Feasibility Assessment for the Otago Peninsula Stoat Eradication

Predator Free Dunedin Trust

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Contents

Predator Free Dunedin

1. Executive Summary

This document looks at the feasibility, and benefits, of eradicating stoats, and/or ferrets, and/or weasels from the Otago Peninsula (the peninsula).

In 2021, Ahikā Consulting Ltd (Ahikā) produced a plan[1] (referred to here on as the 2021 plan) for the eradication stoats from the peninsula. The rationale for the plan was to use cost-effective techniques along with community support to remove all stoats from the peninsula by hitting them once, and hard, through pre-baiting unset traps for a period of 8 weeks prior to eradication trapping. The plan recommended doing this immediately following, or concurrently with, an intensive, peninsula-wide rabbit control operation.

Due to delays in the peninsula-wide possum eradication programme, planning for stoat eradication is being put on hold. The opportunity has been taken in the meantime to further assess the feasibility of eradicating stoats and to assess the potential to eradicate other mustelids too (ferrets and/or weasels).

Further to this, in 2021 the Otago Regional Council (ORC) commenced a community-led rabbit management programme in the area from Portobello to Taiaroa Head. As a result, landowners in the area should be better informed about what effective rabbit management looks like and what their responsibilities are under the Regional Pest Management Plan 2019 – 2029 (RPMP). It could, therefore, be said that the timing is good for exploring the possibility of a more intensive rabbit control operation, which would be necessary for the stoat eradication plan to be effective.

Given recent developments in our understanding of mustelid eradication techniques, the 2021 plan has been reassessed and compared to recent stoat eradication attempts (namely Waiheke Island and Capital Kiwi). The costs of a stoat eradication programme under best-case and worst-case scenarios have been described, and an eradication programme for ferrets has been considered (the costs and benefits of eradicating the different mustelid species have been considered both exclusively and in relation to one another). Interspecies dynamics have been explored, and the effects of different eradication scenarios on native biodiversity have been examined.

The feasibility and impact of eliminating rabbits from the peninsula has also been considered, and the effects of a sudden decrease in rabbit population on mustelid prey switching and 'trapability' have been highlighted as important factor to consider.

This report concludes by recommending that an intensive rabbit control operation is trialled at the top of the peninsula. Before, during, and after this, mustelids numbers should be monitored, and genetic samples collected. The purpose of this trial will be:

[1] Thorsen, M. J., Millar, R., 2021, Stoat Eradication Plan, Ahikā Consulting Ltd

1) To test how to undertake an effective, widespread, intensive rabbit control operation involving many landowners across diverse properties; and

2) To determine what impact the presence of rabbits is having on the occurrence of mustelids, and whether long-term rabbit management is likely to lead to long-term reduction (and possible eradication) of mustelids.

Presuming that the trial demonstrates that a reduction in rabbit numbers results in a reduction in the presence of mustelids, then the trial could be used to inform community members who are concerned that predator control can lead to a surge in rabbit numbers. It would also allow for better evaluation of whether reducing prey availability creates a window for when mustelids can be eradicated.

2. Introduction

From 1870 to the 1920s, domestic ferrets (*Mustela furo*), stoats (Mustela erminea), and weasels (Mustela *nivalis*) were released to areas of New Zealand to control rabbits, which had become widespread since being introduced in 1860 (King, 2017b; King, 2017c; King, 2017d). All three of these mustelid species are now widespread throughout New Zealand and considered invasive predators (King et al., 2017). Controlling populations of mustelids is essential to slowing the decline of remaining native bird species in New Zealand. Through Predator-Free 2050 Limited, the New Zealand Government has identified mustelids, possums, and rats as the subjects for a nationwide eradication to be completed by the year 2050.

The Otago Peninsula is a long, hilly, indented finger of land that forms the easternmost part of the city of Dunedin. Volcanic in origin, it forms one wall of the eroded valley that now forms Otago Harbour. The peninsula runs parallel to the mainland for 20 km, with a maximum width of 9 km. It is joined to the mainland at the south-west end by a narrow isthmus approximately 1.5 km wide. Its proximity to ocean resources made it popular among early settlers and is it now home to around 900 residents.

The area from Vauxhall to Taiaroa Head is in the region of 8,332 ha and encompasses hundreds of properties. The range of property types is large and includes temporarily occupied cribs, permanent residential properties, large luxury homes, schools, public amenity spaces, wildlife reserves, historic buildings, public access walking tracks, monuments, lifestyle blocks, and productive farms. The area encompasses urban areas, areas of native bush and other dense vegetation, steep cliffs, exposed beaches, and open, rolling farmland (to name but a few). The population of Otago Peninsula is concentrated at the beginning of the peninsula and around the coastal settlements on the western shore, whereas the higher altitude properties and eastern coastline tend to less densely populated. Visitor access to the peninsula is common, with many visitors engaging in outdoor activities such as walking, biking and wildlife tours.

Due to its size, population density, and geography, the Otago Peninsula provides a challenging mainland setting for the eradication of mustelids. Whilst New Zealand has led world-leading mammalian eradication programmes on offshore islands, the eradication of mustelids from large, populated parts of the mainland has not yet been demonstrated.

3. Eradication Options

The eradication of mustelids from the Otago Peninsula will require a combination of both proven and innovative techniques to succeed. Eradication methods must generally be perceived as socially acceptable, currently available, affordable, and hold an acceptable likelihood of success.

3.1 Aerial Broadcast of Brodifacoum

Most previous successful mammalian eradication programmes have relied on aerial or hand-spread brodifacoum. For example, New Zealand's largest successful eradication programme featured aerial brodifacoum to eradicate Norway rats from the 11,330 ha Campbell Island (McClelland, 2011). Subsequently, the world's largest successful mammalian eradication also took the approach of using aerial brodifacoum to eradicate rats from the 108,423 ha South Georgia Island (South Georgia Heritage Trust, 2014).

Brodifacoum is an example of a second-generation anticoagulant. Second generation anticoagulants have much greater residual issues; hence they are not allowed to be broadcast on pasture where stock may ingest pellets creating potential issues for export meat. Furthermore, brodifacoum is not registered for the control of all pests, particularly not in a broadcast manner. Therefore, aerial application of brodifacoum is not currently permitted for use outside fenced areas or offshore islands (Ewan, 2014).

The average cost for aerial broadcast brodifacoum predator removal on uninhabited islands is $345/ha (inc. GST), but when incorporating livestock and people, it can be upwards of $920-$8,000/ha (inc. GST) (Curnow & Kerr, 2017). Despite being a cost-effective option, aerial application is not, however, an available option for mustelid control (via secondary poisoning) on the Otago Peninsula for the reasons described above.

3.2 Brodifacoum in Bait Stations

Currently, the most common alternative method to aerial or hand broadcast brodifacoum for eradication of rodents is the use of toxins in bait stations (Beaven, 2008; Brown et al., 2015). Bait stations exclude non-target species from consuming the toxin directly and prevent it from diffusing into the environment where it could be harmful to humans (Broome et al., 2011). Brodifacoum bait stations are proven to be effective against rodents, hedgehogs, and possums through primary poisoning (Alterio, 1996; Eason et al., 2010), and effective against stoats and feral cats through secondary poisoning (Alterio, 1996), but they are not reliably effective against ferrets (Curnow & Kerr, 2017).

Current eradication projects in New Zealand such as Predator Free Wellington and Cape to City use bait stations in combination with trapping to good effect to target rats and (through secondary poisoning) mustelids (Glen et al., 2016; Glen et al., 2019; '2018/19 Impact Report', 2020). Like the Otago Peninsula, these projects must navigate human inhabitants and encourage participation by large landholders (Glen et al., 2016). They are also larger than the Otago Peninsula, with Cape to City and Predator Free Wellington covering 26,000 ha and 30,000 ha respectively (Glen et al., 2016; '2018/19 Impact Report', 2020). While these projects look promising, they do not seek to eradicate mustelids.

To date, the largest mammalian eradication programme using brodifacoum in bait stations covered just 3,105 ha on Langara Island in British Columbia (Taylor et al., 2000). The focus of this eradication programme was, however, only on rats.

The effect of brodifacoum via secondary poisoning depends heavily on the rat component of stoat, ferret, and feral cats' diet (Alterio, 1996). According to an analysis of stomach contents, rats make up a very small percentage of both stoat and ferret stomach content on the Otago Peninsula (Alterio, 1994) (the stomach content of weasels on the peninsula has not been analysed). This means rats may not be a reliable source of secondary poisoning (Murphy et al., 2005) for mustelids on the Otago Peninsula.

Rabbits and hare make up ~ 33% and 77% of stoats' and ferrets' diet respectively (Alterio 1994; Smith et al., 1995). Rabbits can feed from brodifacoum bait stations, but it is likely they would require a separate bait station design to rats (Brown, 2002; Twigg et al., 2001; Twigg, Lowe, & Martin, 2002). It should also be noted that rabbits are extremely neophobic and so it can be extremely difficult to encourage feral rabbits to feed from bait stations, particularly when there is an abundance of other food available nearby (as is often the case on the Otago Peninsula, even in winter). Note also that brodifacoum is not registered for rabbit control, and so rabbit control using commercially sourced brodifacoum on mainland New Zealand must not be attempted.

3.3 PAPP

Another option is the use of para-aminopropiophenone (PAPP). PAPP is a low residue vertebrate toxic agent (VTA) registered in New Zealand in 2011 under the trade name PredaSTOP™ for the control of feral cats and stoats (Miskell 2018). PAPP can be used as a supplement to brodifacoum where there is insufficient rat abundance to kill stoats through secondary poisoning (Eason et al., 2010). PAPP is only used as a supplement as it is only effective against stoats and is not registered for aerial broadcast (Murphy et al., 2011; Brown et al., 2015).

Brodifacoum and PAPP can be provided via OSKA (One Station Kill All) bait stations. Interspecies competition for bait can lead to some species avoiding bait stations (Broome et al., 2014). OSKA bait stations avoid interspecies competition through two access points; a spring-loaded treadle that possums and feral cats push down to access possum bait, and a tunnel with bait that only rats or stoats can access (Pest Control Research, 2020). OSKA bait stations can be set up with both brodifacoum and PAPP for removing rats (through brodifacoum primary poisoning), and stoats (through PAPP primary poisoning and brodifacoum secondary poisoning). However, there is no registered toxin effective against eradicating ferrets (Beavan, 2008).

The cost of a single stainless-steel DOC 250 and box is $153.00 (incl. GST) (Predator Traps, 2014) and cost of a single OSKA bait station is $28.20 (incl. GST) (Pest Control Research, 2020).

A non-toxic sausage bait is also being developed that could be deployed aerially and could contain the toxin para-aminopropiophenone (PAPP) or 1080 (Rickett et al., 2023). This could be effective against stoats and ferrets, but like other aerially applied substances it will pose a serious threat to pets, which will be a large consideration on the Otago Peninsula. Bait stations may help to alleviate this concern.

3.4 Sodium Mono-Fluoroacetate (1080)

While the aerial use of sodium mono-fluoroacetate 1080 is still a relatively controversial practice compared to the other two methods, it is commonly used throughout New Zealand (Green & Rohan, 2012; Eason et al., 2011; Reid, 2008). However, until recently, the application of 1080 has never been capable of full eradication of pests (Eason et al., 2011; Bell et al., 2019). It is a substance which breaks down faster than brodifacoum and is soluble in water, meaning it is safer for neighbouring communities of people, but does not persist long enough to be consumed by 100% of predators in the area and can also cause aversion if an animal becomes sick from consuming only a small amount (Eason et al., 2011). The 1080 bait is consumed primarily by rats, possums, rabbits, hares, and hedgehogs but is also effective at killing feral cats, ferrets and stoats through secondary poisoning (as those species predate or scavenge on poisoned prey) (Eason & Frampton, 1991; Heyward & Norbury, 1999). However, due to its short presence in the environment, 1080 will break down before shy individual rats, possums and hedgehogs consume the foreign object (Dilks, Sjoberg, & Murphy, 2020). Not only does this limit the ability for target animals to be eradicated via primary poisoning, but it also lowers the potential for eradication of mustelids via secondary poisoning.

Zero Invasive Predators (ZIP) trialled a modified method of applying 1080 to test its ability to eradicate possums and rats rather than its usual use to knock them down to low densities (Bell et al., 2019). The project was not only useful for the eradication of possums and rats, but also for the near eradication of stoats through secondary poisoning. Typically, an application of 1080 follows an initial application of non-toxic bait, attracting predators to the pellet. ZIP has modified the technique to carry out two rounds of the non-toxic bait, thus attracting the more neophobic members of the population, and two rounds of toxic bait which use different lures (Bell, 2017). The drop is also applied in a more comprehensive manner to target all areas, including gaining consent to drop closer to water ways. Finally, if survivors are detected, a third toxic bait load is applied in a localised area to directly target those survivors (Bell, 2017).

ZIP have trialled this approach on three separate occasions and locations in the last three years to target possums and rats while also monitoring stoats. The first trial successfully eradicated possums but failed to achieve this for rats in a 1,600 ha valley near Taranaki (Bell et al 2019). On the second trial, ZIP successfully eradicated both possums and rats from 2,300 ha valley in South

Westland (Bell and Phil 2017). Finally, on the third trial the method was deemed to have successfully eradicated possums, rats, and stoats with the use of 1080 for the first (known) time in New Zealand history (Zero Invasive Predators 2019). The location of the third trial was to the west of Mt Cook/Aoraki mountain range in the Perth River Valley (12,000 ha). It was ‘protected’ by natural barriers (mountain ranges), with just one entry point which was protected via a virtual buffer (Nichols & Bell, 2019). After four months of protecting the site, a handful of incursions were detected, targeted, and eradicated to the best of ZIP’s knowledge (Zero Invasive Predators 2019). Stoat-free status has not, however, been sustained. In 2023, stoats were detected in the treatment area in low densities and were unable to be successfully targeted by mop-up techniques (pers.com Tom Agnew)

The combination of exclusion zones, double pre-feeding, bait swath overlaps (i.e., no gaps in coverage), and higher-than-standard bait sowing rates are all considered to have contributed to the successful outcome of the third trial. All these factors are the difference between the trial technique and the current standard technique for aerial 1080 operations for predator control (Bell et al., 2019).

The cost of all four drops is estimated at $90/ha to eradicate rats, stoats and possums (Bell et al., 2019). A limitation to applying this to the Otago Peninsula is that the trial did not target ferrets. Like all other species before this trial, ferrets have only been suppressed to low numbers by 1080 when the toxin is applied for general predator control (Dilks, Sjoberg, & Murphy, 2020).

Furthermore, anecdotal evidence suggests that major landowners on the peninsula are averse to using 1080. It would not, therefore, be possible to replicate ZIP’s aerial distribution method. If landowners allowed 1080 to be hand laid, the cost of the project would then rise significantly (pers, comms Peter Preston). If there were to be any use of the toxin on the Otago Peninsula it may, therefore, likely be limited to a handful of properties.

3.5 Traps

The major benefit to kill traps is that they release no toxins to the environment, which makes them a well-accepted form of predator control and, therefore, easy and non-controversial to implement (Brown et al., 2015). They also catch effectively, kill humanely, are easy to use and maintain, and are light-weight and portable (Brown et al., 2015). Kill traps also rarely kill or damage non-target species as there are several designs which prevent access to anything other than the desired target(s) (Brown et al., 2015). Furthermore, the ability to use a variety of baits can prevent target animals becoming trap shy (Ewans, 2014).

The Otago Peninsula already has an array of trapping networks installed by multiple conservation programmes. Some costs could, therefore, be saved by adjoining eradication grids to the current trapping system when appropriate. To date, large-scale trapping has only been successful at controlling predators to low (rather than zero) densities for large landscapes (Howald et al., 2007; Brown et al., 2015). However, the combination of conservation dogs, night shooting, and using a combination of traps including live traps may make the trapping option more realistic.

Small Islands, such as Anchor (1,130 ha), Chalky (514 ha) and Coal Island (1,163 ha) in Fiordland have successfully been eradicated of stoats via trapping. These are the largest island-based programmes that have used trapping to eradicate stoats. For larger islands (over 1,200 ha), however, (e.g., Secretary, Resolution, Cooper, Long, Waiheke) eradication via trapping has been attempted, but despite initial indications that stoats had been eradicated, the recent discovery of survivors show that eradication is yet to be achieved (Veale et al unpublished). Secretary Island and Resolution Island in Fiordland were assumed to have achieved pest free status in 2008 before detections in 2009 proved that the islands were not only susceptible to reinvasion, but also that the initial eradication attempt had failed. Genetical analysis showed that most captures on the islands were not reinvading animals (as thought) but offspring of residents who had survived the initial eradication attempt. The failure was partly attributed to the remote nature of the islands, which limited traps checks to (at best) every 3 months. This means that stoats were either not killed quicker than they can replace themselves, and/or were not all interacting with traps. It appears that some individuals displayed trap avoidance behaviour for long enough periods of time. One male in particular survived several years in the dense trap network and continued to mate with immigrant females. It is also assumed that the trap density was too low.

Since 2009, additional traps, increased frequency of trap checking, and self-setting A24 traps have all been added to the Secretary Island and Resolution Island trapping regimes. Despite this, however, a proportion of stoats are still not interacting with trap types available and, therefore, breeding continues and small populations (perhaps supplemented by immigrants) are sustained every year (Veale et al unpublished).

The remote nature of the islands limits the ability to use live-capture traps. However, on the mainland, recent innovation in trapping design and remote trap alerts has sought to make live capture trapping an eradication tool rather than just a predator control tool (Bell et al. 2019; Murphy et al. 2019). The Otago Peninsula Biodiversity Group (OPBG) already operate a number of self-reporting cage traps and leg hold traps on the peninsula in easy-access locations. While these are designed and baited for possums, the cage traps have already caught several ferrets. It may be possible to take a similar approach to target all mustelids.

4. Comparison of Current Projects

Thus far, eradication of mustelids from large areas has only been successful with the use of toxins. Widespread toxin use on Otago Peninsula is unlikely to be acceptable for the reasons given above. There are, however, several similar-sized projects in New Zealand currently attempting eradication of mustelids with limited toxin use. Understanding the success and shortcomings of these projects will be important in informing a plan for the Otago Peninsula.

Capital Kiwi is based in the southwest region of Wellington, with the eastern border bounding Wellington city's western suburban fringe. The project area spans over 23,000 ha, with a network of 4,500 mustelid traps. Initially, this project was set up to provide suitable habitat to introduce kiwi to the area by suppressing stoats to low levels. With funding from Predator Free 2050 Ltd, the project is now attempting to eradicate stoats from the southwestern part of the project area (11,000 ha). This is referred to as the ‘core area’. Capital Kiwi replicated a trap network of similar intensity to that which was used eradicate stoats from the smaller Fiordland Islands, but on a larger scale. If eradication of stoats from the core area is successful, then the project will test whether the 12,000 ha northern buffer will protect against reinvasion. Trap deployment began in November 2018 and took approximately two years to complete. In 2023, the project is still detecting low density stoat numbers. Most of the network is on privately owned land, including land used for livestock, wind farming, forestry, and lifestyle blocks.

Waiheke Island, which is 9,221 ha in size, is situated in Hauraki Gulf, Auckland. The island is well-populated and land use includes farmlands, vineyards, housing, and regenerating native forest. The idea of a stoat eradication programme arose when genetic studies identified Waiheke featured almost no stoat immigration (Veale et al., 2015). After successful pilot studies, the Waiheke community established Te Korowai o Waiheke Trust in 2018 and gained funding from Predator Free Ltd to begin preparation for a stoat eradication programme in late 2019. Stoat eradication operations began in early 2020 with a network of 1,500 DOC200 traps across the island. An additional 150 DOC200 traps were later positioned in areas determined to be hotspots (1 per 5.5 ha). Trap positioning and servicing is undertaken by a collaborative trapping team consisting of local farm staff, contractors, volunteers, and Te Korowai o Waiheke staff. In 2023, the project is still detecting low density stoat numbers.

The following tables summaries observations made by Te Korowai o Waiheke Project Manager Mary Frankham, and Capital Kiwi Project Managers Paul Ward, Jamie McNaught, and Jeff Hall.

Key takeaway messages from these parties were:

- Monitoring tools must improve for both detection of survivors and for providing opportunities for project teams to respond immediately to sightings;
- Community support is essential, especially if it enables toxin use, comprehensive project area access, and a community reporting tool; and
- Timelines for eradication should be viewed with caution.

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Table 1: Comparison of the Te Korowai o Waiheke and Capital Kiwi programmes

TIMELINE	
Te Korowai o Waiheke has been operational for three years. The project had planned for stoat detections to have dropped to zero by year three, but they are still being detected. It is difficult to estimate how many stoats are left on the Island. For example, catch rates have been higher than expected this summer, but it is believed that this is due to improving practices rather than an increase in stoat numbers. There have been changes in catch timings (juveniles caught in November/December rather than January/February) which is believed to be due to the network being more effective. Although hot spots have been identified, the project still runs the full eradication trap network throughout the island.	Capital Kiwi is into its sixth year. The project first started with the aim of reducing stoats to a level to allow for the reintroduction of kiwi to the area. In Year 3, Predator Free 2050 became a funder and the focus shifted to eradication. This goal was shared with the Predator Free Wellington (PFW) Project, and the projects formed a coalition that has been working together with landowners and community groups to progressively target the capital's introduced pests. Capital Kiwi work to eradicate stoats from the west, and PFW is endeavouring to eradicate rats from the city, beginning with Miramar Peninsula. This year, Capital Kiwi has reached a stoat density (1.7% RAI) in the core area (10,000 ha) which meets the requirements for reintroducing kiwi. This has come a year later than planned. Regarding the eradication of stoats, the project's leaders are still unsure on how close they are to achieving zero density. There is, however, a decline in catch rates and the monitoring trend is also showing a downward decline.
TRAP NETWORK DESIGN AND DENSITY	
The trap density and design of the Te Korowai o Waiheke network is credited as a strength of the project. The team over-concentrated the 6 trap/ha trap density network deliberately. During the early phase of the	Capital Kiwi did not change their trap density and design for the first three years of the project. The network was installed throughout the core and buffer areas of west Wellington with DOC250s at 300 m spacing, and

project the team infilled the network in some coastal areas and wetlands that they consider hotspots and have not veered from the network since. Initially, the project team used a combination of white plastic boxes and wooden boxes to house DOC 200s. They believe the white plastic ones were effective, but they did not appear to be as effective as the wooden boxes, and so they have since substituted in wooden boxes in some areas. Both rabbit bait and egg bait are used. Erayz (dehydrated rabbit) was found not to be a useful alternative to fresh rabbit despite its longer-life. Stoat bedding is another well-recommended bait. Ferret bedding was found to have little effect on the Waiheke Island stoats (perhaps because ferrets are not present on the island). Traps are checked 1-2 times a week on average, but in hotspots they are checked every four days. 90% of catches come by waterways (coast, wetlands, or streams/rivers). Despite catching non-target species routinely, there are still enough trap nights available for each trap to catch stoats based on the frequency that traps are checked. Weka protectors (wire mesh tunnel) have been used to avoid cat captures.	A24s at 100 m spacing. 50-80% of traps per check had hedgehog catches and were, therefore, not available to catch stoats. The team decided to raise the DOC 250s 100 mm off the ground as a trial to avoid non-target catch. They also installed additional DOC 200 double sets in the core 10,000 ha area. The double sets have a smaller opening which they hoped would deter hedgehogs; however, the trap also has the ability for one treadle to remain open if the other catches a hedgehog (or anything else). Raising the traps was successful and now most traps have been raised. The trap network structure was also modified when the project goal was changed from suppression to eradication. Double set DOC200s were arranged in the core to reflect networks used in successful island eradication programmes. Early chances of success were limited though due to the trap density being too low. Trap density has since been increased in the core area. Farm tracks, public roads, and wind farm access roads etc are critical for servicing the traps efficiently. In hindsight, the team would have installed fewer A24 traps to begin with and replaced them with DOC200s due to the latter's perceived higher catch rate.
BUFFER	
On Waiheke Island, urban areas are not believed to serve as a deterrent to stoats. Despite having hotspots, the captures and detections of stoats are still widespread throughout the island, including in built up, urban areas.	Capital Kiwi has a 10,000 ha core area and a 12,000 ha buffer area. The buffer and the core area began with the same trap density until the double set DOC 200s were added to the core area. The project team do not believe that the state highway is serving as a natural barrier. Stoats are

	believed to be present in residential areas and also moving through the green areas of the city. Several weasels have also been caught in the middle of Wellington.
MONITORING	
Te Korowai o Waiheke use cameras for monitoring but there have been very few sightings. ZIP lure dispensers are not used but this may increase the effectiveness of cameras. The community is considered to be the most important monitoring tool for the project. Time and money have been invested into communication and education, gaining buy-in from the community to the extent that the community reliably reports any stoat captures or sightings in a timely fashion. Community reports are quick and accurate, and sightings are responded to immediately with increased trapping, baiting, and dog work if it is available. Monitoring cameras that sent ID photos of stoats to the project team immediately would be useful. A community detection tool for mustelids such as a chew card or wax tag would be preferable (i.e. a low-cost monitoring tool that the community can easily use), but that has not yet been developed. For native species monitoring, the team monitors birds with 5-minute bird counts. They also coordinate and encourage citizen science projects.	Capital Kiwi uses a mixture of tracking tunnels and cameras for monitoring. A trail camera network has been added exclusively to the core area with a camera every 34 - 35 hectares. The cameras appear to be more sensitive than tracking tunnels as a tool but are not perfect; over the last six months of surveying there have only two detections in the core area camera network, but the tracking tunnels did not indicate any stoats. Last year the tracking tunnel results indicated a population density of 1.7% RAI in the core area and 6.6% RAI in the wider buffer area. The SOP for camera monitoring is based on that designed by Craig Gillies. This involves 150 g rabbit as bait, wrapped in chicken wire and fixed in place. The camera trap is re-baited every 2 weeks. Capital Kiwi considered using the ZIP motor lure but assumed it would get destroyed by stock. Capital Kiwi plans to send ear samples of mustelids to Manaaki Whenua to be analysed by Andrew Veale in the hope that the genetic analysis will give them more confidence in whether they are catching residents or invaders. Currently there is any no pattern to where they are catching stoats.

DETECTION DOGS	
Dog detection hasn't been a key method to date but Te Korowai o Waiheke are planning to acquire an in-house mustelid detection dog to lower the costs and increase the availability. The limited dog detection that has been undertaken has had mixed results. On one occasion, four dogs spent ten days on the island and caught just one stoat.	Capital Kiwi is looking into training a dog to detect stoats. The team has not yet had to use dogs for detecting survivors, but they know resources are scarce and believe having their own in-house dog would be very valuable.
TOXINS	
Fumigation was planned but never executed by Te Korowai o Waiheke due to dens being hard to locate (even with dogs), and because some dens are open stick piles whilst others are burrows with multiple, hard to detect entry and exits. Te Korowai o Waiheke's technical advisory group (TAG) considered trying to use secondary poisoning with rats by surrounding baited rats around a den. However, given the risks of poisoning pet cats and the uncertainty of its effectiveness, they opted against this technique. The TAG is keen to use PAPP sausages around den sites when that becomes a legal option.	Capital Kiwi is looking to facilitate a council-led 1080 operation in 3,000 ha of the core area. If the 1080 operation works well and knocks down stoats, then they might be at a stage where they switch their focus to finding survivors using dogs. The team have not focused on finding individuals to date because they do not believe that is a good use of their time at present.
RABBITS	
Rabbit population density on Waiheke Island is currently relatively low due to the calicivirus having an impact 3 years ago. Te Korowai o Waiheke is not funded for rabbit control and, therefore, no rabbit control has been	Rabbit population density in the Capital Kiwi project area is low and (potentially because of this) there are no ferrets. Rabbit numbers are

carried out. However, night counts are undertaken, and this can serve as a community tool as evidence of the bottom-up relationship between rabbits and mustelids. Te Korowai o Waiheke also pays shooters to supply rabbits for baiting the traps.	increasing but this not perceived as a risk. Serious financial backing would be required for Capital Kiwi to focus on reducing rabbit populations.
SOCIAL LICENCE	
The supportive community of Waiheke is considered to be an important resource. Education through schools and community events has helped grow an 80% awareness of the project throughout the island. The community is also engaged in rat control, a project that was established before the stoat eradication program. The rat control programme has served as a foundation for community education and engagement for the stoat programme to grow from. Communication and education were particularly important at the start of the project, and now that many people are engaged and reporting, not much is required to keep them engaged. Te Korowai o Waiheke staff would encourage a community sighting programme for the Otago Peninsula as it has been more valuable to them than the camera monitoring results. Community stoat sightings are fast, the community is responsive, and so far 50% of the sightings have correlated to a catch. Te Korowai o Waiheke staff also try to monitor what they give back, and track every invoice that has gone back into the local community so they can quantify their contribution to the local economy.	Capital Kiwi staff believe that the community, iwi, and landowners are the most important part of their project. The 10,000 ha core area is comprised of just four to five landowners, so winning over every one of them was essential to the project. It is believed that the reason why there is such positive community support is due to the objective of introducing kiwi to the area. Delaying kiwi introduction by one year was frustrating for many and potentially caused some doubt amongst the project's supporters. However, when the introduction did go ahead it resulted in widespread satisfaction. Kiwi survival is now the easiest and most important measure of success for the project's supporters. It is believed that another reason for the strong community support is because of how responsibly the team have worked with landowners. From the outset a decision was made that volunteers would not work on private land. This was to ensure the landowners knew who was on their land, building trust, and continuing to foster relationships. Capital Kiwi staff receive occasional reports of stoat sightings from the community and have responded to these to reasonable effect but have not relied on this as a monitoring method. Until the project suppresses

Reliable trapping volunteers are also essential to the project. Te Korowai o Waiheke staff are responsible for 70% of trap checks, while the others are attended to by 5 committed volunteers and some contractors.	stoat numbers further, the team do not believe responding to sightings is a cost-effective practice. Capital Kiwi has applied all the tools available for eradication and have not achieved it yet. The team do not consider this a failure, and instead consider this a useful experiment for other projects to learn from whilst still managing significant gains in biodiversity. Communicating this to the community has also been important to gain their continued support.
INTERSPECIES RELATIONSHIPS	
As noted above, Te Korowai o Waiheke staff have placed weka protectors on DOC series traps to avoid catching cats. Their intensive trap checking schedule and rat project means they are taking down many species, but staff do not believe there is an issue of trap availability.	Capital Kiwi staff do not believe rats and mice are in large numbers in the project area and, therefore, they are not focusing on effects on the interspecies relationships. As noted above, all DOC series kill traps were raised to avoid catching hedgehogs.

Predator Free Dunedin

5. Relevance of Current Projects to Otago Peninsula

5.1 Trap Density

The Te Korowai o Waiheke and Capital Kiwi projects both work with trap density similar to that which was proposed in the 2021 Otago Peninsula stoat eradication plan (6 ha/trap). Both projects have adapted their densities during their project; Waiheke responded to hotspots by increasing density and trap checks, while Capital Kiwi added DOC series traps to their core area. The 2021 stoat eradication plan also recognised the need for this. A stoat eradication programme on the peninsula should, therefore, comprise of no less than 6 ha/trap density and should consider adding additional traps to hotspot areas.

5.2 Trap Checking

Te Korowai o Waiheke check traps much more frequently (up to 3 every 3 days) than that which was proposed in the 2021 stoat eradication plan (up to once per week). Capital Kiwi initially relied on self-resetting traps, but due to the efficiencies of their trapping network they also check their traps frequently year-round.

During the possum eradication programme, Otago Peninsula Biodiversity Group has utilised ATVs and vehicles on properties when available. The DOC kill traps could be used in these areas of the peninsula, but there are many areas on the peninsula only accessible by foot. Self-resetting AT220 traps have saved labour costs for the possum eradication programme, and self-resetting mustelid traps should be considered in similar areas. The effectiveness of A24s has, however, come under scrutiny by Capital Kiwi and inefficient traps may jeopardise an eradication project.

5.3 Buffers

There is no specific buffer on Waiheke Island and Te Korowai o Waiheke trap throughout the whole island as eradication is yet to be achieved anywhere. Genetic assays have not identified any re-invaders to the island so far.

The Capital Kiwi project has a large buffer area, which is supplemented further by trap and bait station networks serviced by Predator Free Wellington. Managers from both projects have dismissed the residential areas as plausible barriers to reinvasion, with both groups finding evidence of mustelids in high residential zones.

The 2021 stoat eradication plan suggested that the built-up residential area at the base of the peninsula will deter mustelids from reinvading. Based on observations from the Te Korowai o Waiheke and Capital Kiwi projetcs, it would be wise for the movements of mustelids through South Dunedin's residential areas to be better understood before it is accepted as a likely barrier for reinvasion.

5.4 Reinvasion Risk

The potential rate of stoat invasion of the Otago Peninsula from the across the harbour was modelled by Ahikā Consulting Ltd in 2023 using a simulated stoat movement programme (EZE-BEAST). This model was run under two scenarios: a best-case scenario where trap effectiveness and stoat movement patterns are as expected and where sea water acts as a moderate barrier to stoat movement; and a worst-case scenario where trap effectiveness was poor, movement pattern included longer movements, and water was less of a barrier to stoat movement.

In each of these two scenarios a simulation was made of the movements of 100 stoats randomly originally located in the low-density area of the Halo Project – an area containing DOC200 stoat traps, but not at a density that no stoats will occur in the area (although the current trapping is likely to be resulting in a lowered stoat population density).

In both scenarios, stoats were predicted to cross the harbour onto the peninsula before they were captured by the Halo Project traps (Figure 1). However, the rate of crossing was markedly different under the two scenarios. Under the best guess scenario, 13% of the animals in the low stoat population density area were predicted to cross the harbour. Under the worst-case scenario, 74% of the animals were predicted to cross the harbour, often undertaking this crossing multiple times. The risk of reinvasion would also be reduced if a trapping was maintained throughout the peninsula, though invading animals can be much more risk adverse leading to reduced trapability of these individuals. Stoats have also been shown to be incredibly difficult to catch in these sorts of situations, requiring dedicated effort sometimes spanning 2 years.

The modelling suggests that stoat incursions onto the peninsula would be certain, but how frequently this would result in a reinvasion (formation of a new breeding colony) may be as long as once every 3-5 years or as short as a few months. Based on current knowledge of stoats, it would be reasonable to predict that stoat incursion onto the peninsula would be an annual event and would sometimes occur several times in a year.

The only option to prevent stoat invasion of the Otago Peninsula would be to greatly expand the protective external buffer in the Halo Project and add stoat control into the area south of Dunedin City. Even then it would be likely that stoats would return to the peninsula at some time.

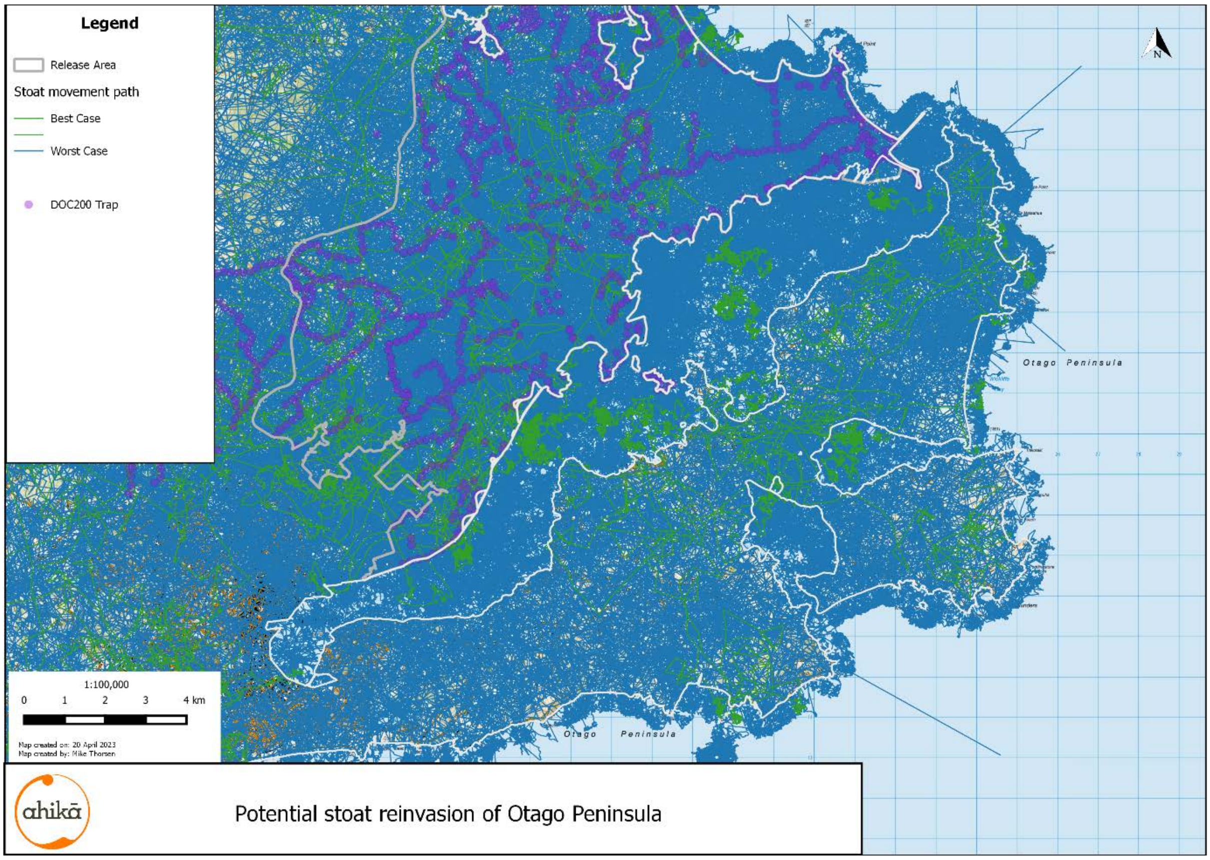

Figure 1. Predicted movement paths of 100 simulated stoats originating in the release area that arrived on the Otago Peninsula under a best case scenario (green lines) and a worst case scenario (blue lines).

5.5 Detection Dogs

Neither the Te Korowai o Waiheke or Capital Kiwi project has used detection dogs in a significant manner. However, they both plan to acquire in-house mustelid detection dogs as the availability for dogs is limited. Currently, there is a local stoat detection dog and handler in residence in Dunedin City, which may support the availability of a detection dog for a peninsula mustelid eradication programme.

5.6 Community Engagement

Community engagement and landowner buy-in were considered the most important aspects of both projects. Community members who were on board with the projects were beneficial to the projects' outcomes, while those unwilling to cooperate were reported to have jeopardised the projects' feasibility.

Community support for predator control has been growing on the Otago Peninsula through the possum eradication programme. However, challenges will be encountered when the community is asked to cooperate with and support a mustelid eradication programme. These challenges need to be well understood and ideally mitigated prior to an eradication programme commencing.

5.7 Monitoring

Both projects suggested that their current camera monitoring network was insufficient for detecting stoats based on comparisons with trap catch data and community sightings. OPBG already have a comprehensive camera network operating on the peninsula, as well as a community reporting programme. Optimising these monitoring networks in preparation for mustelid eradication may give the project an advantage. However, any advancements in monitoring tools should also be considered.

5.8 By-Catch Avoidance

It is likely that hedgehogs, mice, and rats will affect the trapping network throughout the peninsula. Raising traps or increasing check frequency should be considered to avoid by-catch affecting the availability of traps to capture mustelids.

5.9 Rabbit Control

Both the Te Korowai o Waiheke and Capital Kiwi project had low rabbit numbers before the projects commenced and did not, therefore, consider rabbit control as an essential part of their plans. The Otago Peninsula, however, has high rabbit numbers. While rabbit control may not be essential to a mustelid eradication programme on Waiheke Island or in the Wellington region, it is likely to have more influence on mustelid populations on the Otago Peninsula. The effects of rabbit control on a mustelid eradication programme are discussed in more detail later in this report.

6. Decision Making Tools: Costs

Successful mustelid eradication programmes over a large area have historically been heavily reliant on the use of toxins. It can be difficult to use toxins in populated areas and so the density of human occupation can act as a predictor of eradication difficulty. Both the Te Korowai o Waiheke and Capital Kiwi projects have, however, made considerable progress with limited toxin use.

Before attempting to eradicate mustelids on the Otago Peninsula, it is prudent to consider three things:

- How feasible is eradication given the peninsula's size and human population;
- What will the project cost (is it affordable?); and
- What are the benefits from the project.

The following sections apply relevant information in the context of the peninsula and assess the costs of a peninsula-based eradication programme for stoats and for ferrets before exploring potential benefits from the eradication of either species.

6.1 Input Sensitivity Analysis

Conservation planning often focuses on benefits such as increasing native habitat, increasing the biodiversity of an area, or lowering the threat status of a species (Naidoo et al., 2006). This approach often neglects costing and, therefore, potentially limits efficiency of conservation planning. Undertaking a cost analysis allows for an assessment of which methods would be the most viable without testing their effectiveness in the field.

It can be difficult to quantify exactly how beneficial different eradication approaches may be. For example, it may be difficult to quantify the benefits of eradicating only stoats from the peninsula compared to the benefits of eradicating only ferrets from the peninsula. Comparing the costs of these two options provides a quantifiable comparison and is an important initial assessment.

Sensitivity analysis is a financial model that determines how target variables are affected based on changes in other variables known as input variables. This model is also referred to as 'what if' or simulation analysis. It is a way to predict the outcome of a decision given a certain range of input variables. By creating a given set of variables, an analyst can determine how changes in one input variable affect the outcome (Hamby 1994).

To assess the costs involved in a trap-based eradication programme, a sensitivity analysis was performed on the significant inputs involved. The sensitivity analysis stress tested the inputs by changing the costs to represent a realistic, best- and worst-case scenario for that cost. For the peninsula context, a sensitivity analysis was conducted using best- and worst-case estimates for timeline, trap density, trap check frequency, costs of detecting survivors, monitoring, trap buffer size, and trap buffer checks. Estimates for costs were based on available literature and the method outlined in the 2021 stoat eradication plan.

The following costs are based on workings from the 2021 stoat eradication plan if not otherwise stated. The 2021 plan did not include the costs of rabbit control.

6.2 Inputs

Timeframe

As the 2021 plan states, stoats will be considered eradicated from the Otago Peninsula once one of the following criteria are met: (a) two summers have elapsed with no stoat captures; or (b) all stoat captures can be genetically traced to stoats from elsewhere (i.e., reinvasion).

The operational plan for Te Korowai o Waiheke used modelling from Choquenot (et al., 2001) to support their timeline estimates. Choquenot (et al., 2001) had determined how long it would take for a single undetected pregnant female stoat who survived an eradication programme to establish a founding population. The growth for three founding populations of different sizes and composition was modelled under two survival schedules. The study reasonably determined that failure to catch stoats for more than 31 months is a good indication of a lack of stoats on an island. This was later supported by the fact that no stoats have been caught on Chalky and Anchor Islands in Fiordland post eradication (and post reinvasion events) for periods of much more than 31 months. However, the Te Korowai o Waiheke acknowledged that the demographic data upon which the model was based came exclusively from beech forests, and that caution should, therefore, be exercised in extending its results to the colonisation of other areas by stoats.

This means that in the best-case scenario, the trapping network will be deployed for one summer, it will knock-down the population successfully, and it will be followed up by successful removal techniques to have individual stoats eradicated within a year. The trapping network would then continue to be deployed for two more years and be removed thereafter if no more detections were made, which is a total of three years.

Based on a review of the 2021 Otago Peninsula stoat eradication plan, Manaaki Whenua suggested that two hits of the eradication phase would be required before the two-year survey commenced. This would mean two years of undertaking the eradication plan making attempts to find survivors if catch/monitoring rates were low enough at the end of both summers. This would then be followed by two years of the trapping network being in place for monitoring and for proving eradication, which is a total of four years.

Based on smaller trap-based island eradications, this timeframe should theoretically be sufficient. However, larger projects such as Te Korowai o Waiheke, who used similar trap densities, modelling, and assumptions (except for the removal of prey before pursuing eradication), have not met their predicted eradication timeframes.

Remembering that a single stoat on Motutapu Island in Auckland took over 1 year to dispatch (and other instances of reinvasion have all required considerable resources and time before capture of the animal), it is reasonable to assume the Otago Peninsula eradication programme could take at least three years to complete, and two more years to prove the absence of survivors.

It would, therefore, be sensible to suggest five years for the eradication plan as the 'worst case scenario' for the sensitivity analysis, whilst acknowledging that this is still an optimistic time frame.

Trap Density

The Department of Conservation (DOC) has provided official recommendations for effective trapping grids to kill stoats (Brown et al. 2015). These recommendations have been adopted for New Zealand's recent mainland trapping-based eradication projects; Halfmoon Bay (Ewans, 2014), Banks Peninsula (Curnow & Kerr, 2017), and Capital Kiwi. Each of these projects target stoats and/or ferrets, but some differ in their trap density recommendations for each species – all based on expert recommendations. These projects therefore provide both conservative and generous estimations of the trap density required for eradication.

Trapping networks are designed to feature at least one trap in the home range of every target animal to ensure every animal interacts with a trap. This is, however, only a guideline and although this approach has been successful on islands under 1,200 ha, it has not yet been fully effective on larger islands. Based on information from the Resolution Island and Secretary Island projects (e.g. McMurtrie, 2011; Anderson et al., 2016), trap spacing of 9 ha/trap was too sparse. Capital Kiwi's

5.5ha/trap density has been effective, but not yet completely successful in achieving eradication. Eradication proposals for Halfmoon Bay and Banks Peninsula (Ewans, 2014; Curnow & Kerr, 2017) suggest that DOC 200 traps should be set up at either 4 ha/trap or 8 ha/trap depending on stoat population density (and, therefore, average home ranges size). Trapping operations on Waiheke Island and D'urville Island are both based on 6 ha/trap density.

The 2021 stoat eradication plan recommend a trapping density of 6ha/trap over an area of 8,332 ha. Based on this, 1,400 traps will be required; 1,260 double-set DOC200 (630 stainless, 630 mild steel) and 140 single-set DOC250. Manaaki Whenua supported this trap density. If projects using 4ha/trap density prove to be particularly successful, or if rats or other by-kill present a bigger problem than anticipated, this higher density might have to be adopted for the Otago Peninsula programme. The highest parameters of the sensitivity analysis have, therefore, been set at 5 ha/trap, and the lowest parameters have set at 8 ha/trap.

It is worth noting that costs could be saved by conjoining existing mustelid control on the peninsula. These savings have not been included in the sensitivity model but are discussed later in this report.

Bait Check Frequency

The 2021 Otago Peninsula stoat eradication plan suggested that the stoat population knockdown should be carried out in winter, or at least following an intensive rabbit control operation (which usually occur over the winter months). After eight weeks of prebaiting, traps would be carefully set (checking triggering weight and sympathetic triggering) and baited with an abundance of fresh rabbit bait in a trap box with a few scraps left at the trap entrance. Traps would then be checked weekly, captures recorded, and traps rebaited until stoat captures in traps were zero. Individual traps would be moved to a better location if there were no stoat captures within two months of being set.

The 2021 stoat eradication plan also suggested that after two months of zero trap rates, the plan may switch to using the network to detect any remaining stoats. Once it is believed the stoats have been eradicated, the 720 mild steel DOC traps would be removed, and the 504 stainless steel traps would be retained and checked every two months as a monitoring network.

According to trap network optimisation modelling completed for Predator Free Hawkes Bay, if 25% of traps were removed from a trapping network (because they are gummed up from catching non-target animals), 95% of the target animals were still likely to be captured (Warburton & Gormley, 2015). Similar modelling may be able to inform the density at which the Otago Peninsula's mustelid trapping network should be maintained. Until then, the internal, trapping network has been stress tested at 50% and 80% of the eradication stage density.

The 2021 stoat eradication plan suggested that the trapping network would be checked once every two months and would be left unbaited for traps to act as run-through tunnels. Manaaki Whenua suggested that the traps should be baited and, therefore, this option was included in the sensitivity analysis. Additionally, depending on the likelihood of reinvasion to the peninsula, the trapping network may be required to be checked more frequently as responding to invasions can be costly, especially if detection of an invading animals is delayed. Research has suggested that checking traps monthly is sufficient for predator control, but increasing checks in the summer might increase effectiveness (Ewan et al., 2014) and so the sensitivity analysis has assumed that traps will be checked 6 - 18 times a year.

Trap Buffer

As noted above, maintenance of the entire eradication network may be required year-round if catches do not cease. If they do cease, then the 2021 Otago Peninsula stoat eradication plan suggests scaling down the network to operate it as a monitoring tool. External buffers should be utilised to help keep stoats from migrating to the peninsula. The 2021 stoat eradication plan was based on the internal network continuing to be spread throughout the peninsula but at 50% less density than the eradication model, working as an internal buffer and monitoring system. Because invasion of stoats could come from the coast, harbour, or base of the peninsula, an internal trap buffer would have to remain throughout the peninsula to provide maximum security. This network would not, however, be in place to eradicate immigrants immediately on arrival, rather its purpose would be to detect the presence of arrival ideally before breeding could occur. Modelling has been undertaken predicting movements of stoats into the peninsula (see Section 5.4 above). This should inform the design of trap buffers but indicates that a peninsula-wide network will be required.

The Te Korowai o Waiheke and Capital Kiwi projects have both been required to keep their entire trap network operational for three and four years respectively and both programmes continue to capture stoats across the project areas. Te Korowai o Waiheke staff have access to genetic analysis, which has confirmed the individuals caught in traps are survivors, not re-invaders. Capital Kiwi staff have assumed the same given the variable location of the catches (i.e., not just coastal). The Otago Peninsula programme should, therefore, consider the cost of keeping its entire eradication network out for multiple years, or at least forming an operational trap buffer around entry points within the peninsula in between full network seasonal eradication pulses. The eradication phase (full network operational) has, therefore, been costed on best-case scenario of 3 weeks of checks, and a worst-case scenario of 8 weeks of checks. The remaining network has then been costed based on it being checked year-round, whether that be as a buffer to restrain re-invasion or as part of the full eradication network.

External Buffer

The peninsula is flanked by the Otago Harbour and a densely populated area, which might reduce the likelihood of reinvasion, but which will not stop it completely (see Section 5.4 above). The Otago Peninsula eradication project has an opportunity to engage fellow Predator Free Delivery partners City Sanctuary and the Halo Project to form external buffers for the peninsula. Evidence suggests that stoats can travel 10 km through a dense trapping network without being caught (Veale et al. unpublished). Because the peninsula is narrow, any invasion via swimming will result in the stoat being able to reach the core area rapidly. This highlights the importance of large external buffer zones around the peninsula.

Te Korowai o Waiheke has adopted the process of checking traps every 4 days in areas they have identified as hotspots. It may also be useful to take this approach to vulnerable areas of the peninsula’s barrier and check these traps more frequently. The worst-case scenario parameter used is, therefore, 52 checks a year, or one check every week after the eradication phase.

City Sanctuary work throughout Dunedin city on pest control, but thus far have focused on eradicating possums. An entire mustelid buffer would essentially need to be installed to provide a considerable buffer (additional to that offered by the dense housing) from invasion at the base of the peninsula. At a minimum, the ~500 ha of Musselburgh and Anderson Bay suburbs, which form the base of the peninsula, should be bolstered with a trapping network. The entire City Sanctuary project area expands to ~8,000 ha, roughly the same size as the Otago Peninsula. This may not be an unrealistic buffer size, as Capital Kiwi currently utilise a core area and buffer area of similar sizes. The median of 500 and 8,000 is taken to get 2,500 ha as the baseline for the cost analysis. 2,500 ha is approximately the size of the City Sanctuary project area that sits south of the southern motorway. The motorway could offer a logical boundary to a buffer protecting only the peninsula (Figure 2). As there is currently minimal mustelid work in the City Sanctuary project area, an entire network was costed for both installation and maintenance in the sensitivity analysis.

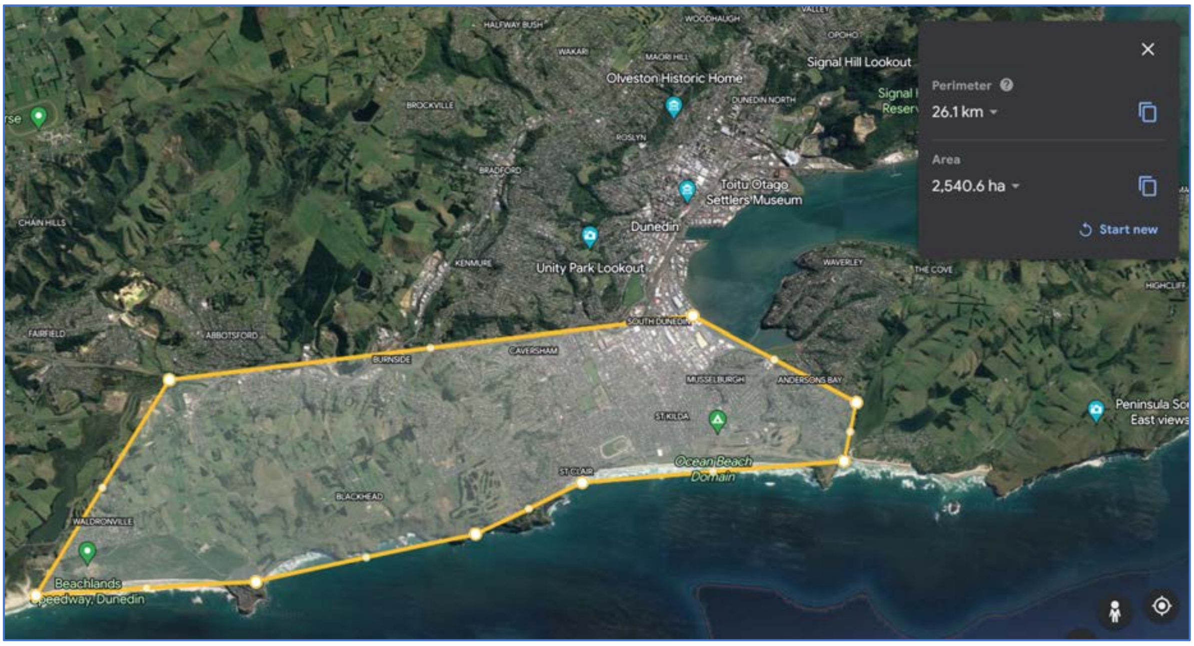

Figure 2: The ~2,500 ha City Sanctuary area that lies to the south of the motorway

City Sanctuary currently have 14 mustelid traps in the field (Figure 3), however, they also have a stock of ~130 DOC 200 traps with tunnels and 70 traps without tunnels ready for installation.

Figure 3: Current stoat control network operated by City Sanctuary to the south-west of Otago Peninsula

Currently, a possible buffer is already forming on the north side of the harbour via the Halo Project. The core area of the Halo Project surrounds the Orokonui Ecosanctuary and covers 11,948 ha north of the Otago Harbour. The Halo Project currently runs a stoat control network with 1 trap every 10 hectares, which totals 1,136 traps over the project area (Figure 4).

Figure 4: Current stoat control network for the Halo Project

Possums are also the current focus of the Halo Project and, therefore. mustelid traps are largely maintained by volunteers and checked infrequently (as little as twice a year). In its present state, the Halo Project will serve as minimal protection to the peninsula; as research from ZIP and Norbury shows, trap buffers of greater density operate at just 60% efficiency at best.

Previous research from Norbury et al. (2014) highlighted that trap buffer effectiveness increases with buffer depth (distance from project edge). Norbury et al. (2014) measured trapping rates and lizard presence (biodiversity gains) at 500 m, 1,000 m and 1 500 m within a trapping network. This found that trapping rates were lowest and lizard presence was highest with a 1,500m trapping buffer depth.

Based on Norbury's estimates, increasing the intensity of the trap network to the 1,500 m that borders the harbour may be a cost-effective solution to creating meaningful protection to the peninsula. This would involve increasing trap management for approximately 30% of Halo's mustelid control network. To reach 6 ha/trap density within the 1,500 m buffer, trap density would have to increase by ~20% (~250 traps to ~450 traps). This would also require an increase in labour costs.

According to current cost estimates of the Halo Project's mustelid eradication (provided by Project Manager Jonah Kitto-Verhoef), an installation of 20% more traps would cost in the region of $20,000 and servicing the denser buffer would cost $1,200.00 extra per service.

It would be advised to check the buffer traps at least, up to 18 times a year. Estimates place costs for this in the region of $81,792 - $122,688 a year. However, both external buffers were costed as an extension of the eradication project during the eradication project timeline and, therefore, stress tested by 17, 26, and 52 annual checks. Like the City Sanctuary buffer, the entire 11,948 ha Halo Project area was used as the worst-case scenario buffer and (in Halo's case) the 2,500 m buffer as the best-case scenario. However, as Halo already have a network installed, installation costs only included the 40% increase required to meet a 6ha/trap density within that 2,500 ha.

For the sensitivity analysis, the results of including internal biosecurity zones and external buffers were separated. This is because the internal biosecurity zones represent fluctuations in a year-long eradication network and is, therefore, integrated into the eradication plan specifically. The external buffer is more important to consider if eradication is achieved and there is a focus on preventing reinvasion. It also involves other projects, and the question of which entity is responsible for the costs of additional mustelid control will require a separate discussion. An effective external buffer will, of course, offer considerable suppression and potential eradication for networks in those areas. This will deliver significant benefits in the form of predator suppression and biodiversity gains to those projects (discussed later in this report).

In practice, a truly effective trap buffer width may be a lot cheaper or a lot more expensive than this design. However, given that it is desirable to create the best possible protection, and that trap buffers are yet to be proven as effective predator exclusion barriers, it is best to be cautious in these estimations for now. This analysis allows for testing the costs without first testing the effectiveness, but to make the analysis powerful it is prudent to be cautious and realistic with the proposed approach.

Monitoring

Based on the comments from Te Korowai o Waiheke and Capital Kiwi project managers, monitoring is essential to the project. While detection dogs will also be required in the monitoring phase to ensure the absence of all target species, they may not be practical to monitor large areas for long periods of time after eradication (Glen et al. 2016). Furthermore, when Manaaki Whenua reviewed the 2021 Otago Peninsula stoat eradication plan, it was suggested that there should be monitoring that is separate to the trapping network.Additional monitoring techniques have, therefore, been included in the costing for post-eradication monitoring.

Common methods for predator monitoring include using trail cameras (Glen et al., 2016), tracking tunnels (Russell et al., 2009), and chew cards (not relevant for mustelids) (Clayton et al., 2015). For post-eradication monitoring, devices are deployed at likely re-entry points, such as coastal sites (Martin & Richardson, 2019; Griffiths, 2014; Curnow & Kerr, 2017) or at the core of eradication sites covering around 10% of the treatment area (Ewans, 2014; Zero Invasive Predators 2017). A tracking tunnel grid at a density of one device per 0.1 ha would likely provide sufficient monitoring for stoats and ferrets, considering their home ranges and recommended trapping grids (Curnow & Kerr, 2017; Clayton et al., 2015).

A growing alternative to tracking tunnels is the use of motion-activated trail cameras (Anton, Hartley, & Wittmer, 2018). Cameras are, however, considerably more expensive to purchase and still require regular checking to replace lures. They also suffer from trigger delay and may miss fast-moving animals.

One innovative technique being used by ZIP and other predator free initiatives is the use of trail cameras paired with automated lure dispensers (Bell et al., 2019). Each lure delivers 0.15 ml of egg mayonnaise each day to ensure that the lure is fresh and at its most attractive. During ZIP's trials, lure dispensers were paired with trail cameras in grids of 700 x 500 m over a 3,700 ha area known to have low densities of stoats. ZIP found that the lure + camera combination detected up to 30 times more stoats than typical track tunnel methods (Zero Invasive Predators 2019). The month-long project cost $17,000 of ranger time to deploy and service the 95 devices. ZIP estimated that running costs (ranger time only) for the devices would be around $60/ha/year. The devices also detected high numbers of possums and rats and could, therefore, be a useful method for OPBG. OPBG already currently use the ZIP lure dispenser and, therefore, considerable capital expenditure could be saved if the system was adjusted for both the current possum eradication project and the proposed mustelid eradication project.

MotoLures cost $143.75 each, and ZIP's choice of camera cost $253 each (Zero Invasive Predators 2019). Establishment costs for trial cameras and lure dispensers, plus ranger time would, therefore, be around $15/ha. In contrast, Curnow and Kerr (2019) estimated that tracking tunnel set up costs $0.184/ha and annual monitoring costs $0.34/ha (based on 0.1 tunnel/ha on Banks Peninsula). These monitoring costs are based on checking and replacing a tracking tunnel inkpad four times per year.

For the sensitivity analysis, the lure + camera combination will be used as the median cost ($15/ha for installation and $60/ha/year for running costs). The median will be stress tested by +/- 20% to represent additions to the monitoring network that may be necessary for optimisation. The area requiring monitoring has been assumed as being 10% of the Otago Peninsula (833 ha).

It is important to note that set up costs do not include route establishment, and it is suggested that routes designed for the trapping grids would be used. Furthermore, it should be noted that data processing costs are not included either. It is, however, estimated that footage from 2,500 trail camera images could be processed in an hour (Zero Invasive Predators 2019).

Targeting Survivors Using Detection Dogs

According to the 2021 stoat eradication plan, once the trap rate is zero for two weeks, the bait would change to high-fat beef, then chicken, then fresh fish/fish oil, and then finally fresh, uncleaned eggs. Any remaining stoats would then be located and targeted with unbaited, buried fenn traps along runs and in run-through tunnels, bait silos of dead laboratory rats (followed by replacement with dead rats laced with brodifacoum), live-capture traps (checked daily or using a remote-reporting Encounter Solutions Celium Network), and PAPP-laced baits. If remaining stoats could not be captured, den locations would be identified using an indicator dog and traps would be placed at the entrance of dens. Finally, a rat control grid of brodifacoum bait stations would be employed if required.

Detection dog costs have previously been estimated at $15/ha by the Halo Project in their planning (provided by Jonah Kitto-Verhoef), though there is no formal evidence for this costing. Local detection dog handler Alex Ghaemaghamy advised that the cost for a mustelid dog team is $350 - $450/day, with the addition of travel and accommodation cost if applicable. Ms Ghaemaghamy was, however, unsure how many days it would take to sweep the peninsula and couldn't, therefore, provide a cost estimate for the work.

As an indication of costs for a detection dog sweep of the Otago Peninsula, costs from recent possum detection work been used. The possum detection dog team have a standard rate of $130/hr and work approximately 30 - 40 hours a week. The work is intense, and so the dog requires a lot of downtime. The detection dog team recently spent three weeks covering sectors 1 – 3 of peninsula, and OPBG Operations Manager Micaela Criby-Crowe suggested that the same amount of time would be needed for sector 4. The detection dog team had a travel rate of $750/day and charged $0.83/km mileage. In total, depending on the hours worked, the detection dog team cost was $8,900 - $10,200 a week, and covered around half of the peninsula in 3 weeks. A full peninsula sweep for possums would cost $17,800 - $20,400, or $7 - $8 per ha.

Mustelid detection dog work differs to possum detection dog work due to possums and mustelids using different habitats. The possum detection dog team tries to focus on areas where possums are likely feed or play in trees and where there will, therefore, be the highest density of scat. Given that mustelids are often found near waterways and spend more time in grasslands hunting rabbits, the mustelid detection dogs need to take a different approach to the possum detection dogs.

As a comparison, a project led by Manaaki Whenua trialled feral cat detection dogs. The detection dog cost $450/day (Glen et al. 2016) and took a total of 541 minutes at a total cost of $4,820 to find (all) five cats over a total of 600 ha. Based on these rates, it would take 0.018 dog days per hectare, at cost of $450 a day, to cover the peninsula ($8/ha).

At the more expensive end, estimates of detection dog costs for multiple species on Rangitoto and Motutapu Islands equalled to 0.27/0.28 dog days per hectare, or $121/ha (based on feral cat contractor rates). Another project estimated that one detection dog team can sweep 50-60 ha per day when looking for rats (Bell and Bramley 2013). Based on this rate, it is estimated that three dog handler teams would take 30 days to sweep a 5,000 ha area for rats (Ewans 2014). Sweeping for mustelids should take considerably less time due to higher detectability and range size (Ewans 2014). It seems unlikely, therefore, that rates from Rangitoto and Motutapu Islands are relevant for stoat-only detection dog work. Additionally, it is unlikely that the whole of the peninsula would need sweeping, but some areas would need multiple sweeps.

These rates are useful references for the parameters of the sensitivity analysis. Estimates from the possum detection dog contractors serve as the low-cost/best-case scenario, while estimates from Rangitoto and Motutapu Islands serve as a worst-case scenario. It is clear, based on the studies above and communications with local dog handler Alex Ghaemaghamy, that costs of detection dogs rise exponentially with the scale of a project. Ms Ghaemaghamy could not, therefore, provide a quote for the project, and instead suggested an area the size of the Otago Peninsula would be very difficult to verify to be mustelid-free through detection dogs. Ms Ghaemaghamy recommended that dogs would be more useful to identify smaller areas of ongoing stoat activity but also noted that there are only 3 trained stoat dogs in New Zealand and that they would most likely only be available for 2 - 4 weeks a year.

Because stoat detection dog rates could not be acquired, the sensitivity analysis parameters remain large to represent the uncertainty in the cost (and effectiveness) of this input. The best-case scenario rates used are $8/ha (possum detection dog cost estimates) and the worst-case scenario rates used are $121/ha (Rangitoto and Motutapu Islands). Halo's estimate of $15/ha falls within that. For the baseline, the median cost of detection dogs has been calculated to be $64/ha.

6.3 Cost metrics

Net Present Value

Because more weight is typically placed on costs that accrue closer to the present day than those that occur later, discounting renders costs occurring in different time periods to present-day terms, or net present value (NPV), according to the formula:

$$\mathrm{NPV} = \sum_{t=1}^{T} \frac{C}{(1+r)^t}$$

Where C is the cost per year, T is the years of the project (3-5), and r is the discount rate. The discount rate is the rate of return used to discount future cash flows back to their present value. The rate is designed to reflect the time value of money and that money today is worth more than the same amount in the future, and that unspent money today could lose value in the future due to inflation or the rate of return if the money was invested. This report uses New Zealand's official discount rate of 0.043 (4.3%). To adjust for inflation, the discount rate is multiplied by the general inflation rate. According to the Reserve Bank of New Zealand the current inflation rate is at 7.2%, therefore, (1 + 0.043) x (1 + 0.0720) = 1.118. This means that the discount rate to be used is 11%.

Annualised NPV

Net present values (NPV) were annualised (often referred to as 'equal annual equivalents') to derive average costs, according to the formula in Guidelines for Preparing Economic Analyses (USEPA 2010):

$$\text{Annualized NPV} = \text{NPV} * \left[\frac{r*(1+r)^{T}}{(1+r)^{T}-1}\right]$$

The equivalent annual cost is a constant, per year cost of owning, operating, and maintaining an asset or project over its lifetime (3 -5 years in this case). It is estimated by multiplying the total NPV of costs by an annuity factor. Although volunteer input reduces costs, all labour hours have been costed to make valid cost comparisons between methods. This also recognises opportunity costs when people volunteer their time. Technically, there are no benefits or income coming into this equation, therefore the result is not Net Present Value but rather just Present Value (PV).

Tornado Plots

Data is presented as tornado plots. A tornado plot is a visualization of the range of outputs expected from a variety of inputs, or alternatively, the sensitivity of the output to the range of inputs. The centre of the tornado is plotted at the response expected from the mean of each input variable. For a given variable, the width of the tornado is determined by the response to a change in each input variable while holding all others constant at their mean. During the analysis only one variable is moved from its mean value at a time.

Variables are ordered vertically, with the widest bar at the top and narrowest at the bottom. The plot attempts to display the relative impact of each variable on the model fit. Traditionally, for linear models, the concept of importance was expressed as the percentage of total response variable variance that is explained by each variable, either alone, or in the presence of the other variables in the module

6.4 Costing Summary

Table 2: Costing Summary

Fixed Inputs	2021 Plan	Best Case	Worst Case
Tunnel purchase cost	$174	$174	$174
Trap purchase cost	$52.5	$52.5	$52.5
Hourly labour rate	$50	$50	$50
Hour per check	0.117	0.117	0.117
Hours for set up/trap	0.36	0.36	0.36
Hours for install/trap	0.16	0.16	0.16
Bait per check	$5	$5	$5
Trap removal	0.16	0.16	0.16
Treatment area	8,332 ha	8,332 ha	8,332 ha

Variables (Original)	**2021 Plan**	**Best Case**	**Worst Case**
Density	5.779 ha	8	5
Eradication Years	1	1	3
Eradication bait check per year	8	8	52
Biosecurity Years	2	2	4
Biosecurity Network	50%	50%	80%
Biosecurity checks per year	6	6	18
Variable Inputs (Additional)	**2021 Plan**	**Best Case**	**Worst Case**
Monitoring ongoing	$60/ha	$48/ha	$72/ha
Target survivors (annual dogs sweep)	$65/ha	$8/ha	$121/ha
Halo External Buffer area	7,974 ha	4000 ha	11,948 ha
City External Buffer area	4,250 ha	500 ha	8000 ha
Outputs	**2021 Plan**	**Best Case**	**Worst Case**
Set up phase			
DOC200 Traps	$151,386	$151,386	$151,386
DOC200 Tunnels	$250,868	$250,868	$250,868
DOC200 Tunnel setup	$11,535	$11,535	$11,535
DOC200 Trap install labour	$26,385	$26,385	$26,385
Total	$440,173	$317,970	$508,752
Prebait phase			
Baits	$57,671	$41,660	$433,264
Rebait labour*	$67,475	$48,742	$506,919
Total	$125,146	$90,402	$940,183
Eradication Phase			
Baits	$57,671	$41,660	$1,299,792
Bait labour*	$67,475	$48,742	$1,520,757
Total	$125,146	$90,402	$2,820,549
Biosecurity phase			
Trap removal	$5,767	$4,166	$2,666

Trap checking*	$25,303	$36,557	$140,378
Total	$31,070	$40,723	$143,044
Total	$1,468,373	$1,078,994	$8,825,055
Additional Variables Outputs	**2021 Plan**	**Best Case**	**Worst Case**
Eradication Phase			
Target Survivors	$541,580	$66,656	$1,008,172
Biosecurity phase			
Baiting Biosecurity Traps*	$3,605	$2,604	$4,166
Monitoring Installation	$124,980	$108,316	$149,976
Monitoring Ongoing*	$499,920	$399,936	$599,904
Halo External Buffer Purchase	$6,071	$3,660	$17,492
Halo External Buffer Install	$479,075	$43,400	$4,044,637
Halo External Buffer Ongoing*	$214,441	$124,279	$295,381
City External Buffer Purchase	$8,090	$1,144	$29,280
City External Buffer Install	$255,338	$5,425	$2,708,160
City External buffer Ongoing*	$149,643	$63,379	$226,686
Total	$2,282,743	$818,799	$9,083,854
Grand Total	**$3,776,419**	**$1,897,793**	**$17,908,909**

*Cost represented are annual, and not multiplied by the years of the project

6.5 Results

Present Value

Totals for the best case, worst case and baseline costs were calculated for the both real-term totals and present-value (time-adjusted) totals. The totals for each scenario are tallied below.

Table 3: Total cost for a stoat eradication programme based on a strategy to eliminate and protect via trapping

Eradication Project	**Best Case Scenario**	**Original Baseline**	**Worst Case Scenario**
Actual Total	$565,430	$1,232,046	$5,277,655
NPV Total	$505,752	$1,102,008	$3,776,727
Eradication and Biosecurity Project	**Best Case Scenario**	**Original Baseline**	**Worst Case Scenario**
Actual Total	$2,682,082	$4,340,319	$26,572,712
NPV Total	$2,199,176	$3,588,776	$17,407,221

The cost of a trapping-based eradication strategy was estimated in realistic worst- and best-case scenarios. Annual costs were multiplied by expected years of eradication/biosecurity, with a maximum of a 5-year timeframe overall as the worst case scenario.

Based on changes to kill trap costs and density, stoat eradication on the Otago Peninsula is predicted cost in the region of $1,102,008 ($505,752 - $3,776,727) in present value terms (and not including any rabbit control costs). With the inclusion of biosecurity work on the peninsula and in external buffer zones (City Sanctuary and the Halo Project) the project would cost $3,588,776 PV ($2,199,176 - $17,407,221).

Ongoing costs of biosecurity and biosecurity in the external buffers would cost approximately $867,609 each year in real terms, and a range of $590,193 - $1,126137 each year.

Tornado Plots

Rather than assessing only the totals for the best- and worst-case scenarios, the sensitivity analysis can assess each individual input’s effect on the total cost under the best-or worst-case scenario. This is represented in the tornado plots below.

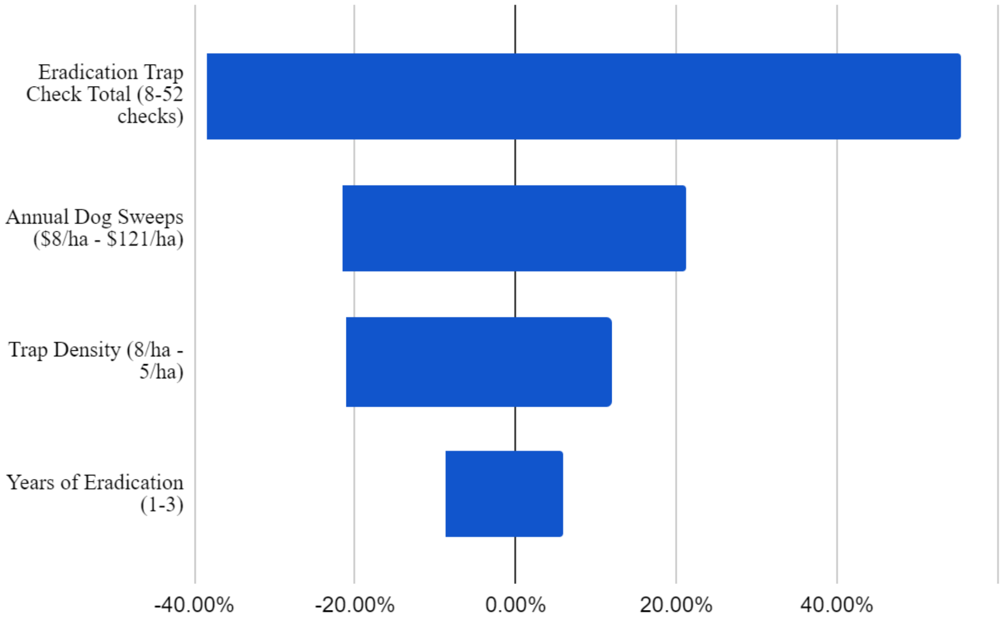

Figure 5: Tornado plots ranking the most influential inputs to a stoat eradication programme based on their effect on PV over four years

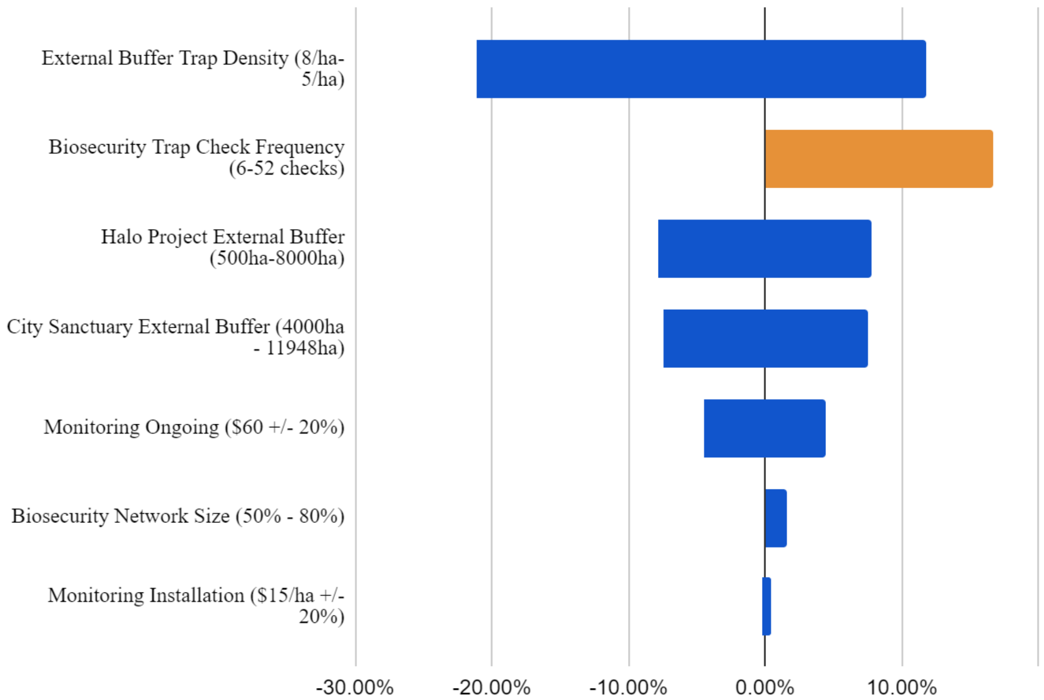

Figure 6: Tornado plots ranking the most influential inputs to the biosecurity phase of a stoat programme based on their effect on PV over four years

Trap Checks

By far the most significant input on the cost of the eradication programme is the amount of trap checks required during the eradication phase. If a successful rabbit control operation is undertaken, and this increases stoat trapability, this could reduce the cost of stoat control as fewer trap checks would be required to reach low density and target survivors. However, if that is not case, a similar strategy to Te Korowai o Waiheke will need to be adopted i.e. weekly trap checks. This will drive costs up more than any other variable. This highlights the importance of understanding how effective the original strategy is likely to be. Given that the number of years of the project affects the overall cost much less than the trap check frequency, the project may wish to consider successive 8 - 10 week pulses each year, rather than year-round trapping. Unsurprisingly, trap density is both a key principle in the feasibility of the project and the cost of the project. This will be a relatively expensive input, but an important one.

Timeframe

As noted above, three years is a relatively optimistic timeframe for eradication compared to similar-sized projects. After five years (3 years of eradication and 2 years of biosecurity), the depreciation of DOC traps may play more significance to the project as replacements may become more frequent. It is, therefore, wise to aim for an eradication within five years.

Detection Dogs

Targeting survivors using detection dogs is another significant driver of cost variability. This reflects the uncertainty around this input, as specific costs for stoat detection dogs were not able to be acquired. It also represents the exponential costs involved with large-scale detection dog operations. If the project attempted to use detection dogs over the entire peninsula to find and eliminate stoats, costs would likely reflect that of Rangitoto and Motutapu Islands ($121/ha) due to the likelihood of pursuing stoats over the same area multiple times. If detection dogs were used in small, targeted areas to identify stoat presence, then the efficacy of dogs may improve, and costs per/ha would drop. A pulsed/periodic use of detection dogs is, therefore, advised.

External Buffers

Trap density, buffer width and buffer check frequency are unsurprisingly among the most significant drivers of cost for the biosecurity phase. This is because the external buffers are essentially replications of the eradication network over a larger area. The buffer is also only costed for the timeline of the biosecurity phase (proving eradication). If eradication is achieved and reinvasion is to be minimised, the project should consider a trapping buffer in perpetuity.

Annual costs of the internal buffer are estimated at a median value of $50,617/yr ($202,470/4) but may range between $14,360/yr ($43,082/3) and $110,268/yr ($5,513,445/5) depending on width, trap density and check frequency (costs are taken from Appendix 1). The sensitivity analysis shows that having a good understanding of the cost of a useful buffer will be essential to this project.

Interestingly, the addition of the buffer areas themselves do not appear as significant in terms of cost variability as the trap density and check frequency. In other words, decreasing density and check rates but increasing the area of the buffer is more cost-effective than decreasing the buffer area but keeping density and check rates high. The feasibility of the project may be, however, highly reliant on trap density and check frequency. This highlights the importance of understanding the ideal trap density and check rate. It also supports the innovation of a self-resetting mustelid trap to significantly reduce costs to the project. As previously noted, the installation of A12s or other multi-capture trap may be considered for hard-to-reach areas of the peninsula.

Monitoring

Ongoing monitoring will be the second largest driver of costs on the peninsula during the biosecurity phase. The relationship between the ongoing check frequency and installation costs shows how expensive labour costs are to the project. The sensitivity analysis ranks the monitoring installation cost as the input which is least influential in driving costs up. This suggests capital expenditure on cameras and ZIP lures may be worthwhile if labour costs can therefore be saved by lowering the check frequency and ongoing costs to the project. This may also support investigation into AI cameras to save overall project costs if they reduce labour costs of monitoring significantly.

6.6 Ferrets vs Stoats

The 2021 stoat eradication plan focussed only on the eradication of stoats from the peninsula, however, it has since been discussed that ferrets could become a separate target instead of, or as well as, stoats and so the costs of a ferret eradication was also assessed. The project area and monitoring techniques remain the same for ferrets and stoats, therefore the only change to the costing model was the trap type and trap density.

Best practice to remove ferrets via trapping is the use of DOC250s at a 1 per 100 ha trap density (0.1/ha) (or one trap every square kilometre). For the parameters of the sensitivity analysis, the trap densities were set at 0.12/ha and 0.08/ha to represent best- and worst-case scenarios. Ferrets may not be as widespread over the peninsula as stoats and, therefore, the trap network should be able to afford some efficiencies by operating at less than 0.1/ha in some areas. According to the Connovation website (www.connovation.co.nz), stainless steel DOC 250s cost $47.00 and the wooden box costs $106.00 (Predator Traps, 2014). The sensitivity analysis designed for stoats was repeated with trap density and capital cost changed to represent a ferret eradication programme. The costs are compared below.

For eradication of ferrets, it may also be necessary to use toxins to facilitate secondary poisoning. This could include Pindone carrot operations to poison rabbits. The cost of a peninsula-wide Pindone carrot operation would be in the order of $1.6m based on per hectare contractor rates, however, for the reasons discussed later in this report a one-off peninsula-wide Pindone operation is unlikely to ever occur. Effective rabbit management would also require ongoing secondary control to target survivors. This is difficult to cost over a large and diverse area such as the peninsula. The best way to compare stoat and ferret costs were, therefore, to omit possible toxin costs from the analysis.

The risk of ferret reinvasion via swimming is considered to be low, therefore the only buffers assumed in the costing were City Sanctuary and the base of the peninsula.

The cost of the strategy was estimated in realistic worst- and best-case scenarios. Annual costs were multiplied by expected years of eradication/biosecurity, with a maximum of 5 years overall as the worst-case scenario.

Table 4: Total cost for a ferret eradication programme based on a strategy to eliminate and protect via trapping

Eradication Project	**Best Case Scenario**	**Original Baseline**	**Worst Case Scenario**
Actual Total	$98,519	$579,815	$1,272,932
NPV Total	$88,121	$518,618	$910,919
Eradication and Biosecurity Project	**Best Case Scenario**	**Original Baseline**	**Worst Case Scenario**
Actual Total	$1,095,894	$1,850,119	$4,589,914
NPV Total	$886,069	$1,534,923	$3,034,046

Based on changes to kill trap costs and density, ferret eradication will cost in the region of $518,618 ($88,121 - $910,919) in present value terms. With the inclusion of City Sanctuary as an external buffer, the project would cost $1,534,923 ($886,069 - $3,034,046).

Ongoing costs of City Sanctuary as an external buffer, and on ongoing internal biosecurity monitoring would cost between $819,465 and $2,448,516 annually with the median annual cost estimated at $1,057,870 in real terms. These costs must be considered if the project hopes to protect the peninsula from ferrets in perpetuity.

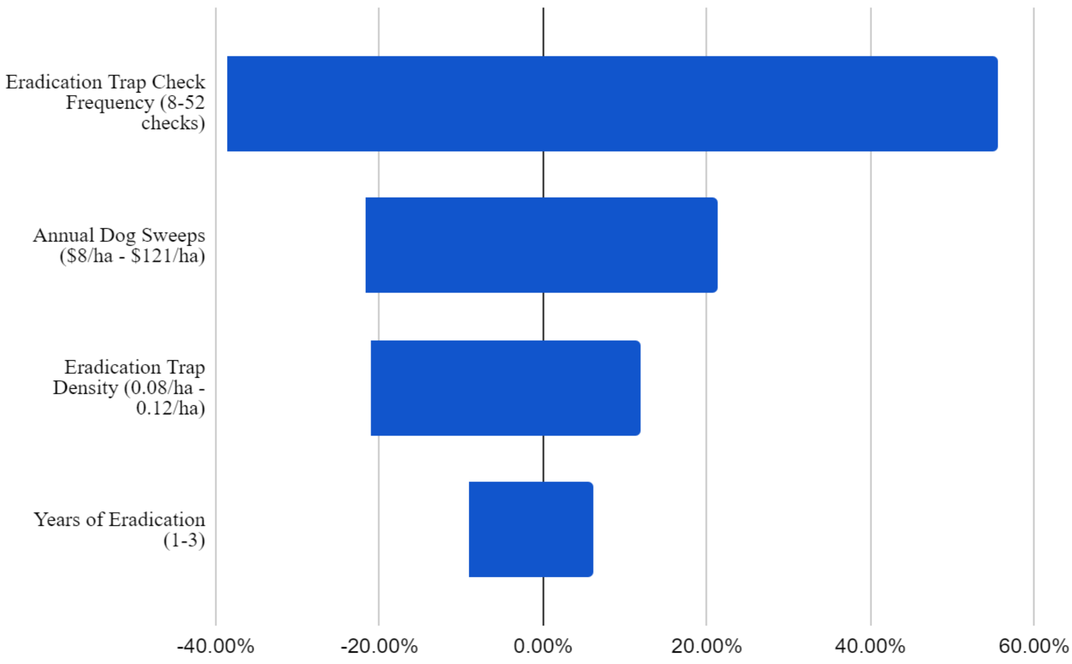

Figure 7: Tornado plots ranking the most influential inputs to a ferret eradication programme based on their effect on PV over four years

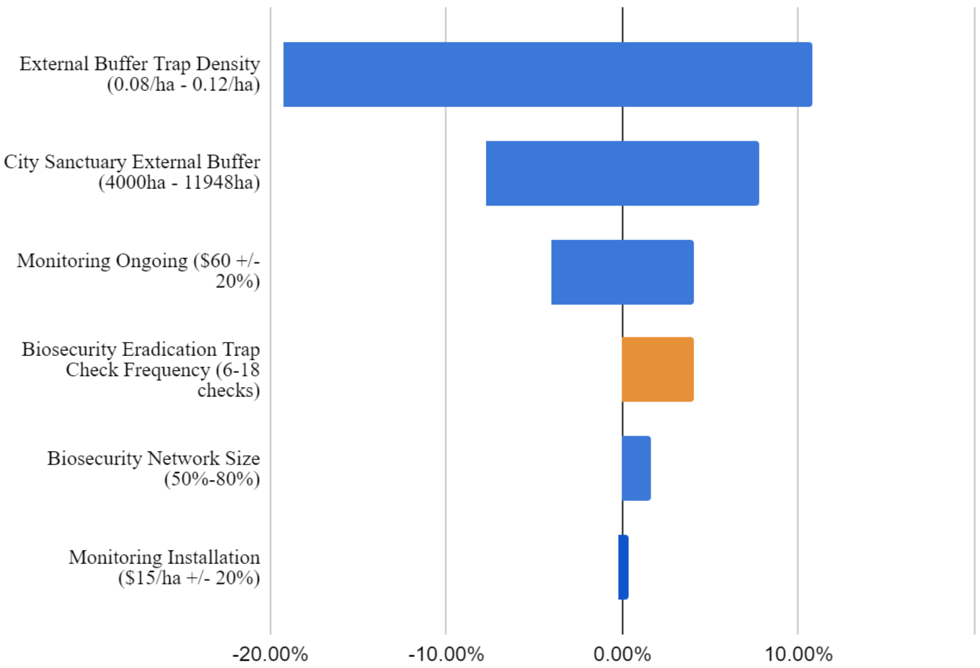

Figure 8: Tornado plot ranking the most influential inputs to the biosecurity phase of a ferret eradication programme based on their effect on PV over four years

As trap density is much less intense in the ferret model compared to the stoat model, the actual cost for trapping ferrets is relatively cheap and trap check frequency becomes less significant in the model. As a result, monitoring (through camera trapping and detection dogs) becomes a more significant driver of costs for a ferret eradication programme. This highlights the need for improvements in the efficacy of the current monitoring tools. Financially, the ferret eradication cost model does appear far more feasible. Detecting survivors or invaders will continue to drive the costs of the project, especially if there are uncertainties regarding the efficacy of the monitoring system (as is the case for the Te Korowai o Waiheke and Capital Kiwi projects). It is, therefore, important to understand the risk of invasion as this may affect how long the monitoring network needs to stay once zero detections occur.

Monitoring using detection dogs may be the second most expensive component over the course of a ferret eradication programme. It is, however, important to remember the uncertainty surrounding costs, and that all detection dogs are currently trained to detect all three mustelids. The handler can sometimes make an educated guess at the species by the dog's behaviour, the context, or by DNA testing fresh scat (pers comms Alex Ghaemaghamy). This may, however, cause confusion if only ferrets have been eradicated and indicator dogs are detecting weasel and stoat presence. Based on the sensitivity analysis, this could be a relatively expensive mistake if rates are closer to $121/ha than $8/ha. It is not impossible for a dog to be trained to provide more specific species indications, or to indicate single species only. They would, however, need to be new dogs receiving specific training (pers comms Alex Ghaemaghamy).

The ferret eradication cost model also supports the idea that if stoat eradication is commenced, ferret eradication should also commence. This is because the addition of a trapping grid for ferrets is relatively inexpensive, and if monitoring tools are being practiced for stoats, this eliminates a major cost driver of the ferret eradication programme. If ferret eradication is commenced instead of stoat eradication, then special attention should be placed on monitoring tools. If high cost/worst-case scenarios become realistic, then marginal gains to the monitoring network significantly decrease. Monitoring would be much more cost-effective if it were also monitoring for a stoat eradication programme. If actual monitoring costs reflect a best-case/low-cost scenario, then a targeted ferret eradication becomes more justified.

6.7 Cost Savings

Finally, either eradication network can save money by adjoining current trapping networks on the peninsula and collaborating with the associated project managers. Thus far, OPBG already have 162 cages in the field (and 30 more in stock) which are self-reporting cages and send notifications of trap captures via the Encounter Solutions Celium Network. These traps could easily be repurposed to target ferrets, but not stoats. Topmaq are the cheapest provider of cages to OPBG, selling them in bulk for around $50 per piece.

For stoat control, OPBG have also installed 75 double set DOC150s and 25 DOC250s around Sandymount and Sandfly Bay. This is a volunteer-run trap line to support Forest and Bird's protection of penguins and tītī in the area. Forest and Bird also run 78 DOC200 kill traps of their own for their seabird protection programme. During the tītī/sooty shearwater breeding season they also install around 20 live capture cage traps on Sandymount and check them daily.

The Yellow Eyed-Penguin Trust run trapping networks throughout multiple hoiho colonies on the peninsula, including 85 mustelid traps in Okia (217.4 ha), 35 mustelid traps at Otapahi (28.97 ha), 24 mustelid traps at Okekiho (3.77ha), and 23 mustelid traps around Hoopers and Papanui inlets, totalling 167 traps altogether.

Mustelid trapping programmes also exist at the head of the peninsula. The Department of Conservation trap for the protection of the Northern Royal Albatross, and Natures Wonders and Penguin Place (two ecotourism companies) also trap to protect yellow-eyed penguin colonies. The extent of their trapping network is unknown, but Penguin Place use an array of traps including cage traps and caught approximately 60 ferrets and 10 stoats over the last two seasons over an approximately 40 ha area.

The total number of permanent mustelid traps on the peninsula that have been accounted for in this report is 507.

Regarding savings on monitoring equipment costs, the Otago Peninsula Biodiversity Group currently have 87 cameras deployed in the field and 22 cameras currently in stock. The cameras are a mix of 70 Bushnell Trophy Cam HD Aggressors, and 50 Browning Dark Ops Pro XD. There are 11 cameras unaccounted for, and it is assumed most are used by community volunteers.

Approximately 48 of the cameras in the field are viewing ZIP MotoLures and the remainder are placed on a mix of ATs, food dumps, and bait stations. There are a further 26 ZIP MotoLures to be deployed of the 74 owned by OPBG. Forest & Bird and the Yellow-eyed Penguin Trust also install trail cameras during the summer to monitor their respective seabird breeding colonies, which could serve as mustelid detection.

6.8 Costs: Key points

1) The involvement of external buffers places more importance on the understanding of trap density and check frequency. The efficiency of trap network design is optimised through understanding mustelid movements. To save the most costs in the project, research and modelling should be used to design optimal trapping networks.

2) Monitoring tools drive the cost of both ferret and stoat eradications. Because monitoring tools can be used for both projects, their cost-effectiveness would increase if both eradications were attempted concurrently.

3) Detection dogs are best if readily available and used to target specific areas for proof of presence vs absence.

7. Decision Making Tools: Benefits

7.1 External Buffers

Operating an external buffer for the Otago Peninsula can also offer three major benefits to the project;

1) The purpose of an external buffer is first and foremost to lower the potential for reinvasion of mustelids back onto the peninsula. Given there is considerable reinvasion risk, particularly for stoats (see Section 5.4 above), decreasing the surrounding population of mustelids should be of great benefit to the peninsula.

2) The planned buffer zones also stand to benefit from achieving low density mustelid numbers. City Sanctuary protects an array of passerines throughout the town belt as well as sooty shearwater and fairy prion in colonies at St Clair Cliffs. Halo Sanctuary borders the Orokonui Ecosanctuary and serves to protect many bird species that disperse beyond the protection of the sanctuary's predator exclusion fence such as kaka and South Island robin, both of which are very prone to predation by mustelids (stoats in particular). Providing these external buffers zones for the Otago Peninsula should, therefore, also provide significant biodiversity gains within the buffers themselves.

3) Without predator control in the areas surrounding peninsula, internal protection would have to remain in perpetuity. External buffers offer an opportunity to lower mustelid numbers to the extent that they no longer pose the threat of reinvasion to the peninsula. If eradication was ever achieved in the buffer zones, intensive protection on the peninsula could cease and resources could be redeployed to improve habitat elsewhere, potentially extending the buffers further.

7.2 Biodiversity Gains

Although the cost of ferret eradication has been estimated to be significantly less that the cost of stoat eradication, it is important to also assess other benefits from eradicating each species. It is also important to consider the extent to which existing predator control networks on the peninsula providing protection of native biodiversity, and what additional gains might be possible through a single- or multiple-species mustelid eradication programme.

All three mustelid species (stoats, ferrets, and weasels) are detrimental to native wildlife and removing mustelids from the peninsula would relieve pressure on the breeding success of native species. If the eradication of only one mustelid species was achievable (financially and feasibly), the question would remain as to whether that would still return significant biodiversity gains to the peninsula. It is, therefore, worthwhile assessing if one species poses a greater threat than the others, and whether the removal of one species would simply result in the remaining predatory species filling the niche left behind.

The large size of stoats relative to weasels, and their superior ability to climb, stalk, ambush, and pursue relative to ferrets, is why they are considered a generalist predator and the most detrimental of the mustelid species to our native wildlife. They are also typically more widespread and numerous than weasels and ferrets both in New Zealand and on the Otago Peninsula. There is no doubt that native biodiversity on the peninsula would benefit from the removal of stoats. Tree nesting birds would, however, still be threatened by rodents and ground nesting birds would still be threatened by ferrets and feral cats. Invertebrates and lizards are also threatened by introduced predators on the peninsula. Unless all predators are removed, threats will remain for native biodiversity on the peninsula.

Whilst the Otago Peninsula is host to several native species found elsewhere in New Zealand, it is also host to the only mainland colony of Toroa/Northern royal albatross (*Diomedea epomophora)* and some of the New Zealand's largest colonies of both critically endangered Hoiho/yellow-eyed penguin (*Megadyptes antipodes*), kororā/little-blue penguin (*Penguin Eudyptula minor*) and tītī/sooty-shearwater (*Puffinus griseus*). For that reason, the Otago Peninsula is considered by some as the 'seabird capital of New Zealand'. Targeting mustelid species that pose significant threats to seabirds would, therefore, provide clear biodiversity gains. If one mustelid species poses a greater threat than others, then this may provide clear justification for the targeted eradication of that species.

Figure 9: Colonies on the peninsula

Predator dynamics and their relation to seabird colonies on the Otago Peninsula were relatively well studied between 1980 and 2000. This research base has helped to inform today's predator control operations, which includes site-specific projects undertaken by five different groups to protect four different seabird species:

1) Department of Conservation: Royal Albatross, tītī, hoiho, and kororā;

2) Yellow-eyed Penguin Trust: Hoiho;

3) Penguin Place: Hoiho;

4) Nature's Wonders: kororā, hoiho and tītī; and

5) Forest and Bird; tītī.

Northern royal albatross, yellow-eyed penguins, little blue penguins, and sooty-shearwater have all been subject to predation on the peninsula. Necropsies performed on corpses of these species in 1999 identified that four yellow-eyed penguin chicks, three royal albatross chicks, and one little penguin had puncture holes in their skin from predator bites. With some level of confidence, the study concluded that all four albatross chicks were likely predated on by stoats, while the predators of penguins were inconclusive (Ratz et al., 1999). On both the peninsula and in other southern coastal sites in New Zealand, ferrets have been identified as a significant and detrimental predator of tītī (Hamilton, 1993)

Earlier work by Darby and Seddon (1990) showed that predation on seabirds fluctuates, as predation rates on hoiho chicks varied between 4% and 62% in different years. Similarly, they found that some breeding areas had been more affected than other sites in the same year. Researchers released and radio-tracked 13 ferrets (*Mustela furo*) and 13 cats, which all took residence in the areas of Ryans Beach and Pipikaretu Beach on the Peninsula. Only one of sixty-six yellow-eyed penguin chicks from the colonies was depredated during that season. It has been suggested that the sporadic nature of predation may result from the chance appearance of "rogue animals", but this may also reflect ecological conditions prevailing at different breeding areas.

More recently, a single ferret was responsible for predating sixteen out of twenty-one tītī chicks in one season at Sandymount on the Otago Peninsula. The colony is monitored and protected through predator trapping by Forest and Bird. Two years later, a Forest and Bird tītī site in the Catlins, Long Point, was also subject to a chick massacre attributed to a single individual ferret. The trapping networks at both sites catch both mustelid species, and more commonly detect stoats (pers. comms. Francesca Cunninghame). Stoat predation on four albatross chicks in 1994 was attributed to the same 'rouge individual' theory (Ratz et al., 1999).

Both stoats and ferrets have been observed predating on yellow-eyed penguins, and the control of each predator species decreases predation rates. Darby and Seddon's work found that trapping in seabird colonies in the Catlins resulted in captures of predominantly stoats. In contrast, ferrets and cats predominated in the predator communities existing in yellow-eyed penguin breeding areas on the Otago Peninsula and in Moeraki in 1992 (Alterio et al., 1997) The Department of Conservation's predator control programme removed between 70% and 82% of the predators inhabiting the Boulder Beach area. This resulted in a lower rate of predation of chicks from nests at Boulder Beach in January 1992. Other trappers reported far fewer chick losses when predator trapping was undertaken done in the mid-1980s on the Otago Peninsula.

Massacres are hard to predict, and although predator control lowers the rate of predation, it does not prevent it entirely. Ecological conditions such as the availability of prey items and the population size of mustelids may influence mustelids' sudden and significant predation on seabirds. Department of Conservation rangers still frequently detect mustelid wounds on adult yellow-eyed penguins and some predation of their chicks (pers. comms. Megan Abbott).

There is little time to respond to a predation out-break when it is detected. Several chicks can be killed each day, and at least a week is required to remove the predators by trapping. This supports the idea that eradicating mustelid species would provide biodiversity gains to seabirds beyond what the current site-specific control provides.

7.3 Species Interactions

In 1997, a study on the Otago Peninsula found correlations between prey and predators. The study initially focused on assessing the use of vegetation buffers to deter predators from yellow-eyed penguin colonies. In reality, stoats were actually attracted to the long grass, while ferrets and feral cats followed tracks used by penguins.

The assumption that rabbits and hares would prefer short pasture to long grass did not hold true; the density of rabbits was even throughout both habitats, while the long grass increased the presence of mice, rats, and birds, which all of the predators target. The analysis of microhabitats could not prove that stoat or ferret numbers followed mice numbers, only that the presence of mustelids and cats increased in long grass.

The study also recorded distributions of stoats and ferrets, and this indicated a possible inverse relationship between the two species (Ratz, 2000). Tunnels with high ferret tracking rates had low stoat tracking rates. Ferrets and cats have been reported to kill stoats (Wodzicki, 1950; Sleeman, 1989) and/or may have deterred, chased away, or even attacked stoats that had established themselves within areas frequented by ferrets or cats.

Alterio et al. (1998) reported that stoats and ferrets shared common grazed and ungrazed areas at Boulder Beach in August, September, and October. However, in Highcliff, Alterio reported high stoat numbers and no cats or ferrets. Ferrets and cats often occur together on the peninsula and elsewhere (Alterio et al. 1998), so the negative correlation observed between stoat and ferret occurrence could have been driven by cats and not by ferrets (given the observation on Boulder Beach). Alterio et al. (1998) hypothesised that stoats may actively avoid areas used by cats and ferrets, or that they increase diurnal behaviour to reduce the risk of predation by cats and ferrets at night.

More recent research from other areas of the country supports evidence of spatial and temporal segregation of mustelids. Garvey et al. (2022) observed that stoats avoid areas with high ferret abundance, and that where the two mustelids overlap, stoats adjust by increasing activity during the day as ferrets are active at night (Garvey et al., 2022).

It is also likely that prey abundance influenced the peninsula-wide distribution of predators. The three predator species have different ecological requirements, and they could be drawn to different areas independently of each other.

Alterio (1994) found that lagomorphs (mainly rabbits, but including hares), birds, and mice were equally important in the diet of stoats residing near yellow-eyed penguin breeding areas at Boulder Beach between September 1992 and February 1993. The ferrets' diet consisted of fewer mice but equal portions of lagomorphs and birds. Lagomorphs dominated the diet of cats, with birds and mice roughly equal in importance.

In previous studies throughout New Zealand and overseas, the differential use of habitats by stoats, ferrets, and cats has been correlated strongly with the abundance of their main prey. (Erlinge, 1977; Pierce, 1987; Pascoe, 1995). Erlinge (1977) found in Sweden that stoats preferred areas with higher prey density. In both the Mackenzie Basin and on Boulder Beach, cats and ferrets occur more often in areas with high rabbit abundance (Pierce, 1987; Pascoe, 1995). However, these predator-prey relationships appear weaker in stoats on the peninsula. Similar studies could not confirm a correlation between stoat distribution with rabbit or mouse abundance, only the correlation between stoats using long grass (Alterio, 1994, King et al., 1996). Similarly, ZIP's research on the West Coast has been unable to show that habitat use by stoats is related to rat density, despite much of Elaine Murphy's research showing that 90% of stoats have rats in their diet (pers. comms Tom Agnew). This may be a result of the more varied diet of stoats and evidence of their hunting ability. This may imply that targeting prey of stoats as a means of suppressing stoats would require targeting multiple prey items rather than just rabbits or mice. Targeting the prey of ferrets through the suppression of rabbits may, however, be more successful. The more limited distribution of ferrets, based on rabbit distribution, may also lend itself to a rolling front, remove-and-protect strategy for the eradication. This would increase the chances of eradicating ferrets in their entirety.

7.4 Rabbit Control

Risk of Prey Switching

Smith et al. (1995) studied the diet of ferrets in Otago and Southland, including the Otago Peninsula. Results from 277 live-trapped animals showed that lagomorphs constituted 77% of the diet by weight and were identified in the stomachs of 65% of the ferrets sampled. Other notable items were hedgehogs (*Erinaceus europeus*), possums (*Trichosurus vulpecula*), and birds. The same study suggested that reducing rabbit numbers could directly reduce the number of ferrets living in these areas but warned that decreased rabbit availability may instead induce a diet shift in ferrets. This response could increase predation on endemic species and could also increase consumption of hedgehogs and possums where available. Given that possums are largely removed from the peninsula, this leaves hedgehogs and birds as the most likely substitute prey for ferrets.

Similarly, Alterio (1994) found that rabbits were the staple prey of small mammalian carnivores living around South Island yellow-eyed penguin breeding areas, and that predation on rabbits increased with increasing predator size. Reduction of rabbit numbers would, therefore, have a greater effect on larger predators. Rabbit numbers also determined which predators were abundant near yellow-eyed penguin breeding areas. For example, stoats dominate in the southern-most yellow-eyed penguin breeding areas where rabbit abundance is lower, whereas cats and ferrets dominate in the northern-most breeding areas where rabbit abundance is higher (Bruce, 1991; Moller et al., 1995).

This is consistent with current trapping data on the peninsula. Trapping records from the previous two seasons at Penguin Place recorded a total of 59 ferrets and 138 feral cats caught in traps versus just 15 stoats. Penguin Place was an area recently identified by the ORC as a hotspot for rabbits on the peninsula as well as being home to one of the larger yellow-eyed penguin breeding colonies on the peninsula.

Alterio (1994) suggested that the removal of rabbits may trigger the replacement of ferrets and cats by stoats in grassland habitats on the peninsula. This was partially based on Pierce (1987) observing that stoats increased after ferret and cat numbers declined following a rabbit poisoning operation in the MacKenzie Basin. Alterio (1994) also suggested that the removal of rabbits may change mustelid hunting behaviour by encouraging more diurnal hunting activity.

Diurnal activity from predators may have implications on seabird colonies. For example, adult yellow-eyed penguins leave their chicks unguarded during the day in early summer (Darby and Seddon, 1990), making them particularly vulnerable to stoat predation. Conversely, adult birds are vulnerable to attack while roosting or guarding young. For example, many adult sooty shearwaters are killed at night on the South Island mainland when returning to breeding burrows (Hamilton & Moller, 1995).

Research on braided river systems found that the single biggest predictor of clutch predation was the decline of local rabbit populations from either disease or poisoning (Pascoe, 1995). Pascoe's (1995) study suggested this relationship was maintained over time. After poisoning rabbits, the increase in clutch predation did not carry into the next season, as presumably the rabbit population was able to grow again the following season. Rabbit disease, on the other hand, is known to lower rabbit populations for successive seasons relative to one-off poisoning events and so when disease lowered the rabbit population, clutch predation rate remained high in subsequent seasons.

It is, therefore, difficult to predict whether a reduction in rabbit numbers would be of net benefit or harm to threatened wildlife species. In rabbit prone areas, such as the Otago Peninsula, the predator-prey relationship is interwoven with issues of management of land and vegetation. It is important to determine how ferrets and stoats are affected by rabbit-control operations and these dynamics should come under serious consideration when planning mustelid control. The mechanism by which predators influence each other's distribution can be tested only with a reversible selective removal experiment.

Feasibility of Rabbit Removal

The 2021 stoat eradication plan places a heavy reliance on the sudden reduction in rabbit numbers, and so the feasibility of the rabbit reduction part of the project must be considered carefully. Like other mammal eradications, rabbit removal has been best achieved on small offshore islands with widespread use of brodifacoum. However, brodifacoum is not legally registered for rabbit control, and is unlikely to be aerially or hand laid on a mainland site like the peninsula. Instead, rabbit control in Otago, usually begins with a toxin operation using baited carrot including Pindone or 1080.

While 1080 is more toxic than pindone, it breaks down faster in the environment, therefore quick uptake from rabbits is essential. Additionally, rabbits die very quickly (within a few hours) and so rabbits must be primed to consume the bait quickly by distributing at least two rounds of pre-feed. The effect of Pindone on rabbits is more gradual, therefore rabbits do not tend to feel the effects of the toxin while consuming the bait and can eat more of it. While this ensures that the rabbit consumes plenty of toxin, it also means that a lot of the bait is consumed by just some individuals.

Best practice for Pindone no longer involves pre-feeding, and instead involves three rounds of toxic bait to ensure multiple individuals are targeted through staged events. Although under ideal conditions you might expect a 90% kill rate with pindone, it is unlikely ideal conditions exist on the peninsula. With 1080, however, 90% would be the minimum kill rate expected. For a lasting reduction of rabbits on the peninsula the process of hand laid toxin carrots will require access and cooperation from landowners peninsula-wide. It will also require each landowner to be able to accommodate toxin being laid on their property for successive years, and to plan to stop reintroduction of rabbits onto their property in the future.

Given the number of different landowners, the extent of public access, the proximity to Dunedin city centre, and the presence of stock and wildlife, it is reasonable to assume that Pindone would be the only acceptable toxin for widespread use on the peninsula. Even so, this would require very careful management, relocation of stock and possibly temporary exclusion of public access from certain areas, and participation from >85-90% of landowners. Coordinating all members of the diverse community (e.g., private landowners, Māori-owned land, conservation trust-owned land) will be very challenging.

The operation would also require minimum lag time between properties to avoid rabbits migrating into previously treated areas. Several contractors would be required to coordinate their efforts and perform at least three feeds peninsula wide. These feeds would also need to be timed during periods of dry weather as during a mild winter rabbits would not be hungry enough to uptake the bait.

The chance of undertaking a successful toxin operation across Otago Peninsula in a single season is, therefore, unlikely. Even if it was possible, the benefits would be short-lived without effective, ongoing, and consistent secondary control work to address the remaining 10% of rabbits. The most successful rabbit control method would likely be to target problematic areas within defendable boundaries and gradually expand throughout the peninsula. However, this method would take many years to result in peninsula-wide control.

The process could be sped up if landowners took more responsibility to control rabbits on their own property rather than the entire project being carried out by contractors. OPBG are hoping to source funding from the ORC to go towards peninsula landowners acquiring a license for using Pindone. This would make rabbit control cheaper and more accessible for landowners.

Following considerable effort by ORC over a 2-year period through the Community-led Rabbit Management Programme, and the looming prospect of compliance action, only half of the 37 non-compliant properties (under the rules in the RPMP) that were approached undertook successful rabbit control. A commonly cited reason for non-compliance is the knowledge that the control will not last if others are not also participating, highlighting the importance of well-led community coordination and greater accessibility for cheaper rabbit control.

Additionally, while enforcement of ORC's RPMP rules could be used to encourage reluctant landowners to participate, the minimum that ORC can ask for is for landowners to maintain rabbit densities at MMS Level 3 or below. While this is a reduction in rabbit numbers for many, it is far from eradication. It is unknown what MMS level might induce considerable change in mustelid foraging behaviour.

Finally, as the climate changes, cold, dry winters may become less frequent on the peninsula. Cold and dry winters make pasture less productive and alternative food sources such as bait more attractive to rabbits. In the presence of mild, wet winters, summer baiting during hotter, drier summers may be necessary. However, because of the risk of prey switching, reducing rabbits during summer may place seabird colonies in more risk if mustelids become hungrier during the breeding season.

To establish an evidence-based plan for mustelid eradication, a trial to monitor rabbits, mustelids, and potentially seabird numbers should be delivered before, during, and after targeted rabbit control. See Section 8.5 below for more details on a proposed trial.

7.5 Cultural Gains

Te Rūnaka o Ōtākou have a large presence on the peninsula and best efforts should be made to work with them in any venture. Rūnaka representative Hoani Langsbury has mentioned the introduction of weka to the Otago Peninsula is of interest to iwi. Weka are of particular significance to some iwi and were traditionally used as a source of food, perfume, oil to treat inflammations, feathers in clothing, and as lures to catch dogs (Beattie 1995). They were, therefore, considered to be an important resource to be managed sustainably.

Unfortunately, early European explorers and settlers also used weka as a resource and the combined pressures of an additional harvest, as well as the significant impact from predation of invasive species, led to a dramatic decline in weka populations. Weka are now a protected species on the mainland, but the provision of a cultural harvest of weka still exists on the Chatham Islands.

Sustainable cultural harvest was integral to mahinga kai. Unfortunately, the decline in resources (including weka) on mainland New Zealand has inhibited the practice. Re-establishing this tradition is of interest to some iwi and many are interested in restoration projects which enable populations to grow to a level where sustainable harvest could be managed. Te Rūnaka o Ōtākou may, therefore, want to engage in a mustelid eradication if it enables the re-introduction of weka, whether that be for cultural harvest or not.

While both mustelid species predate on weka, ferrets are a particularly large threat. Ferret and weka distributions have strong inverse relationships throughout the South Island and it has therefore been suggested that ferrets are responsible for the local extinction of the buff weka (*Gallirallus australis hectori)* in some regions (King 2017e, Watts et al., 2016). Ferret eradication would likely be essential to weka establishing on the Otago Peninsula.

Of the mustelid species, ferrets are also identified as a particularly large threat to tītī (potentially a greater threat than stoats) (Hamilton, 1993). Tītī are also a significant species in the traditions of cultural harvest for Māori (Gaze & Smith, 2009), and their population growth on the Otago Peninsula through the removal of ferrets may also be of particular interest to the Ōtākou Rūnaka.

7.6 Benefits: Key Points

- There is evidence to suggest that ferrets and stoats are somewhat spatially and temporarily segregated on the peninsula. Understanding whether this is due to rabbit density, interactions with cats, or interactions with each other is important in predicting the effects of eradicating just one mustelid species.

- Understanding how mustelids will respond to reductions in rabbit numbers is important to understanding if they become more of a threat to native wildlife, and/or more trapable.

- Gaining support and collaboration from the community must be a priority for successful, peninsula-wide rabbit and mustelid reduction.

8. Discussion and Recommendations

8.1 Stoats

The 2021 stoat eradication plan was designed to eradicate stoats using minimal toxins (with the exception of the toxins required for the rabbit control component) and followed guidelines for small island eradications that gained success through trapping. Due to delays in the possum eradication programme on the peninsula, the stoat eradication programme was put on hold.

Similar projects (in size and resident human population) such as Te Korowai o Waiheke and Capital Kiwi have also begun their own eradication projects. Results from these projects indicate that with the current tools available for trap-based eradications, and without some other means to change the behaviour of target species (such as reducing their prey items), suppression is the best that can be achieved in a five-year time frame. A mustelid eradication programme on the Otago Peninsula would need compelling points of difference to be successful in under five years via a trapping-based plan.

Currently, there is evidence to suggest the coastal barrier around the peninsula will not keep stoats out, but it may slow down re-invasion. Best efforts should go towards understanding the invasion risk to the peninsula through from the coast and base of the peninsula. Genetic analysis is currently the best-known method for understanding mustelid migration in an area. Collecting genetic samples (an ear) from trapped individuals on the peninsula and surrounding areas should be a priority for current planning. Studying mustelid migration on the peninsula will be essential to understanding the effect of the potential natural barriers and their likelihood of stopping re-invasion.

The removal of rabbits to suppress stoats and increase trapability could also be a worthwhile point of difference to the project. A peninsula-wide knock-down in rabbit numbers in a single season does not currently look feasible, and it is also unknown whether a longer-term reduction in rabbit numbers would increase the trapability of a stoat to an extent that makes eradication by trapping plausible. The risk of prey switching in the peninsula context is also not fully understood. Gaining a better understanding of these factors will be key to any stoat eradication proposal for the peninsula.

It is known that widespread use of toxins would significantly improve the likelihood of eradication of stoats. However, significant education and coordination would be required to allow widespread use of those toxins on the peninsula. Increasing the understanding and the scope of where toxin can be used on the peninsula is a critical element to improving the credibility of a stoat eradication plan.

8.2 Ferrets

It is unknown if current trapping tools result in eradication of ferrets. Ferrets have never established populations on islands, and therefore the only ferret eradications undertaken in New Zealand have been within fenced sanctuaries via secondary poisoning with aerially distributed anticoagulants (Veale et al unpublished). It is perceived that the feral semi-domesticated ferrets may be easier to eradicate than stoats because they have higher habitat specialisation, lower dispersal abilities, and probably exhibit less trap aversion. On the Otago Peninsula there is an opportunity to test this and potentially achieve trap-based ferret eradication for the first time in New Zealand.

It is also unknown if rabbit control will be essential to ferret eradication, but it appears to be a significant factor based on the high proportion of rabbits in their diet compared to that of stoats.

The sensitivity analysis highlighted how monitoring techniques can drive the costs of a ferret eradication. It is, therefore, useful to understand more about ferret distribution and movements on the Otago Peninsula, particularly in respect to an eradication. Due to the focus on stoat eradications, there is still a paucity of critical research on ferret behaviour, movement, and control in respect to designing a targeted eradication (Veale et al. Unpublished). Ferrets may use the landscape in a way that makes stoat trapping network designs less effective for them.

8.3 Community Support

According to the Te Korowai o Waiheke and Capital Kiwi projects, strong community backing is essential to an eradication programme. Currently, support for mustelid control is far from unanimous on the peninsula, particularly among some of the larger landowners. Instead, these landowners would rather see rabbits as the focus on pest removal efforts, and some have even indicated that rabbit numbers are the reason why they are averse to mustelid control. Combining rabbit control with mustelid control work may foster community support.

8.4 Biodiversity Gains

It is known that removing stoats will provide significant biodiversity gains compared to ferrets. In contrast, it is not known whether removing ferrets will only provide marginal returns if stoats still persist. Understanding this predator-predator dynamic will help us understand if eradicating both species is essential to improving biodiversity.

Table 5: A summary of key features of an eradication programme, the peninsula context, and recommended tasks

Species	Key Eradication Feature	Predicted Effectiveness on the Otago Peninsula	Recommended Tasks
Stoats	Natural Barriers	Insufficient	Modelling, genetic sampling
	Buffers	Insufficient	Expansion into Halo + City Sanctuary
	Biodiversity Gains	Substantial	
	Support from community Need for Toxins	Insufficient Substantial	Education + Rabbit control Landowner acceptance
Ferrets	Natural Barriers	Potentially sufficient	Modelling, genetic sampling
	Buffers	Potentially sufficient	Modelling, genetic sampling
	Biodiversity Gains	Unknown	Study mesopredator dynamics
	Support from community	Insufficient	Education + Rabbit control
	Need for toxin	Unknown	Landowner acceptance + and trial eradication

8.5 Recommendation: Sector 2 Eradication Trial

To inform mustelid eradication on the Otago Peninsula in the future, there are three key features of mustelid behaviour that need to be determined for this area:

1) Mustelid distribution/movement on the peninsula;

2) The effect of a knock-down in rabbit numbers on mustelids; and

3) Whether a knock-down in rabbit numbers increases mustelid trapability and/or prey switching.

Sector 2 is currently being targeted as the initial zone for more widespread rabbit control by the ORC and OPBG coordinators. It is recommended that rabbit control is carried out in a staged approach with well-designed rabbit fencing to ensure dependability. OPBG are currently planning the installation of significant rabbit fencing in Sector 2 to enable this work. They will start by fencing off the tip of the peninsula, before working further down Sector 2.

Changes in mustelid abundance and distribution should be studied before, during, and after rabbit control in these areas. This could be done through tracking tunnel and camera indices, but it would be more reliable if individuals could be ear tagged and studied through mark-recapture data or by attaching GPS collars to track movements directly. For a robust study, the sample size and site area must be sufficient. According to trapping records from the 20/21 and 21/22 seasons, Penguin Place caught ~30 ferrets over a summer season, mainly in cages. This would provide an excellent sample size for mark-recapture data. On the Otago Peninsula, Dymond (1991) found the home range of a male ferret to be 107 ha. The study site must allow for multiple home ranges within it.

Indices must be measured before rabbit control begins to gain baseline data. Due to the staged approach of rabbit control, there should be sufficient opportunity to gain baseline data at least a season ahead of where rabbit control efforts are next focused.

During this period, genetic samples of mustelids should also be collected at every opportunity from the peninsula and surrounding areas within the Predator Free Dunedin footprint. 100 samples of each species are needed for a robust and informative analysis on mustelid distributions and migrations (Veale pers.comms).

Sector 2 has also been identified by OPBG as the joint most valuable asset of biodiversity on the peninsula (Dale, 2021). It is home to the majority of the peninsula's yellow-eyed penguin, little blue penguin, and sooty-shearwater colonies. It also features the only mainland colony of greater albatross in the world. The effects of rabbit control on these species should also be monitored if possible. Not only will this data serve as important information for the understanding of the mustelid species and their predation on seabirds, but this data should also be observed in case intervention is required to further protect the species in the event of prey switch of mustelids from rabbits to seabirds.

Finally, this scenario should also be used as an exercise to increase community engagement with mustelid eradication. The community involvement will be influential in a successful mustelid eradication, and they will hopefully be enthused by a rabbit control program. Spotlight monitoring for rabbits (preferably using thermal imaging gear where available), reporting of mustelid sightings, and eventually mustelid control via trapping or toxin use could all be encouraged and used to foster community engagement with the programme.

8.6 Final Recommendations

- Eradication is technically challenging. Changing the game by adopting a new approach (such as removal of prey species), could help, but this also adds to the complexity and cost of project;

- Reinvasion of stoats is highly likely to occur unless the Halo Project buffer is expanded to become more efficient, and a buffer added to the city area. Even then reinvasion could occur, and past experience shows it takes considerable time and effort to respond to an invasion event;

- Investment in research is needed to find monitoring tools that improve in both the detection of survivors and provide opportunities for project teams to respond immediately to sightings;

- Investment is needed in fostering community support. It is essential to the project, especially if it enables toxin use, comprehensive project area access and a community reporting tool;

- Timelines for eradication should be viewed with caution;

- Detection dogs are best if easily available and used to target specific areas for proof of presence instead of being used to confirm absence;

- There is evidence to suggest that ferrets and stoats are somewhat spatially and temporarily segregated on the peninsula. Understanding whether this is due to rabbit density, interactions with cats, or interactions with each other is important in predicting the effects of eradicating just one mustelid species;

- Understanding how mustelids will react to reductions in rabbit populations and whether they become more trapable and/or more of a threat to native wildlife through prey switching needs to be better understood;

- Current reinvasion rate should be better understood before commencing an eradication project. Collecting samples of mustelids from the peninsula and surrounding Predator Free Dunedin project areas should be prioritised as an informative action.

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Appendix 1 - WORKINGS OF THE INPUTS

Trap Purchase Cost

Tunnel X trap number + trap x trap number

((Density/area)*tunnel cost)+((Density/area)*trap cost)

Trap Set-up Cost

Cost of set X trap number

((Hourly rate*time to set up)*(density/area))

Trap Baiting Cost

Cost of Baiting X Trap number X Years of project

(((Hourly rate*time to bait)+bait cost per trap)*(density*area*number of checks)))<- check how many after 'hit'

Monitoring Purchase Cost

Low

Tunnel X tunnel number

((Density/area)*tunnel cost)

High

Camera + ZIP lure X cam number

((Density/area)*tunnel cost)

Monitoring Set-up Cost

Low

Cost of tunnel set-upt X location number

((Hourly rate*time to set up)*(density/area))

High

Cost of Cam set-upt X location number

((Hourly rate*time to set up)*(density/area))

Monitoring Baiting Cost

Annual check cost X Years of project

(((area*annual per hectare check cost))* years of project)

Targeting Survivors

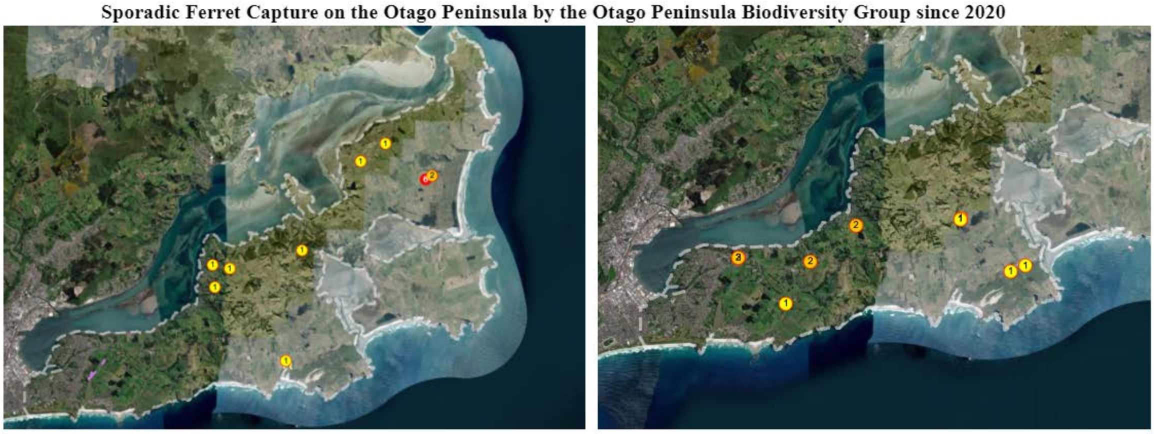
Annual per hectare rate X treatment area X project years - proof of eradication years

Per hectare rate* treatment area*(project years - 2)

Stoat and Ferret Captures on the Peninsula by the Otago Peninsula Biodiversity Group. Captures by the operational group (left and community group (right)

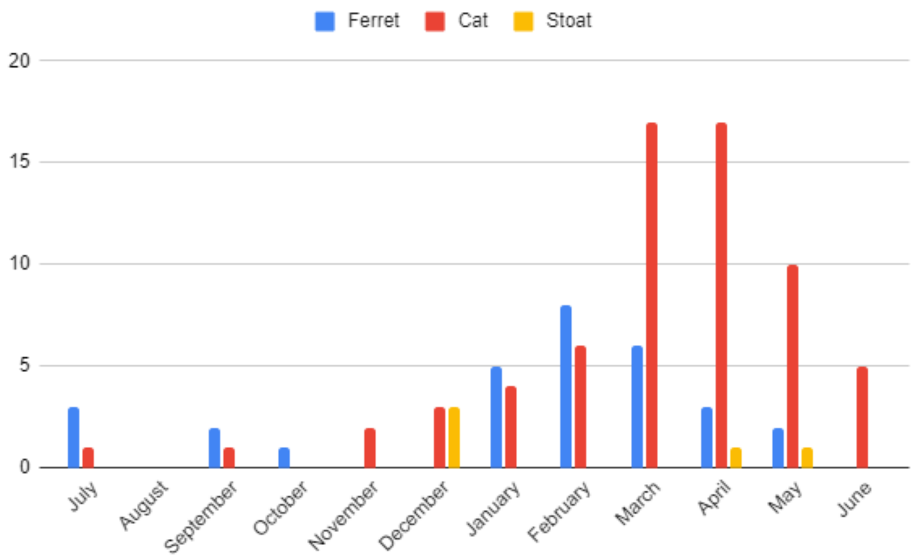
Sporadic Stoat Capture on the Otago Peninsula by the Otago Peninsula Biodiversity Group since 2020

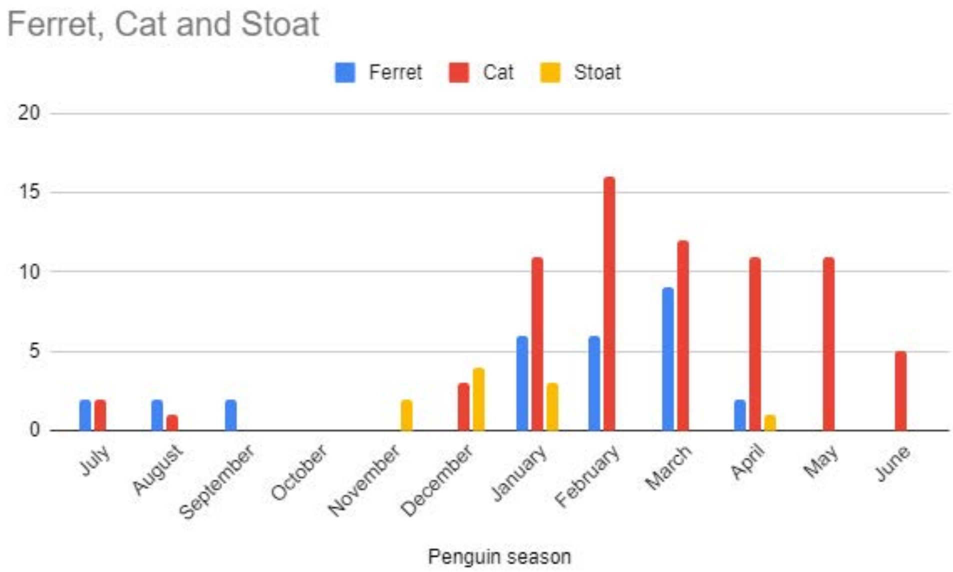
Sporadic Ferret Capture on the Otago Peninsula by the Otago Peninsula Biodiversity Group since 2020



Stoat Capture on the at Lawyers Head red-billed gull colony by Forest & Bird since 2015

Ferret, Stoat and Feral Cat Captures at Penguin Place during the 2020 (a) and 2021 seasons (b)





Mustelid Captures from the Yellow-eyed Penguin Trust since 2017

	Stoat	Ferret	Weasel
Otapahi	74	14	0
Okia	51	112	3
Otekiho	9	3	1