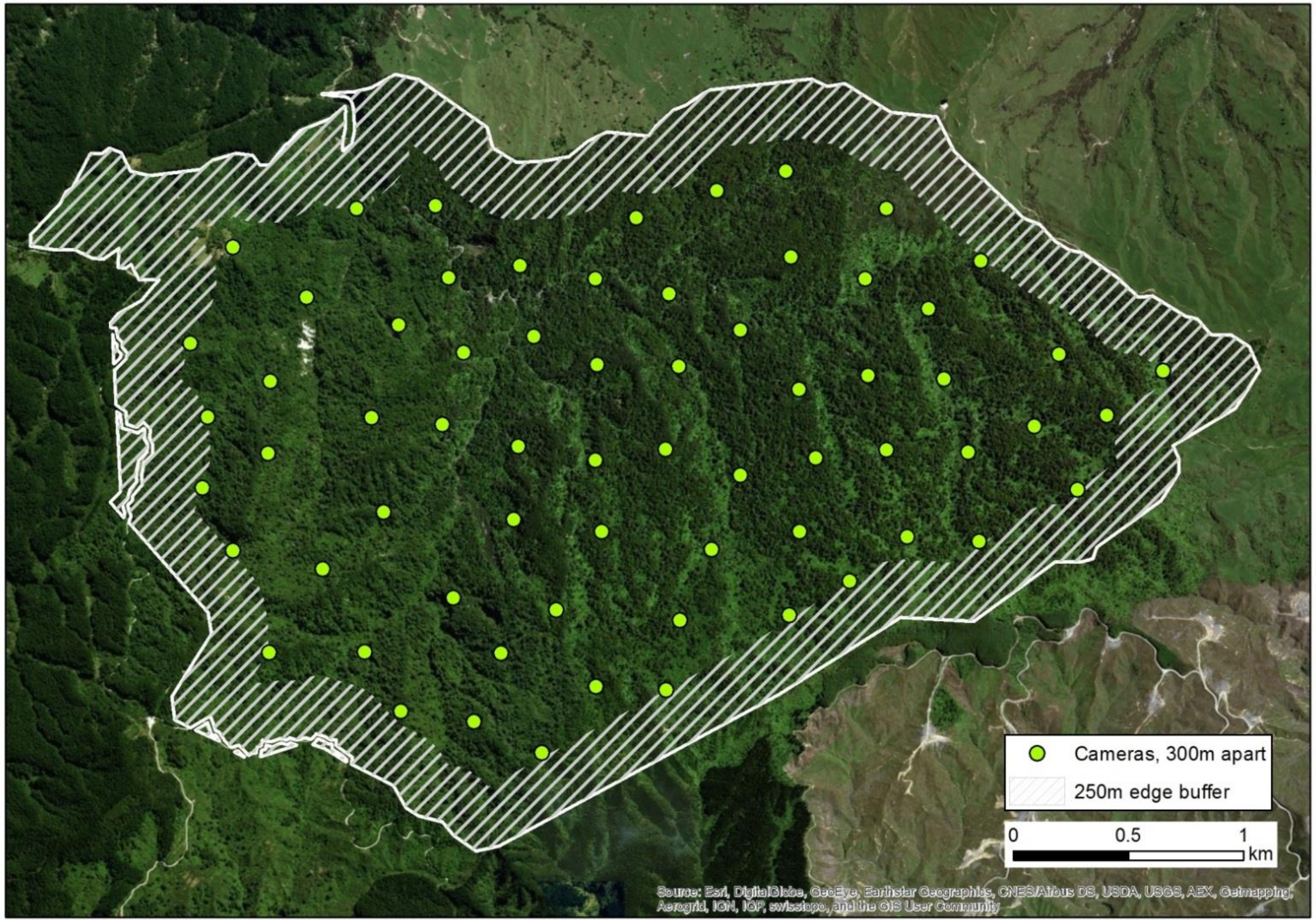

Figure 1 An example deployment of camera traps for monitoring mammal pests in Waingake Waterworks Bush, Gisborne District. In this example, 66 camera traps have been randomly deployed at least 300 m apart. (Local knowledge of the area should be used to adjust these locations based on topography, accessibility, etc.). A buffer of 250 m has been created to minimise sampling animals from adjacent uncontrolled areas, although for the widest-ranging pest species this will be unavoidable.

6 Controlling pest mammals

This section focuses on the tactical options available for sustained control of possums, ship rats, stoats and feral goats in Waingake. Of the tactical options listed below, we consider only those highlighted in bold as potentially feasible options for Waingake:

- **poisoning**
- **trapping** (including capture and removal)
- **ground-based shooting** (including official and recreational hunting, with or without indicator dogs)
- **aerial shooting**
- **Judas animals**
- fertility control
- mustering
- fencing (including exclusion from water)
- as a consequence of commercial harvesting, when this is used by the land manager as a control tool.

The effectiveness of each of these tactics and the benefits gained from their use are likely to be affected by a number of factors, especially the intensity and frequency of their application, the abundance of the pest population prior to and following control, the size of the area being controlled and its proximity to source pest populations, the ability of the affected species or resources to recover, and the relative humaneness of the method.

Some of the tactics listed above will likely be species-specific in Waingake, whereas others will simultaneously control more than one pest species. In general, tactics with multispecies control capability are likely to be more cost-effective. However, if the damage caused by a pest is significant, it is important that the most effective, affordable and humane method is used.

The rationale for excluding fencing and commercial harvesting as viable tactics in Waingake include:

- fencing is likely to be most efficacious for excluding goats from important water sources, but if they are reduced to low densities by shooting the expense associated with building and maintaining fences is unlikely to be justified
- commercial harvesting of possums for fur will be unlikely to reduce their numbers to sufficiently low densities to ameliorate their damage.

Finally, we note that possums and rats are likely to be a greater threat than stoats to the native birds present in Waingake. If funding is insufficient to control all predator species, we suggest that the initial focus be on possums and ship rats.

6.1 Poisoning

The use of toxins is one of the most commonly used methods for the sustained (including pulse) control of pest mammals in New Zealand. In particular, anticoagulants (such as brodifacoum, diphacinone and pindone) and sodium fluoroacetate (compound 1080) have proven to be cost-effective methods for significantly reducing the populations of possums, rabbits, and ship rats over large areas (Innes et al. 1995; Nugent et al. 2012; Warburton & Livingstone 2015). These toxins are also capable of killing mammal pests that depredate individuals that have consumed poisoned baits or scavenged their carcasses. For example, feral cats, stoats and ferrets (*Mustela furo*) are known to have died due to secondary poisoning following 1080 operations targeting possums, rabbits and rats, and this is a commonly used method for reducing predator populations to achieve conservation outcomes (Gillies & Pierce 1999). Importantly, however, secondary poisoning does not necessarily result in a population reduction that ameliorates the damage caused by invasive mammalian predators. Monitoring of the pest/s and the asset is needed to determine this.

We recommend the use of 1080 as the primary toxin for sustained control of possums and ship rats in Waingake. A *pre-fed aerial 1080* operation conducted in winter should be used for *initial knockdown* of the possum and rat populations. This should include one non-toxic pre-feed, followed by an application of c. 1 kg of toxic cereal bait per hectare and should follow the guidelines set out by the National Pest Control Agencies (NPCA 2015a). Because Waingake is a source of freshwater for Gisborne City, it is likely that the regulatory requirements for using toxins for pest control will be more stringent than those for areas that do not provide this resource. It is important that GDC is aware of these regulatory requirements and that they are met. If there are concerns about the aerial application of toxic baits (despite buffers where baits cannot be laid around water features), a hybrid operation may be more suitable, where the non-toxic pre-feed is aerially applied, followed by a ground-laid application of toxic baits (Morgan 2014). The frequency of these operations will depend on the population responses of the pests to control, and monitoring will guide this, but it is likely that operations will need to be repeated every 3–5 years.

Following initial knockdown, we recommend using cyanide (e.g. paste or Feratox®) and then a first-generation anticoagulant (e.g. diphacinone or pindone) for *maintenance control* of possums and rats. Possums should be controlled first, using a cyanide product, to minimise interference with toxins targeting rats, particularly diphacinone. Possum control should occur in winter. We recommend deploying diphacinone (e.g. D-Block or Ratabait, Connovation; www.connovation.co.nz/) in bait stations in late winter through to December to control rats, as this overlaps the breeding season of native forest birds, and rats can have a propensity for irrupting at this time of year (see NPCA 2015b for responsible use of bait stations). This is also predicted to give a good secondary kill of mammalian predators/scavengers like stoats. High-strength pindone is a preferred alternative if diphacinone-based products prove ineffective. Ideally, bait stations should be about 300–500 m apart for possums and 100 m apart for rats.

The anticoagulant brodifacoum is highly effective at controlling possums and rats. However, it persists in animal tissue for at least 9 months and has been found in a host of non-target species (Department of Conservation 2013). Accordingly, DOC has an updated policy for the use of brodifacoum and other second-generation anticoagulants (bromadiolone, difenacoum, difethialone and flocoumafen) on public conservation lands, and this policy restricts the use of these toxins in most areas (Department of Conservation 2013). To our knowledge this policy does not apply to Waingake, but nevertheless we suggest it is good practice to avoid using brodifacoum if possible. However, it may be worthwhile keeping brodifacoum in the toolbox in the event of (for example) a severe irruption of rats, or bait-shy possums that are not manageable using other tools.

Another alternative toxin worth mentioning is D+C (diphacinone and cholecalciferol). This toxin is currently being registered for use on possums and ship rats, and it may become available for sustained control of these species in Waingake in the near future.

Foliage baiting using a poisoned 1080 gel applied to the leaves of preferred trees has been used, with mixed success, to control deer, tahr (*Hemitragus jemlahicus*) and feral goats (e.g. Parkes 1983). However, poisoned carcasses have high secondary poisoning risks to domestic dogs and there is (at least some) public opposition to its use, and therefore we do not recommend using it to control feral goats in Waingake.

Table 1 A list of toxins that may be suitable for controlling mammal pests in Waingake Waterworks Bush, Gisborne District

Toxin	Species	Method	Recommended	Comment
1080	Possum, ship rat	Aerial knockdown	Yes	
1080 gel	Goat	Applied to foliage	No	
Cyanide (paste and Feratox®)	Possum	Ground-laid for maintenance control	Yes	
Diphacinone	Ship rat	Bait stations	Yes	
Pindone	Possum, ship rat	Bait stations	If diphacinone does not work	High-strength pellets
Brodifacoum	Possum, ship rat	Bait stations	No	Possibly as a 'last resort'
Cholecalciferol	Possum, ship rat	Ground-laid for maintenance control	No	Lack of data on efficacy
D+C	Possum, ship rat	Ground-laid for maintenance control	No, but maybe in near future	Not yet registered

6.2 Trapping

Given that the population of stoats in Waingake may not be sufficiently reduced by secondary poisoning in control operations aimed at possums and ship rats, we recommend establishing trapping lines using DOC 150, DOC 200, and/or Modified Victor traps (see Figure 2). In addition to stoats, these traps will kill rats and hedgehogs, and so they may be suitable to use in concert with other methods for maintenance control of these species. If there is concern about damage caused by ferrets in Waingake, GDC may want to consider using the larger DOC 250 traps.

Traps should be set about 500 m apart, ideally along linear features such as ridges, streams or fences to maximise the probability of capture. As mentioned previously, trapping effort must be standardised throughout time, as this will enable trap catch to be reliably recorded to assess trends in the numbers of stoats caught over time. A trapline should be established around the perimeter of Waingake to, insofar as is possible, reduce immigration of pests into this area from adjacent populations (see Figure 2). Traps around the perimeter should be about 250 m apart.

We recommend using Erayz dried mustelid and rat blocks as bait. Also, recent research has shown that lures, such as those containing ferret body odour, can increase the number of visits by stoats to sampling devices and the time they spend at them, and so these may have application for increasing the efficacy of trapping stoats (Garvey et al. 2017). If GDC decides to use a lure like ferret body odour, this should be used from the outset, as choosing to use it partway through a trapping programme will affect trap catch per unit effort.

6.3 Shooting

Ground-based shooting conducted by professional hunters (preferably with indicator dogs) is recommended for goat control in Waingake. This method has proven very effective for reducing goat numbers to low levels (or eradicating them) in many areas, even though the cost per goat killed usually increases significantly as the population declines to low levels (Parkes et al. 2017). Also, goat populations previously exposed to repeated ground-based shooting operations alter their behaviour to decrease hunter risk, and this can also substantially increase the cost per goat killed. Because we recommend keeping the goat population in Waingake at <1 km^2 to mitigate their damage, it is likely that costs per goat killed will also increase as their population decreases to such low levels. Monitoring of vegetation affected by goats (see section 7, ‘Outcome monitoring’) will provide information about this density–impact relationship and whether or not control effort needs to be increased.

Observations of feral goats in the study area suggest they are relatively common in Waingake and some adjacent habitats (S. Hustler, Department of Conservation, pers. comm.; N. Fitzgerald, pers. obs.). High goat numbers in adjacent habitat may significantly hinder control efforts in Waingake, as goats will likely reinvade from these areas, leading to an inability to reduce goat numbers to levels that are sufficiently low to ameliorate their damage. In this case, applying a control buffer of *c.* 1 km around Waingake (if feasible/permissible) should be incorporated into management plans for feral goats. Control in this buffer might include a combination of ground-based shooting (e.g. in neighbouring pine plantations) and/or aerial shooting (e.g. in farmland adjacent to Waingake; see aerial shooting below). Buy-in from adjacent landowners will be critical for reducing feral goat numbers on neighbouring properties.

Aerial shooting from helicopters can be a highly effective method for controlling populations of wild ungulates (Latham & Nugent 2017). Although it may not be feasible to use aerial shooting in densely forested habitats within Waingake, it may have utility in open areas or habitats with lower canopy cover, and potentially areas adjacent to Waingake that are used by feral goats. Aerial shooting may be of particular use if Judas goats are deployed and/or thermal imaging is used as a tool to locate and kill goats (see below).

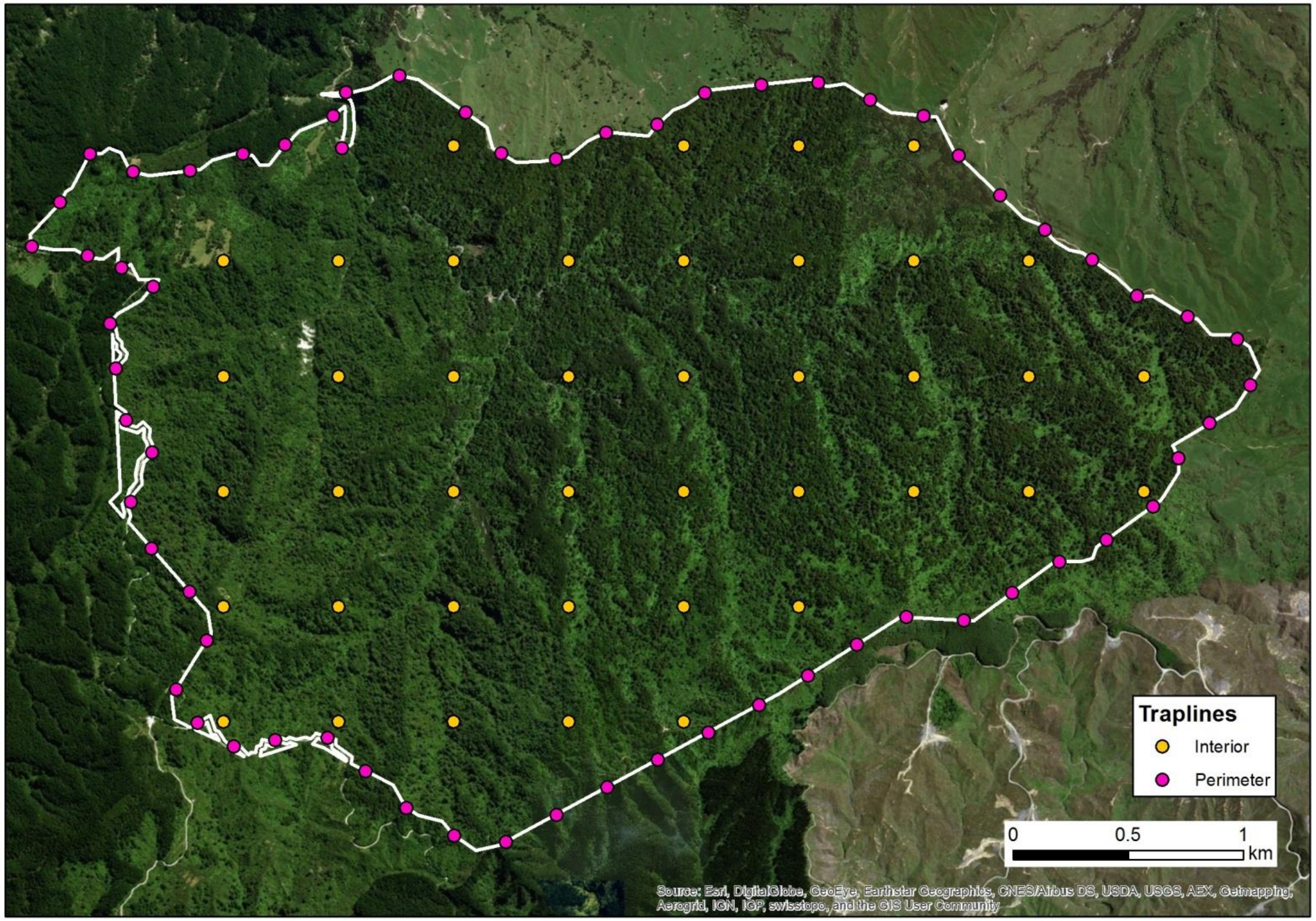

Figure 2 An example deployment of a trapping grid for stoat control in Waingake Waterworks Bush, Gisborne District. In this example, traps are spaced 500 m apart in the centre of Waingake and 250 m apart around the perimeter (local knowledge of the area should be used to adjust these locations based on topography, accessibility, etc.).

Thermal infrared imaging – technology that is able to detect the body heat of warm-blooded animals (e.g. Gill et al. 1997) – may be suitable to use in ground and aerial control of feral goats in areas where it can be safely and humanely used and is predicted to increase kill rates. For example, it has been used by professional ground hunters to detect and kill sika deer (*Cervus nippon*) in the ongoing eradication programme in Russell Forest, Northland (Speedy et al. 2016). Because thermal infrared imaging cannot reliably detect goats (or other animals) through dense forest canopy (Gill et al. 1997), aerial use is likely to be most efficacious in open or scrubby habitat in and around Waingake. It may be particularly useful if Waingake has low numbers of goats that have modified their behaviour to decrease predation risk because of exposure to frequent repeated ground-shooting operations, resulting in high costs per goat killed.

Using 'Judas' animals to track down and kill survivors of eradication or control operations is a commonly used approach for feral goats (e.g. Parkes 1993). The method uses one or more radio-marked individuals released into an area where conspecifics are known or suspected to occur. The idea is that these individuals will seek out and group up with survivors (even if they are not related), allowing hunters to more readily locate and kill survivors using either ground or aerial methods. Very-high-frequency (VHF) or global positioning system (GPS, preferably with a VHF beacon) collars can be deployed on Judas animals. The advantage of GPS collars is that additional information about fine-scale spatiotemporal habitat use, range extent and behaviour can be obtained (Latham et al. 2015), potentially improving future control efforts. The disadvantage of GPS collars is that the cost per unit is high compared to VHF, so fewer units can be purchased (Latham et al. 2015), and if the animal wearing the collar is shot by recreational hunters the collar may be stolen or purposely destroyed.

As discussed above, careful thought should be given to the types of data collected from shooting (ground-based or aerial) programmes, as this information can provide an additional index (CPUE) of abundance for goats.

Some thought needs to be given to who will conduct the shooting. This could be specialised or interested staff within land management agencies, or private contractors. The advantage of using agency staff is that they are usually familiar with the area being controlled and some may have the skills and drive to achieve targeted control to a specified level. The primary disadvantage is that unless staff are dedicated to the task fulltime, their approach to hunting may not be systematic: their efforts may be more or less done out of interest and when they get spare time. Control efforts then become sporadic partial control, and this may not be adequate to ameliorate damage caused by goats. Private contractors have advantages over agency staff in that they can be deployed under performance-based contracts, while in-house hunters generally only have input-based incentives.

Although goats are still relatively common in and around Waingake (N. Fitzgerald, pers. ob.), available information from DOC suggests that their current goat control programme is reducing goat numbers. Using similar effort (200 hours per year), the number of goats shot per hour of hunting by professional ground-based hunters using indicator dogs has decreased from 1.8 in 2014/15, to 1.2 in 2015/16, and 0.99 in 2016/17 (S. Hustler, Department of Conservation, unpubl. data). Thus we recommend that DOC continue to use their current methodology (4 × 50 hour runs annually) in Waingake, but with the inclusion of a 1 km buffer and additional control methods, as deemed suitable, and to reassess their control programme in a few years. If goat control is initiated in a 1 km buffer around Waingake, additional funding will be required to adequately reduce goat numbers in that buffer. At least initially, effort might need to be relatively high (c. 400 hours of ground shooting, plus aerial shooting), but should be reassessed after a couple of years of monitoring goat numbers.

7 Outcome monitoring

The first step necessary to demonstrate that the defined outcomes of control have been achieved is effective monitoring of the pest population being controlled (Clayton & Cowan 2010; see section 5, 'Monitoring pest animals'). If they are reduced to levels deemed adequately low to benefit the asset, this should be detectable from outcome monitoring (i.e. the second key component to monitoring a pest control programme).

Responses of indigenous biodiversity to ecological release are often complex and can be difficult to predict. To give the best chance of detecting these responses, outcome monitoring will need to be done at a temporal scale that captures the response of the asset; for example, the number of nest depredations or chick survival in the breeding season following control compared with data from (preferably) more than one season before control; or recruitment of seedlings of preferred plant species in the years following pest control.

Once the impacts of pest mammals have been reduced or removed, other limiting factors such as competition between indigenous species and the carrying capacity of their habitat will become important. Long-term monitoring of the pest populations and the responses of the assets will provide information about what other factors may be important in the system.

In order to measure progress towards the objective of increased indigenous dominance, we recommend monitoring two broad ecosystem components in Waingake: forest birds and vegetation. Suitable monitoring methods for these are well established, allowing comparison with data from other sites.

7.1 Bird monitoring

Several methods have been used to monitor changes in bird abundance in New Zealand forests. Slow-walk transects and distance sampling have been used to estimate actual abundance, but these rely on assumptions that are often violated in forest and have been found to be unreliable for some native forest birds (Broekema & Overdyck 2012; Spurr et al. 2012).

The 5-minute bird count technique (Dawson & Bull 1975) does not allow for imperfect detection, so gives indices of bird abundance (or relative abundance) rather than measures of absolute abundance/density. Five-minute bird counts have been used extensively in New Zealand and provide valuable and repeatable indices to monitor changes in bird abundance that can be compared with other studies (e.g. Innes et al. 2013; Fitzgerald & Innes 2014).

We recommend 5-minute bird counts of all forest birds be undertaken at Waingake to monitor changes in the avian community following pest mammal control.

7.1.1 Five-minute bird count methods

It is important to standardise bird counts as much as possible to avoid seasonal changes in abundance and other factors that can affect bird behaviour and conspicuousness. Counts should be conducted by experienced observers at least 1 hour after sunrise and 1 hour before sunset, during November to December. Heavy rain and strong wind should be avoided, and count stations should not be located near noise sources such as streams or busy roads.

The count procedure involves counting all birds seen or heard within c. 100 m of the (stationary) observer during a 5-minute period. Unusual birds detected outside of the 5-minute period should be noted separately, but not included in count tallies. No birds should be knowingly counted more than once (e.g. if a bird calls from one location and the same species was subsequently heard from a new location, this would be counted as one individual if it was observed moving between the two points from which it was heard; otherwise it would be counted as two individuals).

Count 'stations' should be at least 100 m from the forest edge to avoid non-forest habitat and 200 m apart to avoid overlapping count areas, and their locations recorded using GPS. Count stations should cover the altitudinal range at Waingake and may be located on marked tracks (e.g. bait lines) or unmarked lines that are efficient to travel. It is generally more efficient to decide on suitable count locations in the field rather than navigating to predefined locations that may be inaccessible or unsuitable on the ground. The large (and largely unseen) area covered by each count station means biased selection of sites is not a problem.

The number of count stations must be sufficiently large for analytical techniques to identify statistically significant changes over time. We conducted power analyses to determine an appropriate number of count stations using the simr package (Green & MacLeod 2016) in the R statistical computing environment (R Core Team 2017). We based power simulations on 5-minute count data of four relatively common species (silvereye *Zosterops lateralis*, tūī, tomtit and grey warbler) and one uncommon species (bellbird) from two sites in Waikato (Landcare Research, unpubl. data). These analyses indicate that to have confidence that the counts will be able to identify a 10% change per year in relatively common birds, 100–250 count stations are required. Less common birds will probably require longer periods of monitoring, or larger increases in abundance for any identified trends to be statistically significant. Therefore, we recommend 150–200 count stations be established at Waingake and counts undertaken every 2–4 years using the same count stations each time.

See Appendix 2 for an example field sheet for recording 5-minute bird counts.

7.2 Vegetation monitoring

Permanently marked vegetation monitoring plots allow changes in vegetation composition and structure to be monitored over time. We give three options for GDC to consider based on the amount of information required and the resources available.

7.2.1 Exclosure plots

Exclosure plots paired with adjacent non-fenced plots provide direct comparison of the effects of residual goat numbers with unbrowsed vegetation. However, the construction and maintenance required for exclosure plots means they are expensive. One exclosure plot (paired with two non-fenced plots) was established at Waingake in November 1981. Data for this plot are publicly available from the National Vegetation Survey Databank (NVS; https://nvs.landcareresearch.co.nz/). If the plot can be relocated and repaired, this may be a worthwhile addition to other monitoring methods.

7.2.2 20 × 20 plots

Permanently marked 20 m × 20 m plots have been widely used in New Zealand forests, and the methodology is described in detail by Hurst and Allen (2007). Full measurement typically involves tagging and measuring the diameter of all trees and saplings, measuring the height of seedlings in 24 circular subplots, and a ‘recce’ description of the vegetation structure and composition. However, it is not necessary to make all these measurements at each re-measurement if the data are not required or if the cost is prohibitive. Seedlings are most likely to change in response to goat control, so measurement of these should be prioritised.

We recommend at least 8 to 10 plots be established at predetermined random locations in the rimu–tawa forest that dominates Waingake, and another 8 to 10 plots in beech forest if the budget allows. The plots should be re-measured at 5–6-year intervals.

Recorded data should be entered in NVS for secure storage. NVS also provides some data summary tools.

7.2.3 Seedling ratio plots

The species richness of tall and short seedlings has been used as a simple way to quantify the effect of browsing ungulates on forest understorey (Sweetapple & Nugent 2004). This method assumes that the species richness (number of species) of short (<30 cm tall) seedlings is unaffected by browse, while taller (30–200 cm) palatable species are selectively removed by browsers. If this method is used, 20 plots should be spaced 20 m apart along each of five randomly placed transects.

7.3 Bats

Although tangential to previous discussions, bats are worth a brief mention. Bats have not been recorded at Waingake and no recent surveys are known to have been conducted for them, but long-tailed bats (*Chalinolobus tuberculatus*) have been recorded from two locations (11 km away in 1995 and 21 km away in 1997) that are within the foraging range of this species (Moira Pryde, Department of Conservation, pers. comm.). North Island long-tailed bats are currently classified as Nationally Vulnerable (O'Donnell et al. 2013), but review of their status currently underway is expected to see them reassessed as Nationally Critical (C. O'Donnell, Department of Conservation, pers. comm.). Their presence at Waingake, if confirmed, would be a significant addition to the known indigenous biodiversity of the forest. We recommend using automatic bat detectors to survey Waingake for the presence of bats. Detectors should be spaced approximately 1 km apart in likely foraging flight paths during a window of fine weather when night-time temperature is at least 10°C.

If bats are found to be present, the initial survey data could be used as a baseline index of activity for ongoing monitoring using the same recording stations. Manual recorders have also been used to obtain indices of activity and suggest it may take 15 years or more to detect changes in a population (O'Donnell et al. 2003).

8 Recommendations

- Pest mammal populations should be monitored using four methods: camera traps, chewcards, trap catch, and catch-per-unit-effort.
- A camera trap monitoring programme will require about 60 cameras in order to be sensitive to any changes in pest populations following control. Camera traps should be deployed randomly about 300–500 m apart, using a passive survey design. If there are sufficient cameras, a subset of cameras should be deployed along game trails to target goats. Cameras should be set to take photos continuously if an animal is detected.
- We recommend deploying baited chewcards every second year using standard methodology to determine how post-control densities of possums and rats, as indexed by cameras, compare to the recommended 5% trap catch required for an adequate reduction of predation pressure on native birds and browse pressure on flora.
- Trapping protocols for stoats and ground-shooting methodology for feral goats should be standardised, as this will allow trap catch and catch-per-unit-effort to be estimated.
- If there is insufficient funding to control all predator pests, we recommend that possums and ship rats be the priority, with stoats controlled thereafter. Possum and ship rat populations should be knocked down using a pre-fed aerial 1080 operation conducted in winter. Bait stations containing cyanide and a first-generation anticoagulant (e.g. diphacinone) should be used for maintenance control of possums and rats, respectively. Rat control will probably need to start in late winter–early spring, and monitoring will help determine the appropriateness of this.
- A trapping grid should be established to maintain stoats at low numbers. Centrally located traps and perimeter traps should be c. 500 m and 250 m apart, respectively.
- Feral goats should be controlled using shooting conducted by ground-based hunters with indicator dogs. Some combination of aerial shooting, thermal infrared imaging

and Judas goats may improve efficacy. If possible, goats should be controlled in a 1 km buffer around Waingake to prevent reinvasion.

- Five-minute bird counts should be undertaken every 2–4 years using the same 150–200 count stations.
- At least 8–10 permanent 20 m × 20 m plots should be established in tawa–rimu forest to monitor change in vegetation structure and composition. Measurement of seedling subplots should be prioritised if all components of the standard method cannot be measured.
- Automatic bat detectors should be used to survey for long-tailed bats.

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Appendix 1 – Use of trail cameras

1 Background

The use of trail cameras for wildlife monitoring has escalated over the last decade. Landcare Research's Wildlife and Ecology Management (WEM) team have also increased their use of trail cameras in recent years. The WEM team currently use Reconyx, Bushnell and Buckeye (see photos below) for their wildlife research projects. These models were selected because of their good detection zones and rapid triggering, and their overall utility for monitoring a range of different-sized animal species (e.g. mice to deer). They are capable of recording data on animal behaviour and interactions with devices over extended periods (up to several months between camera checks).

All of these cameras record photos and/or video on Secure Digital Memory (SD) cards with varying maximum capacity. For example, the Reconyx PC900 HyperFire can store 10,000 photos on a 4 GB SD card. Some camera types are better suited to some projects, which is why the WEM team use multiple makes and models of trail cameras. Other makes and models of trail cameras are available, but we do not discuss them here.

Reconyx PC900 HyperFire

Reconyx XR6 UltraFire

Bushnell Trophy Cam

Bushnell Trophy Cam Aggressor

Buckeye Orion

Figure A1 Example makes and models of trail cameras that are available for use in wildlife studies (photos approximately to scale).

The battery requirements of the different makes and models vary. For example:

- Reconyx cameras need 12 AA batteries (NiMH rechargeable)
- Bushnell cameras need eight AA batteries (Trophy Cam model: NiMH rechargeable batteries; Aggressor model: alkaline batteries)
- Buckeye cameras need one 6-volt battery.

2 What camera will suit your purposes?

Researchers need to clearly identify their question and what data they will need to collect to answer this question. For example, if the objective is to obtain a wildlife inventory (presence/not detected), then most types of trail camera will be suitable. However, if data relating to a species' behaviour at a site are needed to answer the question, then video capability may be important. Some species move more rapidly than others, so rapid camera trigger speed may be a priority for some species. Table A1 provides a detailed list of the key specifications of each make and model of trail cameras used by the WEM team. All these cameras have infra-red illumination at night to minimise the disturbance of the target species.

Table A1 Key specifications of trail cameras owned by the Wildlife and Ecology Management Team, Landcare Research, Lincoln

Camera type	Picture trigger time	Video trigger time	Detection range	Illumination range at night
Reconyx PC900 HyperFire	0.2 s	N/A	30.5 m	15 m
Reconyx XR6 UltraFire	1.0 s	1.0 s	30.5 m	24 m
Bushnell Trophy Cam	0.6 s	3.2 s	27 m	14 m
Bushnell Trophy Cam Aggressor	0.2 s	0.7 s	33.5 m	Not specified
Buckeye RC-5060 Apollo	0.2 s	Not specified	Not specified	Not specified

3 Camera care and security

Consider who else is likely to see your cameras once they are deployed in the field, because this has implications for security (theft) and potentially privacy. If possible, place cameras where they are less likely to be seen by the public. If you require that cameras be set in high (public) use areas, then consider/budget for the purchase of python locks and purpose-built metal security boxes so that cameras can be secured to trees. The metal security boxes Landcare Research owns are specific to the Reconyx XR6 cameras, but the python lock can be used with other camera types. Alternatively, mount the cameras so that they are not easily seen by passing people (e.g. recessed into a hollow or camouflaged with vegetation). If possible, select private land for trial sites, where public access is restricted.

Livestock will interfere with cameras. Cattle, in particular, will lick cameras and potentially knock them over or out of alignment. If working on farmland, mount cameras very securely, or isolate the cameras from livestock.

Possums and rats will investigate cameras. Rats can chew through some devices used to secure the cameras, such as bungie cords, so it is important to check this when servicing camera traps. Carry extra bungie cords (or other devices) to replace any that are badly damaged. Consider using metal mounts (see section 4) if rat density is anticipated to be high and cameras will be deployed for a long time.

4 Mounting cameras

Several options are available. Many models have either nylon straps or bungie cords to attach the cameras to trees/posts. These are versatile and allow flexibility in choice of site. Metal adjustable wall and ceiling mounts are available for some makes and models (e.g. Reconyx). These can be used to deploy cameras in open or forested habitats, using either wooden or metal stakes. Nuts and bolts can be used to secure the mounts to metal stakes or screws to wooden stakes. The Bushnell cameras have metal mounts designed to screw into trees.

5 Camera set-up

Consider the size of the species you are targeting and erect the camera at a height and orientation that maximises the probability of detection. For example, if targeting large animals such as pigs or deer, have the point where you expect to encounter the animal (whether this is an attractant or a game trail) about 4–5 m away from the camera. Conversely, if mice are the target, setting the camera about 1 m from the point of interest may be more appropriate. Angle the camera facing slightly down so that it only triggers when animals are in the target zone and not passing in the distance.

6 Reliability

Landcare Research has had Reconyx and Bushnell cameras deployed in high-rainfall environments for up to 9 months at a time; these makes and models have been, on average, highly reliable. Not unexpectedly, however, there have been camera failures and lost photos. Over 4 years there has been a 5% fail rate of Reconyx cameras per annum. All of these have promptly been repaired when sent back to the manufacturer in the US. Most units are repaired free of charge, but postage can be expensive.

Common causes of camera faults include:

- faulty when sent from manufacturer
- damaged by rough handling
- animal damage (e.g. possum chewing PIR motion detector cover)
- moisture damage

- known or unknown fault that has developed with use.

For example, the WEM team purchased 100 Bushnell Aggressor cameras in August 2016. Four of these were faulty from new and subsequently replaced by the manufacturer. Since then four units have been damaged by weka pecking at them and splitting the PIR sensor cover. These were replaced by the manufacturer with no charge. Seventy-two Bushnell cameras were deployed in a high-rainfall area on the West Coast for 6 months and took 60,000 photos during that period. Given that 1.5 m of rain fell during the same period, it is indicative of how reliable they are in wet areas.

7 Main reasons for lost photos

Batteries

Rechargeable batteries have a limited life span. As they get older they discharge faster. A defective battery in a batch of 8 or 12 will draw charge down in the good batteries: the battery 'pack' is only as good as its weakest link. You need to be diligent in tracking battery age.

Use the batteries specific to the camera model you have. Instruction manuals usually detail what type of battery is suitable and which to avoid. **DO NOT** use rechargeable batteries if the manufacturer stipulates not to use them. This is because they may have insufficient voltage to reliably activate the camera, or could cause some camera fault.

Do not mix battery types in cameras. Different types have different voltage and capacity.

Use the discharge function every time NiMH batteries are charged. This will help with the longevity capacity of rechargeable batteries. Charge NiMH batteries at completion of camera use so that they are stored charged.

Moisture

Any moisture in the camera can cause significant corrosion and damage to components and prevent the camera from working optimally, or at all. When closing the camera, ensure the rubber/silicone seals are clear of any obstruction that could create a gap and let moisture in. Use desiccant packs if these are recommended for the model of camera that you use.

Cameras pointing incorrectly

Field personnel vary in the way they aim cameras. People need to be diligent in ensuring the camera is on line and focusing at the point of interest. The person deploying the camera needs to put themselves at the focal point and look at the fixed camera to ensure it is pointing exactly where they want it. It is good practice to set the camera up, let it take some photos, and then review the photos taken to see if the subject is framed correctly. For camera models without an internal screen, the SD card can be put in another compact camera or laptop and reviewed.

Ensure cameras are well secured. Possums *will* play with cameras. If securing straps or bungies are not tight, the camera may be knocked off-line. Weka can also damage cameras if they are secured <50 cm from the ground.

Always try to place your trail camera looking north or south (south is particularly desirable in winter, when the sun is at a lower angle). If the camera faces into the rising or setting sun, the light will wash out any pictures that are taken during that time, potentially obscuring important observations.

Cameras not turned on

Different models of cameras are turned on in different ways. In most cases cameras left on standby will not switch to on, and thus will not record photos. Staff and contractors need to familiarise themselves with the different models of cameras prior to field deployment. Most camera models show a flashing red diode as they arm – get in the habit of looking for this before walking away from the camera trap site.

8 Other points to consider

Obstructions

Tree fern fronds and vines can droop into the field of view and obscure or partially obscure photographs. Some camera makes or models are sensitive to grass, fronds or branches moving in the wind, and this can cause false triggering and many photos being taken of moving vegetation. Clear away overhanging vegetation as required.

Keep lens clean

Use lens wipes to clean the lenses each time you check your cameras.

Transporting cameras

Treat the cameras with great care. These are precision instruments and need to be treated as such to ensure they keep functioning smoothly. When freighting or travelling in a vehicle, ensure cameras are placed in foam-padded bins, or something similar. When carrying cameras in the bush, wrap them in bubble wrap (or something similar) to ensure the sensor and lens covers are not scratched. When cameras are returned from field deployment, leave them opened out to ensure they are completely dry before storage.

Appendix 2 – Example bird count field sheet

Waingake Bird Counts

Line:	Observer:
Date:	

Station:										
Cloud:										
Rain:										
Wind:										
Other Noise:										
Start time:										
Bellbird										
Blackbird										
Chaffinch										
Fantail										
Goldfinch										
Greenfinch										
Grey warbler										
Kereru										
Kingfisher										
Long-t cuckoo										
Magpie										
Rifleman										
Robin										
Rosella										
Shining cuckoo										
Silvereye										
Song thrush										
Tomtit										
Tui										
Whitehead										

Cloud:		**Rain:**		**Wind:**		**Other noise:**	
Sunny	0	None	0	None (leaves still or move silently)	0	None	0
Cloudy	1	Dripping	1	Light (leaves rustle)	1	Moderate	1
Raining	2	Drizzle	2	Moderate (leaves and branches move constantly)	2	Loud	2
		Moderate	3	Strong	3		
		Heavy	4				