

Using rabbit control to enhance the effectiveness of ferret control

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Summary

Project and client

Ferret (*Mustela furo*) abundance in New Zealand is usually driven by “bottom-up” processes whereby their densities and the carrying capacity of their environment can depend on the abundance of rabbits (*Oryctolagus cuniculus*), which are their primary prey. The Department of Conservation (DOC) contracted Manaaki Whenua – Landcare Research (MWLR)¹ to provide guidance for future field trials by DOC on whether prey control can enhance control of ferrets. This was accomplished by analysing existing data relating to the effects of rabbit control on ferret control operations.

Objectives

- Determine whether rabbit control increases the capture probability of ferrets based on the analyses of historical field data.
- Guide future experimental designs on the extent to which rabbit removal can facilitate control of ferret populations.

Methods

- We analysed historic field trial data (Cliff et al. 2020) to evaluate whether rabbit management can help to optimise ferret control.
- Ferret capture-mark-recapture and rabbit relative abundance data were collected over two years (1994–1996) at three South Island tussock dryland sites. At two sites data were collected before and after rabbit control operations using aerial 1080 (sodium fluoroacetate). One site was a non-treatment site that had no rabbit control or predator control.
- We estimated capture probabilities and apparent survival of ferrets using Cormack-Jolly-Seber open population modelling.
- We investigated the effects of treatment (rabbit control) and season on ferret capture probabilities and apparent survival using linear regression.
- We predicted that rabbit control would increase the capture probability of ferrets and reduce their survival.

Results

- Estimated capture probability of ferrets was highest at the Bendigo site (treatment) and lowest at the Earnsclough site (non-treatment) but the difference between study sites was not statistically significant.
- Ferret capture probability at each site did not differ significantly before and after the aerial application of 1080 and the associated reduction in rabbit abundance.

¹ On 01 July 2025 Landcare Research New Zealand Ltd became the New Zealand Institute for Bioeconomy Science Ltd; Manaaki Whenua – Landcare Research operates as an internal group within this Institute, which is less formally known as the Bioeconomy Science Institute (BSI).

- We speculate that ferret capture probabilities did not change most likely due to a combination of factors including: a remnant population of primary prey, increased reliance on secondary prey, and a reduction in intraspecific competition.
- The capture probability of ferrets differed between seasons, with captures being highest in autumn and lowest in spring.
- Apparent survival did not differ significantly between sites.

Conclusions

- There was no significant relationship between the reduction of rabbits and the survival or capture probabilities of ferrets based on the analysis of a historic data set.
- Seasonal effects were more pronounced than the impacts of prey reduction, emphasising the importance of the timing of predator control operations.

Recommendations for field trial design

- For an initial field trial, we recommend a minimum of five sites having ferret and rabbit management (treatment) and three sites with ferret management only (non-treatment). Intensive rabbit control should be conducted using multiple tools, including aerial application of 1080 followed by a ground-based mop-up operation.
- Trials should ideally be conducted in spring and summer in pasture and tussock grasslands in Otago and Canterbury. When selecting sites, landscape features such as rivers could be used to reduce ferret immigration into the study area, and areas should be at least 1000 ha to ensure sufficient ferret numbers to achieve statistically robust results.
- Ferret control should be conducted using kill traps, with trapping effort matching that used at the non-treatment sites. Ferret traps should be deployed at least one month before the start of the trial to reduce the risk of neophobia (i.e., trap avoidance).
- Rabbit and ferret relative abundance should be monitored using an independent network of camera traps, and any additional ferret sightings during rabbit shooting sessions should be documented to inform future monitoring operations.

1 Background

Feral ferrets (*Mustela furo*) are one of the target species of the Predator Free 2050 programme. Rabbits (*Oryctolagus cuniculus*) are the primary prey item of ferrets in pasture and tussock habitats where rabbits are abundant (Murphy et al. 2004; Cliff et al. 2020). Rabbit–predator systems are usually controlled bottom-up, i.e. predators are limited by rabbit (prey) abundance (Ruscoe et al. 2006; Cruz et al. 2013). Although predation by ferrets is a limiting factor for rabbits, rabbit abundance is primarily regulated by resource availability, habitat, climate, and disease (Norbury & Jones 2015). Monitoring with spotlights indicates ferret sightings decline within a year after rabbit reduction, and ferret densities generally decline when rabbits become less abundant (Norbury & McGlinchy 1996). However, even when rabbit populations are reduced to very low numbers (less than 1 rabbit per km of spotlight searched), ferret populations can persist (Cliff et al. 2020).

In the original study by Cliff et al. (2020), rabbit abundances were reduced with a single application of 1080, leading to a reduction in ferret densities at two treatment sites. This research supported the suggestion that ferret population dynamics in New Zealand’s drylands are driven by ‘bottom-up’ processes. In our current study, we re-analysed this historic dataset to determine whether ferrets that persist on the post-control grid are easier to trap. This is based on the prediction that, due to the reduction in prey resources following rabbit control, ferret capture probabilities will increase, as the lack of food increases their propensity for ferrets to engage with control tools (i.e., DOC traps).

2 Objectives

- Determine whether rabbit control can enhance the effectiveness of ferret control based on the analyses of historical field data.
- Guide future experimental designs where rabbit removal can facilitate control of ferret populations.

3 Methods

We analysed a historic dataset from a study examining the effects of prey control on predators in New Zealand’s South Island. We employed an advanced open population model, that allows estimation of capture probability and apparent survival, to determine whether rabbit control increases ferret interaction rates with control tools (DOC traps). This approach, based on bottom-up pest management, involves managing prey at lower trophic levels to help control the focal pest at the higher trophic levels (Norbury, 2017). Our dataset included a ferret capture-mark-recapture study from 1994–1996 that was conducted at three sites: Bendigo, Grays Hills, and Earnsclough pastoral stations in the Mackenzie basin and Central Otago. Capture probability is the chance of detecting or capturing an animal during a trapping session, if it is alive and present in the study area. Apparent survival is the probability that an animal survives and remains in the study area from one trapping session to the next.

For the capture-mark-recapture study, ferrets were individually marked upon capture and subsequently released. Ferret trapping was conducted every 4–6 weeks from March 1994 to March 1996. There were 18 trapping sessions at Earnsclough, 20 at Grays Hills and 21 at Bendigo. During each 4-day trapping session, live-traps were set for ferrets and checked every day. Rabbit relative abundance was estimated every 4 months from spotlight counts along permanent transects. In September 1994, 1080 (sodium fluoroacetate) baits were applied aerially

at two treatment sites, Bendigo and Grays Hills, to reduce rabbit abundance. No rabbit control was conducted at the non-treatment site at Earnsclough. For a detailed site and method description, see Norbury et al. (1998) and Barlow and Norbury (2001).

For our analysis we performed the following tests. All analyses were done in R (R Core Team 2021).

We used a Cormack-Jolly-Seber model to estimate capture probability (p) and apparent survival (ϕ) of ferrets using the package *OpenCR* (Efford 2023). Cormack-Jolly-Seber models are statistical methods used in mark-recapture studies to estimate the survival and capture probabilities of animals in open populations.

- 1 We performed two-sample t -tests for each site to compare ferret capture probability before and after the toxin application.
- 2 We fitted a linear regression model to analyse the effect of site and season on ferret capture probability using the R package *lme4* (Bates et al. 2015). The fitted model was:

$$\text{Ferret capture probability} \sim \text{Site} + \text{Season}$$

- 3 We fitted a linear regression models to analyse the effects of site on ferret apparent survival using the R package *lme4* (Bates et al. 2015). The fitted models were:

$$\text{Apparent survival} \sim \text{Site}$$

4 Results

Average ferret capture probability was highest at Bendigo and lowest at Earnsclough (Figures 1–3). Cliff et al. (2020) reported 82% reduction in rabbit abundance at Bendigo and 98% reduction at Grays Hills after the rabbit control operation.

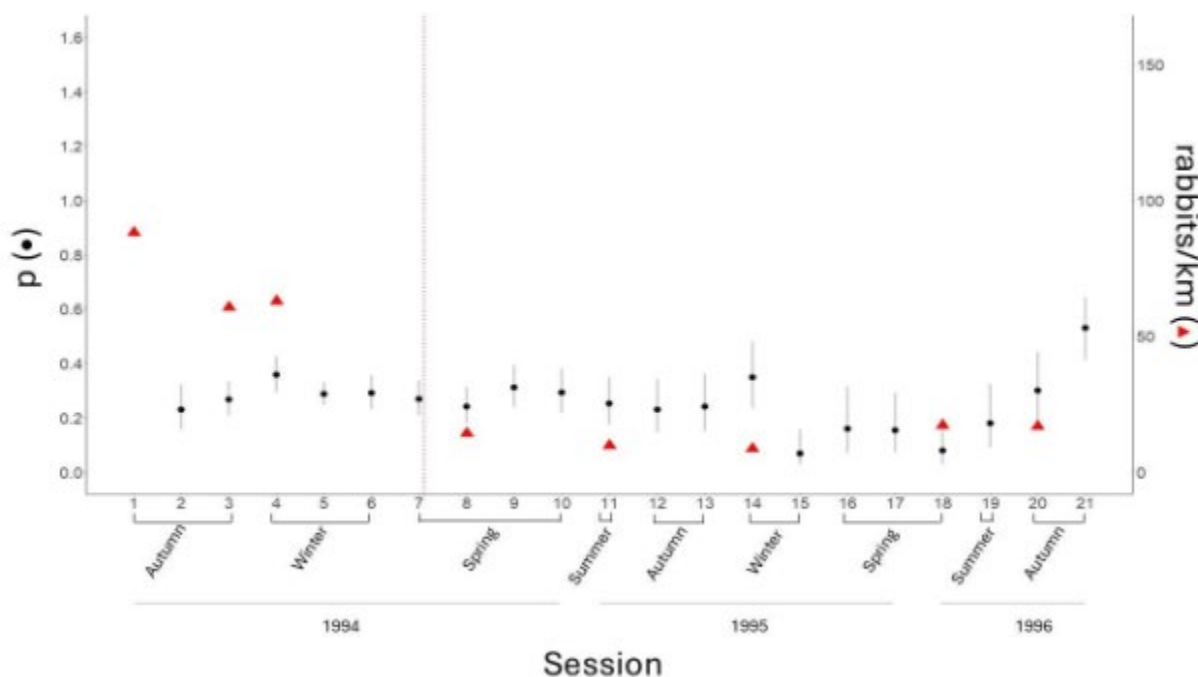


Figure 1. Capture probability p (•) of ferrets ($\pm$ 95% confidence intervals), and the number of rabbits per km from rabbit transect counts (▲) at the Bendigo site 1994–1996. Ferret live-capture trapping sessions are shown on the x-axis. The vertical line represents time of aerial application of 1080.

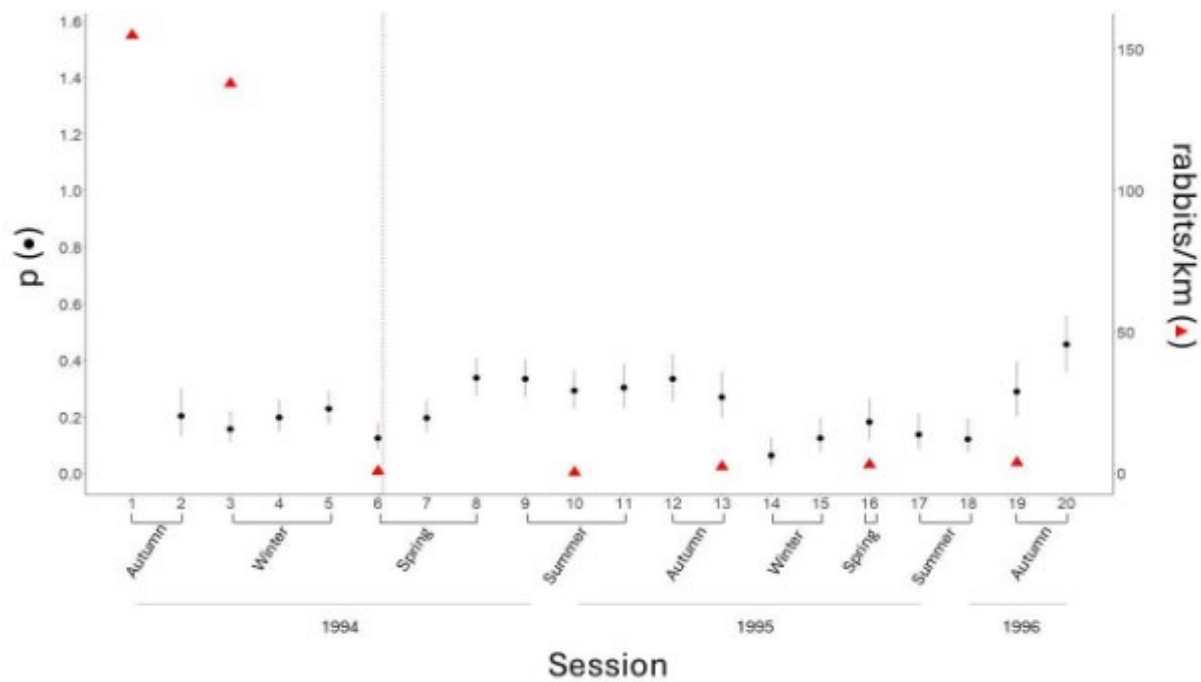


Figure 2. Capture probability p (●) of ferrets ($\pm$ 95% confidence intervals), and the number of rabbits per km from rabbit transect counts (▲) at the Grays Hills site 1994–1996. Ferret live-capture trapping sessions are shown on the x-axis. The vertical line represents time of aerial application of 1080.

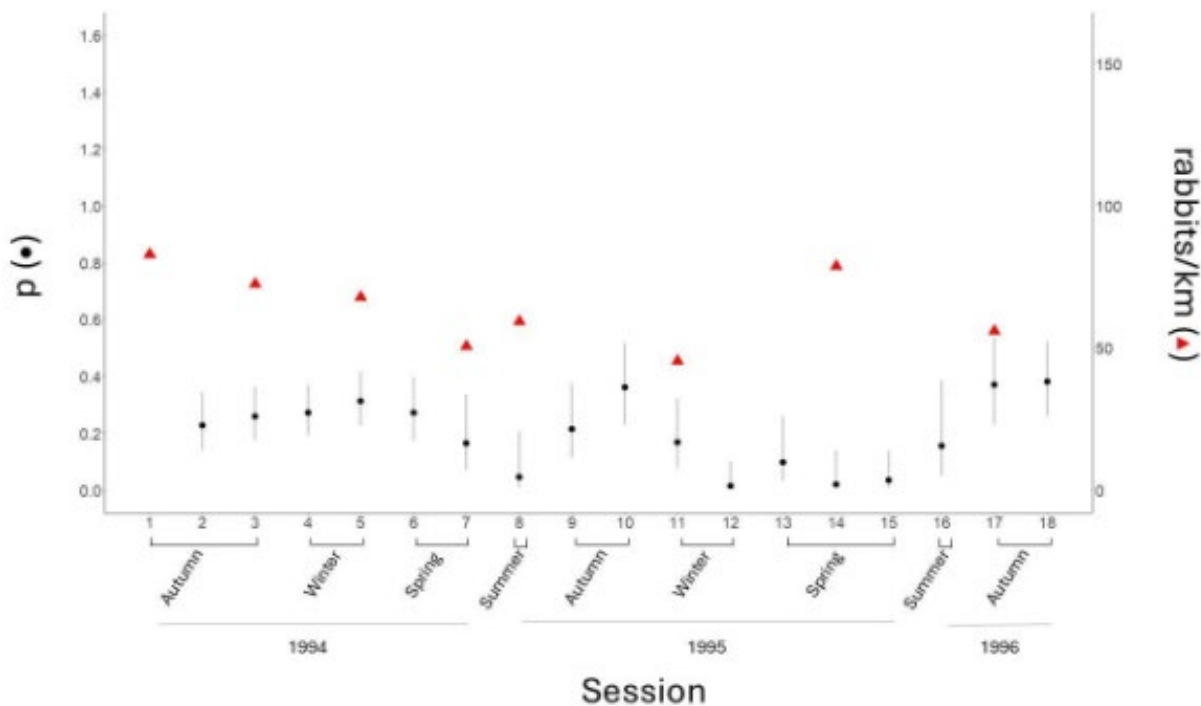


Figure 3. Capture probability p (●) of ferrets ($\pm$ 95% confidence intervals), and the number of rabbits per km from rabbit transect counts (▲) at the Earnsclough non-treatment site 1994–1996. Ferret live-capture trapping sessions are shown on the x-axis. No 1080 was applied at this site.

Ferret population density declined by 50% at Bendigo and 71% at Grays Hills, and increased by less than 1% at the non-treatment site (Cliff et al. 2020). Ferret capture probabilities at Bendigo ($t(18)=0.835$, $p=0.21$), Grays Hills ($t(17)=1.223$, $p=0.12$) and Earnsclough ($t(15)=1.564$, $p=0.07$) did not differ significantly before and after rabbit control.

The regression model did not show a significant difference in ferret capture probability between sites (Table 1). Ferret capture probability differed significantly between seasons, being highest in autumn and lowest in spring.

Table 1. Linear regression results analysing the effects of season and site on estimated ferret capture probabilities from March 1994 to March 1996 (Ferret capture probability ~ Site +Season). Reference level: autumn and Bendigo (treatment).

	Estimate	SE	<i>t</i>	<i>p</i>
Intercept	0.3338	0.0296	11.272	< 0.001
Spring	-0.1253	0.0340	-3.680	< 0.001
Summer	-0.1035	0.0409	-2.532	0.014
Winter	-0.1003	0.0353	-2.845	0.006
Grays Hills (treatment)	-0.0254	0.0319	-0.794	0.057
Earnsclough (non-treatment)	-0.0629	0.0322	-1.952	0.431

Apparent survival of ferrets did not differ significantly between sites (Table 2).

Table 2. Linear regression results analysing the effects of site on estimated apparent survival probability of ferrets from March 1994 to March 1996 (Apparent survival probability ~ Site). Reference level: Bendigo (treatment).

	Estimate	Std. error	<i>t</i>	<i>p</i>
Intercept	0.8180	0.0357	22.934	< 0.001
Grays Hills (treatment)	0.0499	0.0511	0.976	0.3333
Earnsclough (non-treatment)	-0.0974	0.0526	-1.851	0.0697

5 Discussion

5.1 Data analysis

We investigated a historic dataset to determine whether ferret capture probabilities increased following rabbit control, compared to sites with no rabbit control. Despite the reduction in primary prey, there was no evidence that suppressing rabbits increased the capture probabilities of ferrets.

One explanation for our results is that there were sufficient rabbits remaining post-control to sustain the remnant population of ferrets, so that their motivations to interact with traps remained unchanged. Supporting this conclusion, a dietary study at our sites revealed that rabbits remained the main prey of ferrets following the control operation (Cliff et al., 2020). Similarly, a predator tracking study found that there were no obvious changes in ferret movements or behaviour until the rabbit population had been reduced by over 99% (Norbury et al., 1998).

Prey switching by ferrets could also contribute to the lack of an increase in capture probabilities, as the dietary study found that secondary prey, such as lizards, increased in the period six months following rabbit control (Cliff et al., 2020). Additionally, as the ferret population declined, there

would be a concurrent reduction in intraspecific competition. Our results, showing that rabbit control did not increase the interaction probabilities with traps, were likely driven by a combination of these factors - a remnant population of primary prey, increased reliance on secondary prey, and a reduction in intraspecific competition due to a decrease in ferret density.

Rabbit control by 1080 would reduce ferret densities through a combination of secondary poisoning, starvation, and migration. If the remaining ferret population had sufficient food resources post-control, and if rabbit control removed individuals at random (i.e., independent of personality traits), we would expect capture probabilities to remain unchanged. Recent studies have shown that interactions with traps are driven by the individual traits (i.e., personalities) of the pests (Johnstone et al., 2024; Johnstone et al., 2025). In contrast to pest control with traps, control using toxic baits does not remove individuals with specific personality types. Although this was not tested in this study, the lack of an increase in interaction rates with traps following rabbit control supports the idea that removals were random with respect to personality. As a result, trait distributions likely remained stable, and interaction probabilities remained unchanged, as there were sufficient food resources to support the remaining population. This suggests that, despite the utility of bottom-up control to reduce ferret densities, the reduction of primary prey was insufficient to increase the capture probability of the remaining ferrets.

Our analysis showed that ferret capture probability varied seasonally, although the reason for the increased capture probability in autumn was unclear. Juvenile ferrets disperse in late summer and autumn, which increases the number of animals available to traps, and could contribute to the increases in ferret capture observed in autumn (Byrom 2002). However, Norbury et al. (1998) analysed the movement behaviour of ferrets after the 1080 operations at the Bendigo and Grays Hills sites. While some ferrets dispersed after rabbit abundance was reduced, others did not, and they found no seasonal pattern in capture probability

5.2 Field trial design considerations

Pest animal control operations in an eradication context are often divided in two parts: i) an initial knock-down; and ii) a mop-up phase (Parkes et al. 2014). During the knock-down phase the targeted population is reduced rapidly with a tool that is affordable enough to be applied at landscape scale, effective enough to remove most of the population, and fast enough to ensure recruitment rate is lower than the removal rate. In the mop-up phase a variety of tools are used to target the remaining individual survivors. The knock-down is characterised by a high number of killed individuals per unit effort within a short time. In the mop-up phase the effort is increased, but the kill rate is low, which can result in difficult, prolonged operations that can last years (Parkes et al. 2014). This leads to significant cost differences between the two phases.

Both knock-down and mop-up phases need to be improved for landscape-scale operations to ensure eradication feasibility and to reduce costs. For mainland operations, the first step is to optimise the initial knock-down. This will increase effectiveness of control operations and be beneficial for future eradication attempts. A more effective knock-down phase can increase the positive biodiversity outcomes of control programmes. For eradications, a faster knock-down and a mop-up of fewer survivors will shorten the time and effort needed in the operation, resulting in reduced operational costs. Currently, predator eradication on the mainland is only feasible in areas with predator proof fences, as immigration cannot be prevented or reduced enough without fences.

Because of these considerations, the field trial design and recommendations below focus on the initial rapid and effective elimination of the ferret population in the knock-down phase of rabbit management.

6 Conclusions and recommendations

Two questions need to be answered to improve ferret control and optimise the knock-down phase of future eradications:

- 1 Does the removal of rabbits result in a faster reduction in ferret numbers in ground-based ferret management using kill traps?
- 2 Does the removal of rabbits as the main prey item increase the efficacy of ground-based ferret management using kill traps, leading to a more effective knock-down phase, i.e. fewer individuals left before the more expensive mop-up phase begins?

One challenge in eradication science is to obtain sufficient data for conclusive results from experimental studies. Eradications are usually one-off operations, and each eradication has a unique context. Additionally, statistically robust data is difficult to collect on the survivors of pest management operations, i.e. the number of individuals is low. Statistical significance can often only be achieved through a high number of replicates of experiments. However, qualitative results and trends should not be discarded.

6.1 Future field trial design - general

Recommendation 1:

- *For an initial field trial, we recommend including a minimum of five sites having both ferret management and rabbit management (treatment) and three sites having ferret management without rabbit management (non-treatment).*

Ferret and rabbit control and monitoring should be conducted for at least six months (see following sections for details). The variables measured should include ferret relative abundance and time to achieve a 95% (and 99% and 100% if achieved) reduction. If rabbit control enhances ferret control, ferret abundance will decrease faster at the treatment sites and reach lower levels. These field trials would also provide information about the time and effort needed to reduce rabbit abundance to lower levels than a single aerial application of 1080 can achieve.

6.2 Rabbit management before future trials

Recommendation 2:

- *Intensive rabbit control should be conducted using multiple tools, including aerial application of 1080 followed by a ground-based mop-up operation*

An intensive toxin operation will be required to reduce rabbit abundances sufficiently before trials can be undertaken. This can only be achieved on a landscape scale with an aerial application of toxin, and 1080 is the only available tool for mainland sites. An aerial operation of 1080 cereal bait pellets requires two pre-feeds with non-toxic pellets (NPCA 2020). After an initial knock down, ground-based control can include shooting, trapping, and the application of additional toxins (e.g. pindone) in bait stations, starting two weeks after the aerial toxin application. This aligns with the strategy used in the successful eradication of rabbits from Rangitoto–Motutapu Islands (Griffiths et al. 2015). That strategy included the aerial application of cereal pellets with brodifacoum and the subsequent use of leghold traps lured with male rabbit urine and silenced shooting. Where more

than just individual survivors were detected, pindone was applied to carrot baits (Griffiths et al. 2015).

6.3 Ferret management before future trials

Recommendation 3:

- *Ferret control should be conducted using kill traps. Ferrets should be controlled with the same intensity as at the non-treatment site(s), but without rabbit control.*

Ferrets should be targeted with a network of DOC250 kill traps. Ferret home range size estimates in New Zealand range from 2 ha to 372 ha (Garvey & Byrom 2021). After removing rare outliers, 20 ha is a reasonable assumption for the minimum home range for most ferrets (Moors & Lavers 1981; Norbury et al. 1998). A 400 m × 400 m trapping grid will provide one trap per 16 ha, placing at least one device in every individual ferret's home range. DOC250 traps should be placed inside a wooden trap box to reduce disturbance and non-target captures. Where possible, the trap boxes should be placed along natural runways, e.g. fence lines, hedges, or streams. Trap entrances need to be free of obstructions, such as weeds or debris.

Recommendation 4:

- *Ferret traps should be deployed at least one month before the start of the trial to reduce the risk of neophobia in ferrets.*

During this month, traps should not be set or baited. Thereafter, traps should be lured with fresh rabbit meat given rabbits are the main prey item of ferrets, although dried rabbit meat provides a secondary option if required. Both lures are short lived and need to be replaced regularly. An egg could be added in addition to the rabbit meat to provide a long-lasting visual lure. To maintain a high standard for lure quality and trap presentation during the trial, a service interval of up to 7 days is recommended.

6.4 Monitoring and data collection during future trials

Recommendation 5:

- *Rabbit and ferret relative abundance should be monitored using an independent network of camera traps; any additional ferret sightings during rabbit shooting sessions should be documented to inform future monitoring operations.*

The fundamental measurement for evaluating predator management is the number of captures per unit effort over time. This number is derived from counting ferret captures when servicing the traps and calculating an index of number of captures per service interval. The service interval needs to be standardised, e.g. 7 days, across all sites. If successful rabbit management increases ferret capture probability, then the number of captures should initially increase but subsequently decrease faster at the treatment site compared to the control site.

Camera traps can detect a change in rabbit abundance of >90% and are a useful tool for evaluating the outcomes of rabbit management operations using aerial application of 1080 (Latham et al. 2012). Gillies and Brady (2018) showed that camera traps can also be used to monitor ferret relative abundance. Latham et al. (2012) placed cameras near rabbit warrens and burrows to

increase detection probability of rabbits. This non-random placement may also increase detection probability for ferrets as their activity is higher where rabbits are present.

Analysing the correlation between locations of ferret and rabbit detections, as well as ferret capture locations, will provide further insights. If ferret activity and capture probabilities are linked to rabbit availability, ferret captures, and relative abundance will be closer to zero in areas with zero rabbit relative abundance. The last ferret detections would be expected in proximity to rabbit detections. Ferret relative abundance should be derived from a standardised independent monitoring system. The camera traps we recommend can be used concurrently for rabbit monitoring. A 400 m × 400 m camera grid, with cameras at least 100 m away from the closest trap will allow for an independent estimate of relative abundance. An index of relative abundance can be derived by calculating the number of ferret detections per unit time, e.g. 100 camera days (Rovero & Marshall 2009).

6.5 Timing of operations for future trials

Recommendation 6:

- *Future trials should be conducted in spring and summer.*

During spring and summer, ferrets show the strongest dependence on rabbits as main prey item. The first rabbit litter is born in October and November and young rabbits are usually independent by January (Garvey & Byrom 2021). Having a relatively high number of naïve rabbits in the population during ferret management may increase the probability of success. Additionally, the trials would result in positive outcomes for native species when ferret numbers are reduced before a natural prey switch away from rabbits occurs.

Rabbit management can be conducted all year round. The data set we analysed for this report showed that ferret capture probability was highest in autumn. Additionally, previous studies have suggested that ferret diets vary seasonally in New Zealand, and that during autumn and winter ferrets consume fewer rabbits and more lizards and birds (Mills 1994; Ragg 1998). Ferret abundance is highest between late summer and early winter, usually peaking in March to April (Garvey & Byrom 2021). Cliff et al. (2020) showed ferrets mostly increased their consumption of lizards and invertebrates in the first six months after rabbit control.

6.6 Future trial site selection criteria

Recommendation 7:

- *Sites for future trials should be pasture and tussock grasslands in Otago and Canterbury.*

Most studies on ferret diets are from Otago and Canterbury and they show a high frequency of rabbit remains in ferret gut contents (Garvey & Byrom 2021). The only three studies in the North Island were conducted in swamp and forest where rabbits would not be expected to be an important part of ferret diet (see Table 9.8, Garvey & Byrom 2021).

In regions where rabbit abundance can also be high, e.g. Hawkes Bay or Manawatu–Whanganui, ferrets may also depend on rabbits as their main prey source.

Recommendation 8:

- *When selecting a site, landscape features such as rivers could be used to reduce ferret immigration into the study area.*

Ferrets may avoid open river gravel and, being poor swimmers, rivers and coast could be used as natural barriers (Fish & Baudinette 2008; Garvey & Byrom 2021).

Recommendation 9:

- *Ensure study sites are at least 1,000 ha so that sufficient numbers of ferrets are present to provide statistical power.*

Ferret density estimates are lower in the North Island than in the South Island. However, all estimates for the North Island are from summer and from removal studies only. Barlow and Norbury (2001) estimated the long-term carrying capacity in semi-arid habitats of 0.5 – 2.9 ferrets per km².

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