Predator Free South Westland Impact Report

Actions, results, and native plant and bird outcomes of predator elimination in Te Tai Poutini South Westland

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ZERO INVASIVE PREDATORS
Enabling a new future

PREDATOR FREE SOUTH WESTLAND

Photo on cover page: Chad Cottle

Photos on this page: Chad Cottle (top), and unknown (bottom).

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Photo: A ZIP ranger alongside a tarn in the Butler Range, Chad Cottle.

Summary

In March 2021, the Predator Free South Westland (PFSW) project was launched by the then Minister of Conservation, with the ambitious goal to, by 2025, eliminate brushtail possums[1] (*Trichosurus vulpecula*), ship rats (*Rattus rattus*) and stoats (*Mustela erminea*) from the project area of 107,000 hectares.

The project is a partnership between the Department of Conservation (DOC), and the NEXT Foundation, with the support of the tangata whenua of South Westland, Te Rūnanga o Makaawhio. Funding has also been provided by Predator Free 2050 Limited, Jasmine Social Investments, and OSPRI. The PFSW project is governed by the Board of Predator Free South Westland Ltd (PFSW Ltd), and implemented by Zero Invasive Predators Ltd (ZIP); both PFSW Ltd and ZIP are not-for-profit companies.

'Elimination' will be achieved when possums, ship rats and stoats are largely absent from the area and any that incur into the area are detected and removed before they establish and spread across their potential habitat. In general, *core zones* within the project area are almost always

[1] Referred to throughout as 'possums'

maintained as predator-free, while surrounding *buffer zones* are subject to the sporadic presence of predators as a result of incursion.

This report describes the *actions* that the PFSW project has taken to eliminate possums, ship rats and stoats from the project area, the *results* of the actions, and some of the *native plant and animal outcomes* of the project through to June 2024.

Photo: Whio at the Perth River, Naomi Aporo.

Actions

ZIP's broad approach to eliminating predators from the PFSW project area has four steps (refer Figure 3, p. 17):

- Select a highly defendable boundary of the project area and determine the sequence of internal management 'blocks'
- Establish a surveillance network to detect predators
- Remove predators from across an entire management block
- Prevent predators from re-establishing in the management block

These steps are underpinned by ongoing community engagement and consultation. The sequence is then repeated in the adjacent management block (until the full project area is complete).

The boundary of the project area is defined by big, fast-flowing rivers, alpine mountain ranges, and the ocean, because these natural barriers slow incursion by possums, ship rats and stoats. The project area is divided into seven blocks of land that comprise similar vegetation and landform types and require similar tools and techniques to eliminate predators. Block boundaries are modified to reflect new knowledge, and workflow risks and benefits.

The core of the surveillance system is a network of cameras. As at June 2024, the network comprised 914 Browning trail cameras that are serviced manually (to recover the images), and 216 ‘ZIP cameras’ that automatically transmit the images that they take. Possum and rat detection dogs, along with traps, are also used as part of the detection system. The utility of environmental DNA (eDNA) to detect predators is currently being investigated.

In areas of extensive natural vegetation cover, the initial step to remove predators from across an entire block is to apply the ‘1080 to Zero’ technique. The technique has two phases, each of which comprises two applications of non-toxic pre-feed bait followed by one application of toxic bait. As at June 2024, the 1080 to Zero technique has been applied over five of the seven blocks. Almost all of the 1080 bait was applied by helicopter, over approximately 74,000 hectares. 1080 cereal bait was also applied by drone (126 hectares), by hand (258 hectares), or in bait stations (65 hectares), on farmland, along roads, or along sensitive boundaries. Brodifacoum bait, targeting ship rats only, was also used in bait stations over approximately 2,000 hectares, mostly along forest edges that could not be aerially sown with 1080 bait. Following the 1080 to Zero treatment, smaller-scale follow-up aerial 1080 operations, bait stations, traps and hunting, are used to remove survivors and animals that incur into the treated blocks. Stoats are removed through secondary poisoning by their consumption of toxic rodent carcasses (that is, carcasses of rodents that had either consumed 1080 bait or been laced with 1080 in liquid form).

On farmland and townships, ground-based techniques are used to remove predators. Possums are removed using: cage traps (approximately 200); cyanide (in the form of paste or strikers); and hunting with a possum dog. Recently, thermal drones in conjunction with a possum dog have been trialled to detect and remove possums. Ship rats are removed using bait stations (approximately 6,000 at the peak of the elimination effort)[2], and traps (1,115 ZIPinn traps and 128 DOC200 traps), which are also used as part of the surveillance system. Stoats are removed using traps, and through secondary poisoning by their consumption of toxic rodents.

When the surveillance system indicates that all of the original inhabitants of the block are likely to have been removed, then the focus of the work moves to prevent predators from re-establishing in the block. The transition from the removal to the prevention step usually occurs about nine to twelve months after the 1080 to Zero treatment is completed, and is driven mostly by ship rats. Ship rats have been the most difficult of the three species to eliminate, with their ability to reproduce quickly in areas of

[2] Most bait stations are baited with brodifacoum, although pindone and 1080 have also been used in small areas.

available food abundance. Modelling the growth of an emerging ship rat population, with assumptions made around residual rat density, litter size, dispersal movement, and detectability suggests nine months of continuous detection effort provides > 95% confidence that an emerging rat population would be detected.

Results

As of June 2024, the elimination status of the combined Perth-Barlow, Whataroa-Butler, South Ōkārito and Burster blocks[3] is:

- 83% of the total catchment area of the three blocks are free of possums, ship rats and stoats (that is, 58,536 of 70,433 hectares)
- 78% of available habitat for possums, ship rats and stoats are free of all three species (that is, 43,405 of 55,303 hectares)
    - 95% of the potential habitat for possums is free of possums (that is, 52,716 of 55,303 hectares)
    - 80% of the potential habitat of ship rats is free of ship rats (that is, 32,079 of 39,995 hectares)
    - 92% of the potential habitat for stoats is free of stoats (that is, 50,685 of 55,303 hectares).

ZIP is developing a new method for measuring the elimination status of a block. The method (described currently as eliminated *core* and incursion management *buffer zones*) is currently being tested by a collaborative group of experts in the predator suppression, eradication, and elimination fields; using the Perth-Barlow block as a case study. The Perth-Barlow block has the longest history of predator elimination management in PFSW, with now five years of ongoing detection and response work. Detections in the core have become very infrequent (primarily within the vicinity of a hut), while the detections in the buffer zone are now relatively constant, at approximately one ship rat detected per month. The depth of buffer zones (1.5 km deep) managed for incursion are currently most appropriate for ship rats and possums, with stoats evaluated alongside. However, stoats likely require much larger buffer zones (in the order of ~5km) in order to encompass most roaming individuals; so targeted methods for stoat 'mop up' are expected to be used throughout the managed blocks until the scale of the predator elimination work is increased.

[3] The initial 1080 to Zero operation has been completed in the Price block as of June 2024, but we allow 12 months post-operation to build confidence in the absence of detections and/or undertake mop-up of any remaining survivors before we can confirm the resident populations have been removed. Hence, the results for the Price block are not included in this report.

As discussed, this method is still in the development process. However, a breakdown of the elimination status in core vs buffer zones across all managed sites is as follows:

- 96% of the potential habitat for possums in the core zone is free of possums (that is, 46,718 of 48,535 hectares)
- 85% of the potential habitat for ship rats in the core zone is free of ship rats (that is, 28,649 of 33,719 hectares)
- 91% of the potential habitat for stoats in the core zone is free of stoats (that is, 44,265 of 48,535 hectares)

Photo: Perth River, Chad Cottle.

Outcomes

Owing to the reasonable level of uncertainty at the inception of the PFSW project about whether the goal to eliminate predators was achievable, the work has focussed on the actions required to achieve the elimination result, including work to develop the required new knowledge, tools and techniques. The project has not set any specific outcome targets; that is, desired changes in the natural heritage of the project area (Department of Conservation, 1999).

Despite that, a range of sources indicate that the PFSW project is likely to be benefitting the natural heritage assets of the project area. The sources include: detections of native birds on trail cameras, the Kea Survey Tool, and observations by ZIP field rangers, locals, and other people. That said, informal observations do not provide the same degree of certainty as a carefully-designed research project to measure the outcomes.

The most conspicuous outcomes observed to date for native plant and bird species are summarised below.

Table 1. Native plant and bird outcomes observed in PFSW Project (as of June 2024)

Native species	Detection/observation
Kiekie (Freycinetia baueriana subsp. banksia)	Have been seen fruiting and flowering around Ōkārito township for the first time in living memory
Miro (Pectinopitys ferruginea), **Supplejack (Ripogonum scandens)**	Uneaten berries are now seen on the ground in forests, especially along river terraces and flats
Rimu (Dacrydium cupressinum), **Kāmahi (Weinmannia racemosa)**	Regrowth of seedlings observed in the South Ōkārito block after predator removal.
Kākāriki / yellow-crowned parakeet (Cyanoramphus auriceps)	Kākāriki sightings and kākāriki flock sizes observed by the ZIP team have increased since predator removal in 2022/2023. Prior to 2022, kākāriki were observed in the forest canopy; since then, our trail camera network has regularly recorded them on the ground.
Kea (Nestor notabilis)	Percentage of trail and ZIP cameras detecting kea increased between 2022 and 2023. Kea sightings and kea flock sizes have increased since 2018.
Korimako / bellbird (Anthornis melanura) **Pīwakawaka / fantail (Rhipidura fuliginosa)** **Kakaruwai / South Island robin (Petroica australis)** **Ngirungiru / tomtit (Petroica macrocephala)**	Percentage of camera network detecting these four species indicate that summer peaks in detections are larger following 1080 to Zero operations.
Rowi / Ōkārito brown kiwi (Apteryx rowi)	As at June 2024, only one of the recent breeding season chicks have died due to stoat predation in the South Ōkārito block, which is likely to be due to a combination of the results of targeted aerial 1080 'spot' treatments, ZIPinn traps, and the deployment of toxic rodents.
Matuku-hūrepo / bittern (Botaurus poiciloptilus) **Kotoreke / marsh crake (Zapornia pusilla)** **Pūweto / spotless crake (Zapornia tabuensis)** **Mātā / fernbird (Poodytes punctatus)**	These species were not observed on camera or by ZIP field staff prior to aerial predator removal operation in the South Ōkārito block, but have been seen relatively frequently since then.
Whio / blue duck (Hymenolaimus malacorhynchos)	Counts taken before 2019 operation showed 6 pairs of whio in the Perth-Barlow block, and similar numbers were recorded immediately after the 1080 to Zero operation (albeit in slightly different locations on the river). Whio have been observed in Perth River since 2019, with groups of ducklings seen most years. 12 individuals have been reintroduced to the upper Perth and Whataroa catchments in 2024
Pīwauwau / rock wren (Xenicus gilviventris)	Counts of pīwauwau taken in 2019 before the Perth Barlow operation showed 47 individuals in the Abel Lake area (upper Perth Valley), and 29 individuals in Prospectors Creek (Barlow River tributary) Counts taken using different methodology in January 2024 in a smaller portion of the upper Perth Valley found > 30 birds; meaning numbers appear to have remained stable for this area A pīwauwau was reported on Ōkārito beach from February-April 2023.

Benefits and Significance

To date, the PFSW project has delivered four main benefits:

1. Demonstrated that a predator-free state is achievable at the landscape scale on the mainland of Aotearoa New Zealand
2. Enhanced the ability for nature to thrive in the project area, and provided opportunity to reintroduce species that were formerly present
3. Developed new tools and techniques that can be used for a wide range of conservation management purposes (i.e. not just to eliminate predators)
4. Identified the critical factors that underpin a successful landscape scale elimination project.

While the PFSW project has made significant progress towards the elimination goal over a period of approximately five years, there's still a lot to learn, and additional new tools and techniques will need to be developed.

Final Comments

The PFSW project and its elimination goal are scheduled to be completed by the end of 2025. Before then, the major challenges will be to maintain the elimination gains in the Perth-Barlow, Whataroa-Butler, South Ōkārito, and Burster blocks, and to eliminate predators from the Price, North Ōkārito and Whataroa Farmland blocks. There is still a lot to do!

Looking to the future in Te Tai Poutini South Westland, proposals are being investigated to extend the PFSW boundary into adjacent areas. Doing so will help increase the size of the predator-free core zone and reduce the ratio of length of the boundary vulnerable to predator incursion relative to the size of the total area. In turn, this should reduce the associated cost of preventing reinvasion.

Photo: Rainforest near Teichelmann Hut, Chad Cottle.

Introduction and Purpose

The goal of the Predator Free South Westland (PFSW) project is, by 2025, to eliminate possums, ship rats and stoats[4] from an area of 107,000 hectares on Te Tai Poutini West Coast of Te Wai Pounamu South Island of Aotearoa New Zealand (Figure 1). Elimination will be achieved when possums, rats and stoats are no longer established in the area and any that incur into the area are prevented from re-establishing there.

This report describes the *actions* that the PFSW project has taken to eliminate possums, ship rats and stoats from the project area, the *results* of the actions, and some of the native plant and animal observations likely to be *outcomes* of the PFSW (and previous predator management) actions[5].

[4] That is, *Trichosurus vulpecula*, *Rattus rattus* and *Mustela erminea* respectively.

[5] The report does not cover other outcomes, such as the reduction in bovine Tuberculosis (TB) risk through elimination of possums, the potential to shift tourism focus in Franz Josef from an evaporating glacier to rebounding native birds, the business employment benefits of the project, and the contribution of the project to overall community well-being. It also does not cover in detail the costs of the predator elimination approach described, which will be the subject of a separate report.

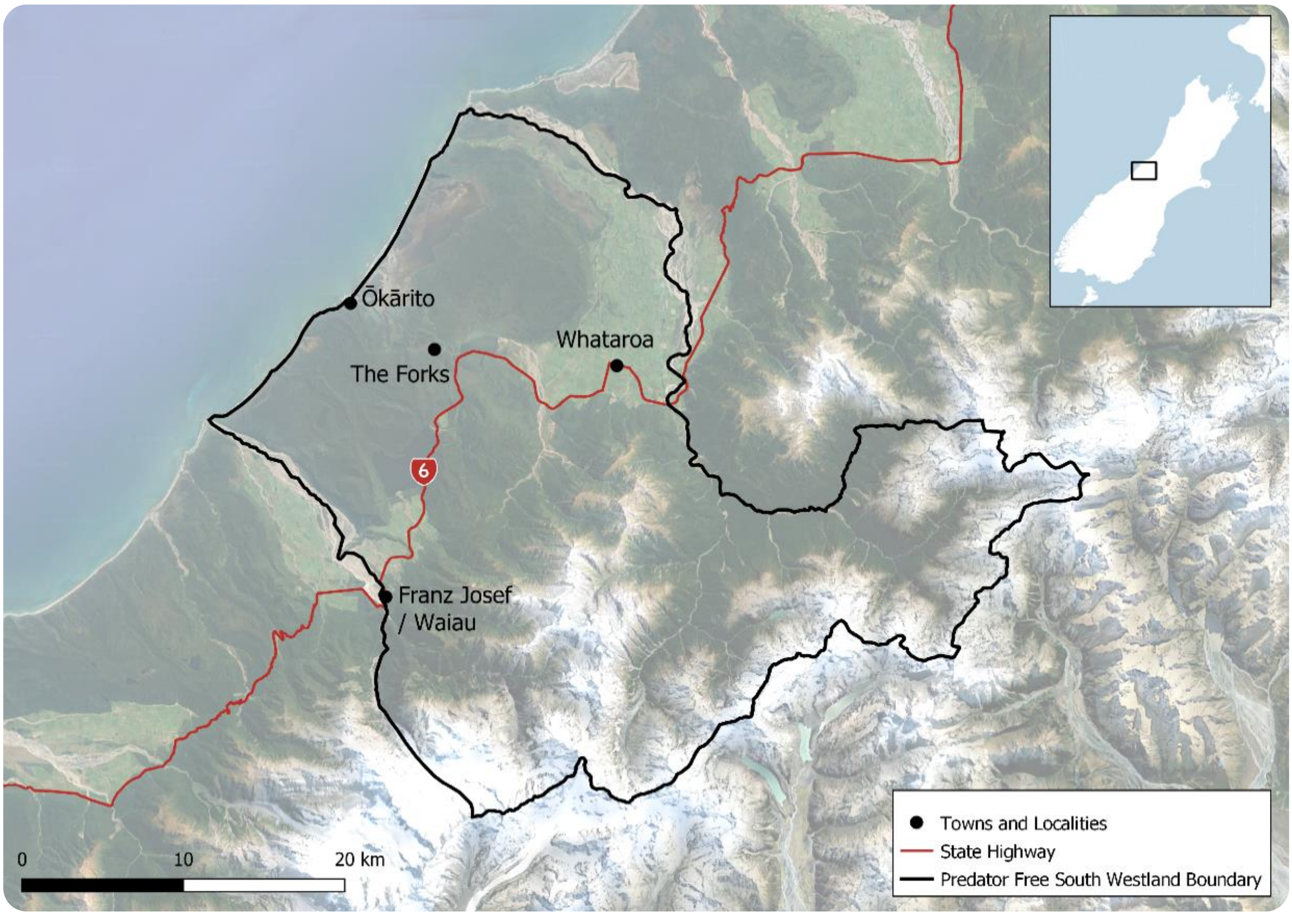

Figure 1 Location of the Predator Free South Westland Project

The report demonstrates, and celebrates, that a predator-free state is achievable at landscape scale on the mainland of Aotearoa New Zealand.

The purpose of the report is to provide a detailed summary of what the ZIP team has done, learned and achieved as we have wrestled with the elimination challenge here over the past five years. We welcome feedback from readers.

Photo: Regrowing rata, Chad Cottle.

Biodiversity Challenge

Worldwide, the decline of biodiversity is a massive environmental challenge. Aotearoa New Zealand has made international commitments to reverse this decline (such as by being a signatory to the Convention on Biological Diversity).

With the exception of two species of bats, New Zealand has no native land mammals. For 65 million years our plants, birds and other animals evolved in isolation, protected by the oceans from mammalian predators. In such remoteness diversity flourished, and many of our 80,000 native species are found nowhere else. However, these native species have also evolved with few defences against some of the mammals that arrived with human settlement (Parliamentary Commissioner for the Environment, 2013).

Today, New Zealand has one of the highest extinction rates in the world due largely to introduced pests, both plants and animals. Three animal pests are especially damaging – possums, rats[6] and stoats (Parliamentary Commissioner for the Environment, 2013)[7].

The omnivorous diets of possums and ship rats means that these species have pervasive and direct negative impacts on both flora and fauna,

[6] 'Rats' are actually three different species in New Zealand – ship rat, Norway rat, and kiore (pacific rat). Ship rats are the only rat species known to be present within the PFSW project area.

[7] While not a target of the PFSW project, mice (*Mus musculus*) are also significant predators to New Zealand's native animals (Samaniego et al., 2024). Appendix 1 describes some detections of mice in the PFSW project area.

especially birds (Parliamentary Commissioner for the Environment, 2011). Since the arrival of humans, Aotearoa New Zealand has lost 40-50% of its bird species, and over half of these extinctions have been the result of predation by introduced mammals (Fea et al., 2021).

Photo: Sunbeams on the Whataroa River, Chad Cottle.

New Zealand has led the world in the development of technologies to eradicate invasive mammals from our offshore islands (Murphy et al., 2019; Towns et al., 2003). Since the first success on 1 ha Maria Island in 1964, our skill and technology has grown from ground-based bait stations to aerial distribution of brodifacoum across islands as large as 11,000 ha Campbell Island (Towns et al., 2003). These islands are now considered to be some of the 'jewels' of the New Zealand conservation crown, and are the last refuge for a number of critically endangered species such as kākāpō (Lloyd and Powlesland, 1994). Some of these techniques have made their way to the mainland, aided by the advent of predator fencing (Murphy et al., 2019). However, their use to date has been limited by scale, cost, and regulation.

In remote, rugged and mostly forested areas of the mainland, the most extensive approach to managing these predators has been to *suppress* their numbers to low levels so they do less damage (Elliott and Kemp., 2016; O'Donnell et al., 2012). The only tool available to do this at large- or landscape-scales is the toxin sodium fluoroacetate (1080), applied using helicopters, sometimes supplemented by networks of traps. Possums and ship rats are removed through direct consumption of 1080 baits, while stoats are killed through secondary poisoning (Murphy et al., 1999; Nichols et al., 2021, 2022). Predator suppression is a critically important approach for relieving pressure on some native species.

The suppression approach recognises that individual predators may survive a 1080 operation (Nugent et al., 2019), and others will reincur into the treatment area (Carpenter et al., 2023). For example, ship rats can quickly repopulate a treated area that now has plenty of food and little competition for it (Carpenter et al., 2022). In order to maintain the benefits to native plants and animals, predators need to be supressed by a 1080 operation over the entire treatment area every few years. The financial cost of doing this constrains the scale at which this approach can be applied across Aotearoa New Zealand.

Ideally, to halt the decline in native plants and animals, and indeed enable them to thrive, possums, rats and stoats would be *eliminated* from mainland Aotearoa New Zealand. In 2016, the Government launched the ambitious mission to achieve a predator-free New Zealand by 2050. Predator Free South Westland is one of the projects that is demonstrating how we might be able to achieve this lofty goal.

PFSW Project Background and Area

Project background

The project is a partnership between the Department of Conservation (DOC), and the NEXT Foundation, with the support of the tangata whenua of South Westland, Te Rūnanga o Makaawhio. Additional support has also been provided by Predator Free 2050 Limited, Jasmine Social Investments, and OSPRI. The PFSW project is governed by the Board of a not-for-profit company, Predator Free South Westland Ltd (PFSW Ltd).

The project was formally launched in March 2021, with a plan to complete elimination of possums, ship rats, and stoats by the end of 2025. The PFSW Limited Board appointed Zero Invasive Predators (ZIP), another not-for-profit company[8], to plan and implement the programme of work to eliminate predators. ZIP had been working since 2018 to develop tools and techniques to eliminate predators in a 12,000 hectare block in the Perth River valley. The results of that work provided funders with the confidence to launch the PFSW project. Combined with the neighbouring Barlow valley, this original trial site became the first block in the PFSW project area, now referred to as the 'Perth-Barlow block'.

The elimination of the three predator species will help to restore the *mauri* (life force), *mana* (integrity) and *wairua* (spirit) of *te taiao* (the environment). The goal of the project does not encompass the reintroduction of species into the project area—although achieving the goal will create a habitat that significantly increases the potential value of the area for reintroducing species.

From 2026 onwards, the project is planned to enter a new phase to maintain the predator-free status of the project area.

As of June 2024, the ZIP team comprised 71 full- and part-time team members covering a broad range of skills and roles, including field and community rangers, scientists, developers, technical and support

[8] ZIP was established by DOC and the NEXT Foundation in 2015, to rapidly innovate the tools and techniques required to eliminate possums, ship rats and stoats from the mainland.

specialists and managers/directors, based in Wellington, Lincoln, Twizel, and South Westland.

Project area

The 107,000-hectare project area ranges from sea level to just over 3,000 metres above it. The large rivers flow in swiftly from the alps to the sea, forming braided riverbeds in their lower reaches.

Throughout, we describe the project area in terms of total catchment area (all landcover types including rock and ice), and the potential predator habitat (ship rats: all forested areas up to 1200 m above sea level; stoats and possums: all vegetated habitat up to 1800 m above sea level). The overall Predator Free NZ mission will include all of NZ (total catchment areas), thus it is important to show both measures for this work.

Land Cover

The land cover of the project area is shown in Figure 2 and summarised in Table 2.

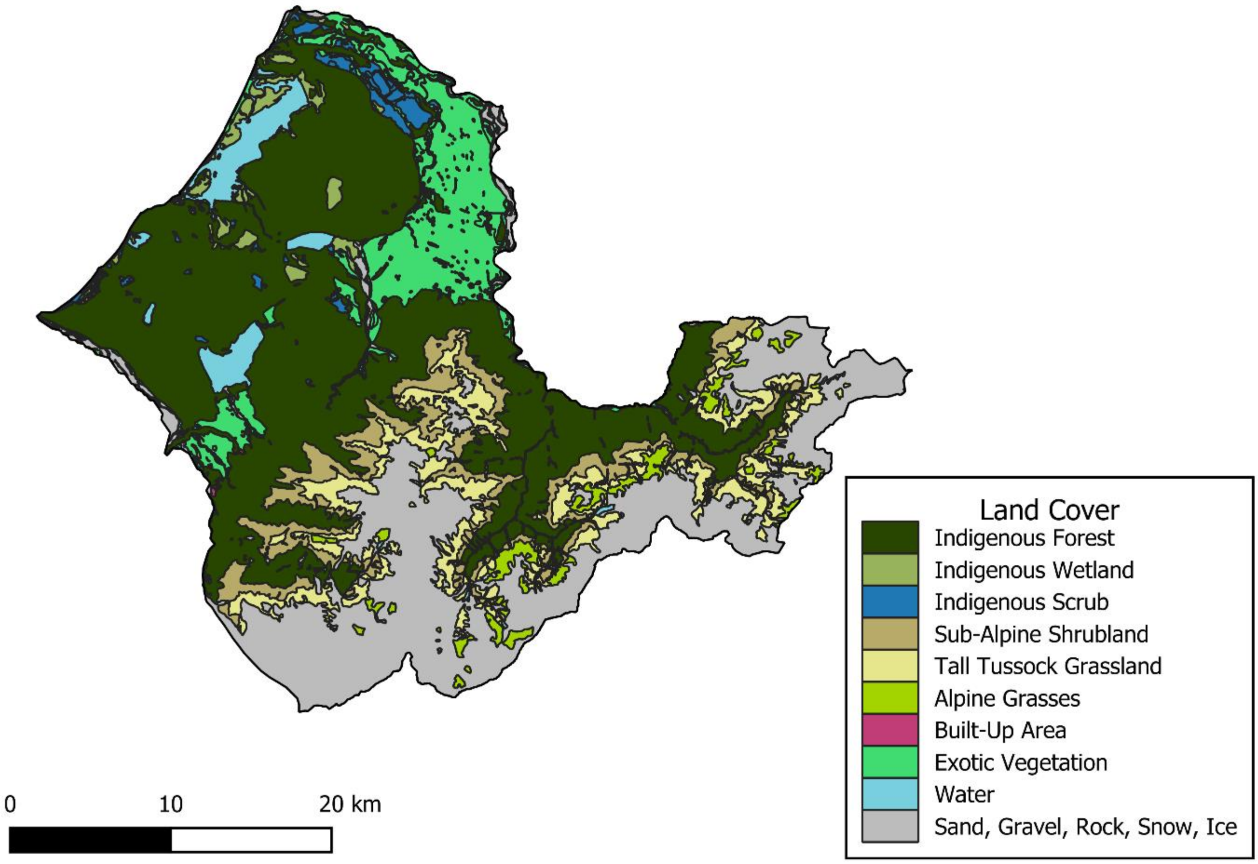

Figure 2 Land cover types in PFSW. The cover classes are derived from Manaaki Whenua – Landcare Research (November 2021). Refer to Appendix 2 for a description of the Land Cover Database (LCDB) land cover classes summarised in this figure.

Table 2 Land cover types in PFSW

Land Cover	Hectares	% of Project Area
Indigenous Forest	44,772	42
Sand, Gravel, Rock, Snow and Ice	25,401	24
Exotic Vegetation	10,474	10
Tall Tussock Grassland	8,572	8
Sub-Alpine Shrubland	8,063	8
Water	4,072	4
Alpine Grasses	2,382	2
Indigenous Wetland	1,895	2
Indigenous Scrub	1,582	1
Built Up Area	94	<1
TOTAL	107,308	

The indigenous forest includes southern rātā (*Metrosideros umbellata*), rimu (*Dacrydium cupressinum*), and kāmahi (*Weinmannia racemosa*) from 150 to 800 metres above mean sea level. From 800 metres above mean sea level to the treeline are makomako (*Aristotelia serrata*), kōtukutuku (*Fuchsia excorticata*), horoeka (*Pseudopanax crassifolius*), Hall's tōtara (*Podocarpus hallii*), māhoe (*Melicytus ramiflorus*), patē (*Schefflera digitata*), and haumakaroa (*Raukaua simplex*) (Stephens and Grunner, 2016).

The area lies within the Westland Beech Gap (Wardle, 1988), where beech species (*Fuscospora* spp. and *Lophozonia* sp.), dominant in other parts of the South Island, are not present. Therefore, the native forests in the project area are not subject to the sequence of widespread masting (intermittent heavy flowering and production of seed) and related predator boom and bust cycles (Elliott and Kemp, 2016), which occurs elsewhere. It should be noted that sporadic masting events are known to occur in rimu and miro (*Prumnopitys ferruginea)* which are found at the lower elevations; and wī kura (snow tussock; *Chionochloa* spp.) which are present at higher elevations.

Above the tree-line, vegetation is primarily herb fields and snow tussock grasslands up to approximately 1,800 metres above mean sea level. Beyond this elevation are glaciers, bare rock and ice.

Wetland and estuarine vegetation in the lowlands includes rushes such as oi (*Apodasmia similis*), grasses such as toetoe (*Austroderia richardii*) and sedges such as rautahi (*Carex geminata*) (Norton, 1994).

The built-up areas include the settlements of Franz Josef (population 500), Whataroa (population 300), Ōkārito and The Forks (population both < 100). Surrounding the built-up areas of Franz Josef and Whataroa is ~11,000 ha of rural production land, primarily dairy farming, consisting of extensive pasture and small scattered patches of scrubland/forest (native and exotic).

Habitat of possums, ship rats and stoats

In the PFSW project area, possum and stoat habitat is considered to extend to approximately 1,800 metres above mean sea level; above this elevation, the landscape is generally characterised by bare rock, snow and ice. Very few possums and stoats have, however, been detected above the forest treeline, which is approximately 1,200 metres above mean sea level (Nichols et al., 2021).

Ship rat habitat extends to 1,200 metres above mean sea level; although most detections occur below 800 metres above mean sea level.

History of predator management

Prior to the start of the PFSW project, DOC, OSPRI and West Coast Regional Council (WCRC) had undertaken aerial 1080 operations to suppress mammalian pests in the Whataroa River catchment and the Ōkārito area. The history of aerial 1080 operations prior to the PFSW project is shown on Table 3.

Table 3 History of aerial 1080 predator operations prior to the PFSW project.

Site	Area (ha)	When[9]	By
Glacier Valley and Callery Catchment	2,730	November 1995	DOC
Between Waitangitāhuna River and Lake Wahapo	3,600	1996	WCRC
Whataroa and Perth catchments	11,000	January and June 1997	DOC
South Ōkārito	8,746	November 1998	DOC
Waiau and Callery	3,075	September 1999	DOC
Whataroa and Perth catchments	8,400	June 2000	DOC
Whataroa and Perth catchments	7,119	May 2004	DOC
Waiau and Callery	3,386	May 2005	DOC
Whataroa and Perth catchments	6,497	February 2007	DOC
Price Range	4,200	June 2010	OSPRI

[9] Where no month is given, this means we were unable to find that detail.

North and South Ōkārito	30,000	September 2011	OSPRI
Burster Range, extending down to Lake Wahapo	10,000	September 2011	OSPRI
Whataroa, Upper Perth and Barlow catchments	11,858	October 2012	DOC
South Ōkārito	9,920	September 2016	DOC
Price Range	3,900	September 2018	OSPRI

Ground-based control has also been conducted, but at a much smaller scale relative to aerial operations. This included use of traps and cyanide by the Department of Conservation (DOC) from 1993/94 in South Ōkārito, from 1996 in Whataroa, and from 1995 in the Glacier Valley and surrounds, where ground-based control was often used for buffer control around aerial operations. OSPRI has conducted ground-based control of possums within PFSW, in and around farmland (such as Whataroa Farmland and Waiau River Valley) since 2007.

This history of control has undoubtedly improved the natural heritage values of the project area, and is particularly evident in the regeneration occurring in the native forest in the South Ōkārito block.

Meaning of ‘Elimination’

While the term elimination is a relatively new, undefined word in pest management; it has origins in disease management, such as the management of malaria (Moonen et al., 2010), and Covid-19 (Heywood and Macintyre, 2020), where disease elimination is the absence of sustained endemic community transmission in a country or other geographical region. Its use is becoming more common to describe the status of an eradicated, or near zero *core zone*, protected with a *buffer zone* of predator incursion management (Patterson et al., 2024).

Here, predator elimination is described as a management approach designed to completely remove (i) every resident predator within a *treatment area* and (ii) any other individual animals that incur across the *boundary* of the area before they are able to re-establish a sustained breeding population (Patterson et al., 2024). Elimination is an approach that is designed to secure the long-term benefits of predator removal within a core zone, without the on-going requirement to suppress predators across the entire treatment area or to fence large tracts of land around a core (> 10,000 ha).

At the national scale, we believe that is the pathway to a ‘Predator Free New Zealand’ – whereby we’ll need to *eliminate* target predators from large areas of the mainland, step-by-step, until we have achieved *eradication* across the country. Noting, of course, that constant vigilance will always be needed, given that possums, rats and stoats will continue to cross our national boundaries (through ships and aircraft).

ZIP is collaborating with colleagues from the Department of Conservation, Predator Free 2050 Limited and other members of the predator-free community to refine the elimination concept.

Actions

As of June 2024, work to eliminate possums, ship rats and stoats has been initiated or completed over ~92,000 hectares (or 86% of the PFSW project area). Based on the time required to build confidence in the elimination results, we report on progress across ~70,000 hectares of the project area here.

ZIP's approach to eliminating predators from landscape-scale areas, including the PFSW Project, has four steps (refer Figure 3):

- select a highly defendable boundary of the project area and determine the sequence of internal management 'blocks'
- establish a surveillance network to detect predators
- remove predators from across an entire management block
- prevent predators from re-establishing in the management block

These steps are underpinned by ongoing community engagement and consultation. The sequence is then repeated in the adjacent management block (until the full project area is complete).

The steps are broadly sequential (Fig. 3), but while it is preferable to establish a surveillance system before beginning to remove predators from across an entire block, that may not always possible (depending on timing and weather conditions for conducting aerial 1080 to Zero treatments, and the availability of field team members to deploy cameras).

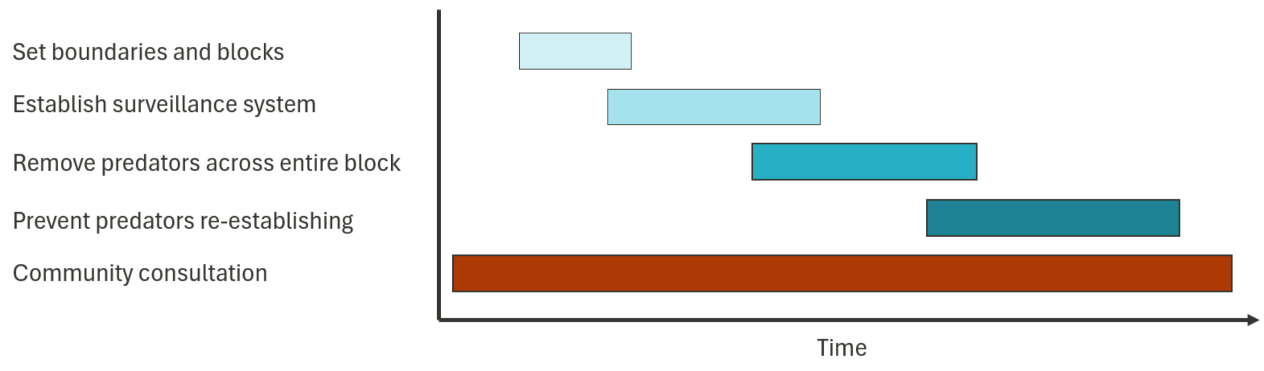

Figure 3 The steps of the ZIP approach to elimination

Ideally, the approach would be repeated in an adjacent landscape-scale area, in order to increase the size of the core zone and reduce the ratio of length of the boundary vulnerable to predator incursion[10] relative to the size of the total area[11].

Select defendable boundaries and define management blocks

Big, fast-flowing rivers, alpine mountain ranges, and the ocean are natural barriers that slow incursion by possums, ship rats and stoats (Cook et al., 2021; Foster et al., 2021; Nichols et al., 2021).

The natural barriers that form the boundaries of the PFSW project area (Figure 1 and 4) are:

- the Waiau / Waiho River
- the Whataroa-lower Perth-Barlow Rivers
- Kā Tiritiri o te Moana / the Southern Alps, and
- Te Tai o Rehua / the Tasman Sea.

Blocks of land that comprise similar vegetation and landform types, and require similar tools and techniques to eliminate predators, were defined as the basis for planning the PFSW work programme since its inception. In general, the size and shape of the blocks has remained constant, but there have been some changes over time to reflect new knowledge, and workflow risks and benefits.

The current blocks are shown in Figure 4.

[10] We use the word 'incursion' because this is a term that is generally used in the context of the New Zealand biosecurity system in relation to the arrival of foreign pests and organisms.

[11] Increasing the scale of these predator-free areas is important for the expansion in populations of rowi (although little is known about their movement ecology), kererū and several other native forest birds such as kakaruai, toutouwai, tūī, and miromiro that have natal and food-driven dispersal distances greater than the scale of most mainland sanctuaries (Innes et al., 2022).

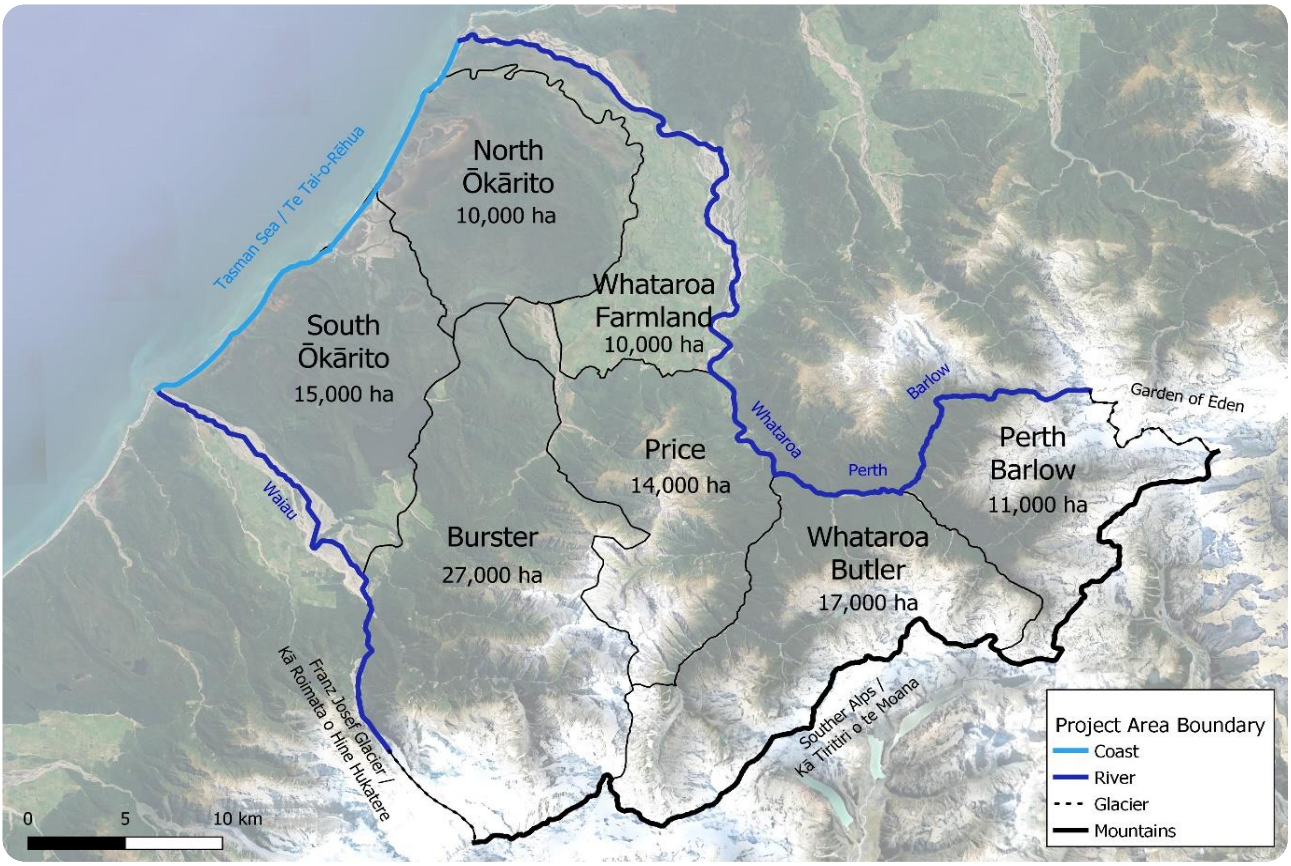

Figure 4 The current blocks used to plan the work programme for the PFSW project. Note that the stated size of each block does not include any large water bodies, e.g. lakes or lagoons, within them.

Table 4 The status of the work programme in each block, summarized below

	Step			
Block	Select boundary and define 'blocks'	Establish a surveillance system	Remove resident predators from an entire block	Prevent predators from re-establishing
Perth-Barlow	✓	✓	✓	✓
Whataroa- Butler	✓	✓	✓	✓
South Ōkārito	✓	✓	✓	✓
Burster	✓	✓	✓	✓
Price	✓	✓ [12]	✓ [13]	
North Ōkārito	✓			
Whataroa Farmland	✓			

[12] The full surveillance network was still being deployed as of June 2024, due to competing priorities and supply chain issues

[13] The initial 1080 to Zero operation has been completed as of June 2024, but we allow 12 months post-operation to build confidence in the absence of detections and/or undertake mop-up of any remaining survivors before we can confirm the resident populations have been removed. Hence, the results for the Price block are not included in this report.

Establish surveillance system

The purpose of the surveillance system is to provide data and information about the presence of predators, which are used to design the elimination work plan. The system largely comprises a network of cameras, supplemented by a network of traps, eDNA, and the deployment of predator dogs.

All trail cameras are continuously serviced, with current intervals of 6–10 weeks between battery and SD card refreshment. ZIP thermal A.I cameras remote report to a server, where all detections are manually verified to confirm species categorization. All GPX track logs of predator detection dogs and any positive detections made are recorded. Sampling for eDNA involves positioning small filters in waterways for several days across which precipitation events are forecast (in order to transport any viable eDNA from terrestrial habitats into waterways). Samples are collected and sent to Wilderlab for processing, and a metadata file is returned with a list of all species and their associated DNA read count per sample.

Trail camera metadata is manually categorized into species using a program called Classifier (https://zip.org.nz/products-list/2022/5/zip-classifier), and loaded into QGIS (QGIS 3.22.11) for viewing. Daily camera detections of each species ('1' or '0' per 24-hrs) are summarized into monthly naive occupancy trends. These trends provide relative abundance and activity information on both targets and non-targets across site, over time.

As of June 2024, ZIP had established a camera network across the PFSW project area that comprised 914 Browning trail cameras that are serviced manually (to recover the images), and 216 'ZIP cameras' that automatically transmit the images that they take[14] (Figure 6).

[14] https://storymaps.arcgis.com/stories/3a4283b1086b47a1a16b2368927f568e

The ZIP Camera

Figure 5 ZIP (A.I) cameras and example images of target species

These cameras developed by ZIP comprise a low-powered, thermal camera with built-in artificial intelligence software that identifies the species of predator detected, and then remotely reports the results every 24 hours. They have greatly reduced the time taken to learn that a predator has been detected—from potentially six weeks to just one day, thereby providing the opportunity to eliminate an emerging population before it becomes a bigger problem.

The brief was to develop a device capable of remotely reporting detections of target species, whilst only requiring servicing once per year. Thermal was chosen over other forms of detection due to its low power consumption and relative ease of image recognition (e.g. warm body vs cold ground). The camera unit is vertically mounted, which aids A.I recognition of an image due to the uniform background and scale.

To keep data packet size for transfer manageable, all A.I computing is done onboard at the camera site.

The camera unit itself is now reliable and has battery capacity out to 9-12 months.

Camera development continues focusing on further improvements to battery life, integration of the camera and the remote reporting unit, and A.I training for more species (including rabbits, hares, hedgehogs and feral cats).

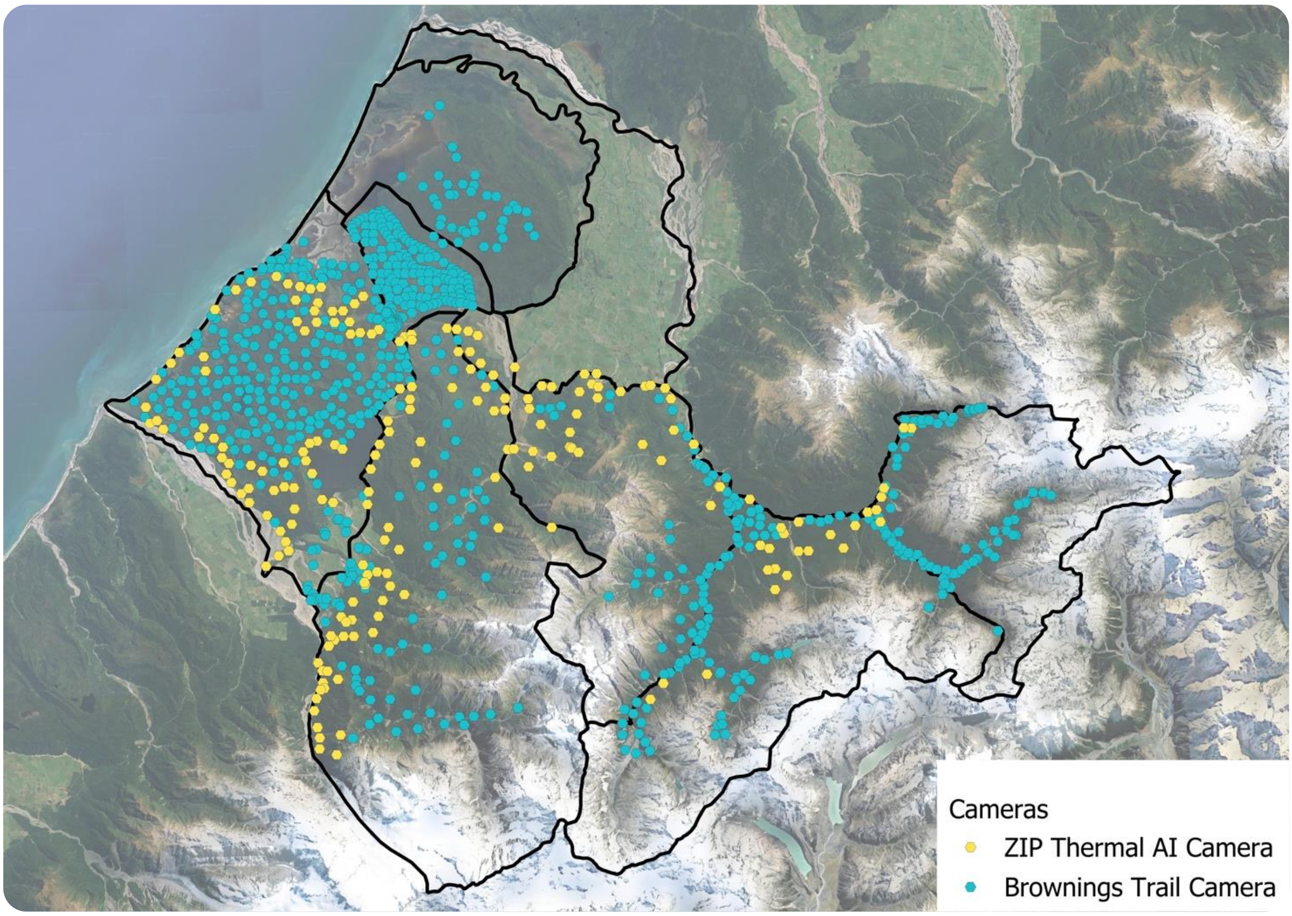

Figure 6 Current network (as at June 2024) of trail cameras and ZIP (A.I) cameras in the PFSW project area.

As of June 2024, the camera surveillance network is completed in the Perth-Barlow, Whataroa-Butler, South Ōkārito, and Burster blocks, and still being established in the Price block (and beginning in North Ōkārito). The intensive network at the northern end of South Ōkārito is to provide early detection of incursion, to protect the South Ōkārito block. Each camera is paired with a device (ZIP Motolure) that automatically dispenses egg mayonnaise to lure animals to be detected (ZIP, 2019; Nichols et al. 2021).

In the remote forested blocks (front and back country), the network is established at a density of one camera per 35 hectares up to approximately 1,200 metres above sea level. This extent provides an effective sphere of surveillance to the maximum extent of rat habitat in this project area, that is 1,200 metres above sea level. Baseline presence and distribution of predators is gathered from the available cameras one month prior to operations; and for post-operation surveillance, the networks are designed to detect emerging populations of ship rats, based on movement of a natal dispersal event by Nathan et al., (2020); and individual stoats (Nichols et al., 2022) and possums (Cooke and Mulgan 2022).

In areas where ground-based actions are used to remove predators (rather than the aerial application of 1080), such as around townships and on farmland, cameras are established at a density of approximately one camera per hectare.

Another part of the surveillance system is the network of traps used to remove predators from areas where aerial 1080 cannot be applied (e.g. near where people live or on some farmland). As of June 2024, the trap network comprised 1,115 'ZIPinn' (see below) and 128 DOC200 traps[15] (Fig. 7). Each trap is paired with a ZIP MotoLure (Fig. 8), to lure ship rats and stoats.

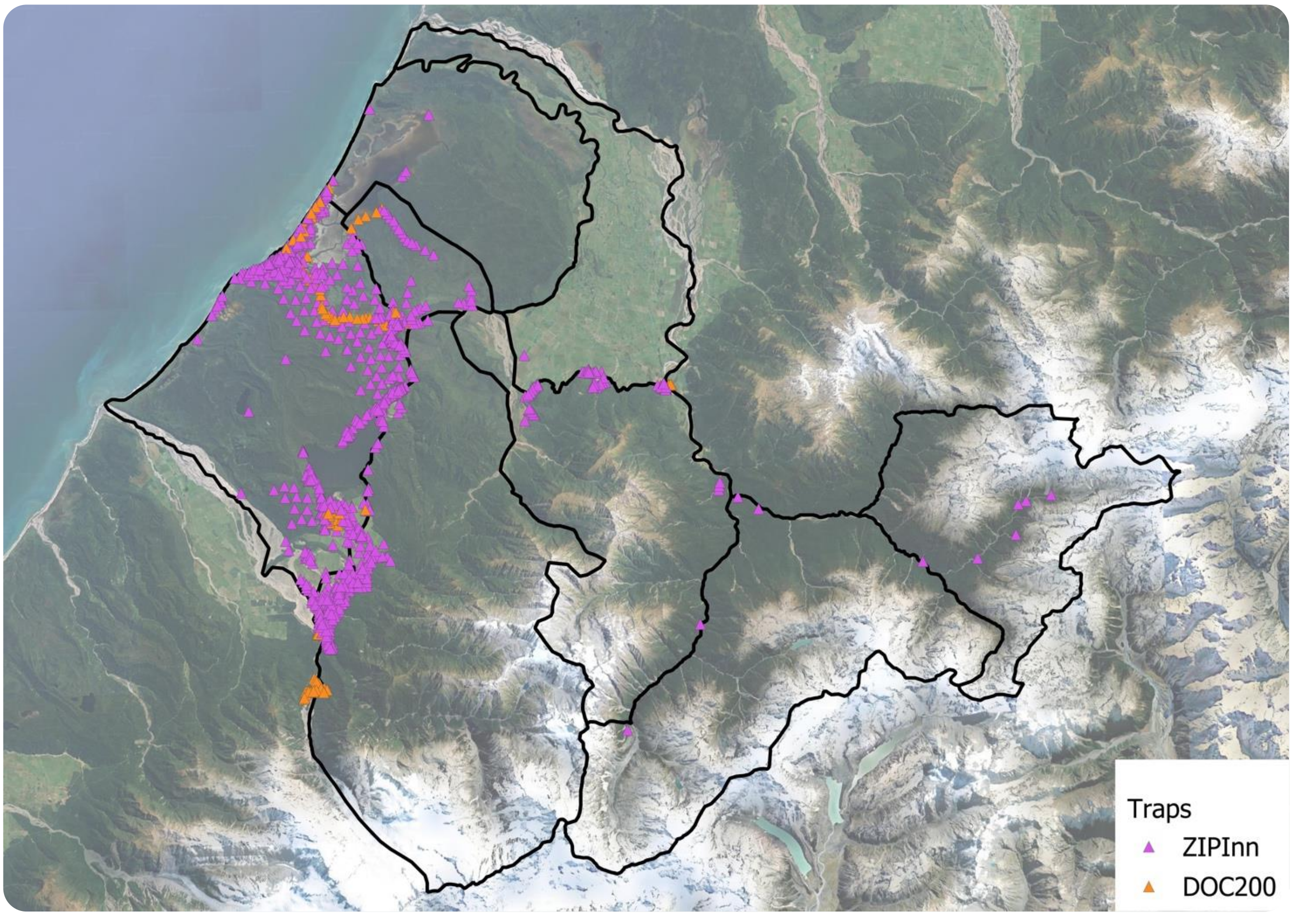

Figure 7 Current network (as at June 2024) of active ZIPinn and DOC200 traps in the PFSW project area.

ZIP is working with others (e.g. Wilderlab, University of Otago) to develop a surveillance technique using environmental DNA (eDNA). eDNA samples from waterways can be used to detect which species are present upstream in the catchment on large spatial scales (Reji Chacko, 2023). To

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[15] Refer: https://www.doc.govt.nz/documents/conservation/threats-and-impacts/animal-pests/doc200-predator-trap.pdf

date, eDNA sampling in PFSW has detected possums, ship rats and stoats, and 20 native bird species (refer Appendix 2).

Predator detection dogs are a highly targeted tool which do not require interaction between an animal and a device (Glen et al., 2023). They are used in PFSW as part of the surveillance system in areas where the rat and possum density is low and individual animals may not be interacting with cameras or traps; and in areas where devices are not able to be installed (for example around dwellings). Dogs have been most useful once a camera or eDNA detection has been made, to delineate the extent of predator presence in the area to inform the response effort required. Following response efforts, dogs have been used in addition to cameras, eDNA, and traps, to confirm absence, particularly in the core zone.

Modelling the probability of absence of each target species in the predator-free core post-initial treatment involves incorporating key parameters such as detection probability, home-range size, effort, type of surveillance method, and time. Often, layers of the above surveillance methods are used in addition to the stationary camera networks to increase confidence of a predator-free state within a certain time period.

The ZIPinn

The ZIP MotoLure

Figure 8 The ZIPinn trap (left) and ZIP Motolure (right)

The **ZIPinn** (top left) is a highly effective rat and stoat trap that was developed by ZIP because some ship rats are able to trigger and escape from traps that use kill bars—such animals may be less likely to further interact with such traps. This trap comprises a plastic tunnel with spring-loaded doors at each end, which close instantly when a rat or stoat activates the treadle in the centre of the tunnel. Caught animals are automatically euthanised using carbon dioxide, which is a standard humane laboratory technique; the clean kills can provide information on the breeding status of captured ship rats and stoats (via autopsy).
The ZIPinn in the figure above has a ZIP MotoLure and a node for automated reporting attached to it.

The **ZIP MotoLure**[16] (top right) is a robust tool, also developed by ZIP, that dispenses a preset amount of fresh mayonnaise lure for possums, rats and stoats, for up to one year without requiring manual service. This device can be used as a lure for traps, a prefeeding tool, as part of a detection system, and as a biomarking tool.

[16] See https://zip.org.nz/products-list/motolure for more details

A brief comparison with standard monitoring methods

In April 2018, ahead of the Perth-Barlow 1080 to Zero operation, standard suppression monitoring methods were used to assess the relative abundance of stoats, rats, and possums. The Department of Conservation often relies on standard monitoring methods such as tracking tunnel indices to gauge the optimal timing for landscape scale aerial operations (Brown et al., 2015; Elliott and Kemp, 2016). In some sites, such as the Perth-Barlow, a minimum tracking rate for rodents of 15% was needed to justify the aerial operation, in part to increase biodiversity gain through secondary poisoning of stoats.

Tracking tunnels were carried out as per Department of Conservation best practice guidelines (Gillies and Williams 2013). Possum monitoring was carried out using best practice guidelines for Waxtag® monitoring (Bionet and NPCA 2020). Overnight rat tracking was at 12.5%, mouse tracking was at 5%, and 3-night stoat tracking was at 1.7%.

Due to weather delays, the Perth-Barlow 1080 to Zero operation was postponed until April 2019. Ahead of the operation, in February 2019, the camera network was installed across site, with a fully complete network in place, and continuous luring from the beginning of March. The naïve occupancy rates (proportion of cameras occupied by each target species, for the month of March 2019) were significantly higher than the standard monitoring results – ship rats on 65% of cameras, stoats on 35%, and possums on 96%. Mice were recorded on 14% of cameras.

While extrapolation of trail camera results to standard monitoring techniques must be cautioned (the monitoring duration, spacing, and luring were different between the camera network and standard monitoring techniques); these differences show the increased sensitivity potential of cameras. Trail cameras are known to be more sensitive than tracking tunnels for detection of low-density stoats (Smith and Weston, 2017) and rats (Davis et al., 2023). Saturation of devices can become an issue with enough time (Davis et al., 2023), which can be accounted for date and timestamped records using cameras. These results help contextualize the naïve occupancy rates of target species in the Perth-Barlow pre operation with starting conditions at similar sites under management. While these monitoring events did not happen in the same time period, they provide some comparison of starting conditions as measured between the two methods.

Remove predators from across an entire management block

Initial predator removal in remote areas

In areas of extensive natural vegetation cover, the initial step is to apply the ‘1080 to Zero’ approach that ZIP developed to remove possums, and ship rats from a treatment area (Nichols et al., 2021). Possums and rats can be knocked down to extremely low numbers with aerial 1080 (Nichols et al., 2021; Nugent et al., 2019); and stoats are removed through secondary poisoning after consumption of toxic carcasses (Murphy et al., 1999; Nichols et al., 2021; 2022).

The 1080 to Zero approach has two phases, each of which comprises two applications of non-toxic pre-feed bait followed by one application of toxic bait. Almost all of the bait was applied by helicopter, over a footprint of approximately 74,000 hectares. 1080 cereal bait was also applied in very small areas by drone or by hand or in bait stations—approximately 380, 285 and 65 hectares respectively—on farmland/private land or along roads and other sensitive boundaries of treatment areas. Brodifacoum bait, targeting ship rats only, was also used in rat-specific bait stations over approximately 2,000 hectares, mostly along forest edges that could not be aerially sown with 1080 bait.

The baits used in the 1080 to Zero technique were six-gram, cereal-based pellets (Wanganui No. 7/Wet Forest or RS5/Dry Forest), masked with orange or cinnamon lure. The bait type and lure were changed between the first and second applications of toxin, in order to overcome any bait aversion or any bait shyness in individuals that survived the first phase (Nichols et al., 2021; Nugent et al., 2019, 2020).

In the first phase, pre-feed bait was applied at 2 kilograms per hectare and toxic baits applied at 4 kilograms per hectare. This achieved a significant reduction in target individuals, and as a result bait quantity was reduced in the second phase to 1 kilogram per hectare for prefeed and 2 kilograms per hectare for toxic. The reduced pre-feed quantity during the second phase was intended to minimise the risk of survivors caching prefeed, and therefore not seeking out and consuming toxic bait. This risk is elevated as survivors may increase their home ranges as a result of a reduced population after the first phase (Nichols et al., 2021).

Pre-feed baits were applied with a 10% overlap, and toxic baits with a 50% overlap (Nichols et al., 2021). This application approach is utilised to avoid gaps in bait coverage on the ground, which maximises bait exposure for all of the target individuals within that resident population. In order to achieve minimal gaps in coverage, regulatory permission (from DOC and Ministry of Health) is sought to minimise exclusion zones within the treatment area;

including the ability to sow into waterways, over tracks (which are then cleared), and over any huts (which have the water intake pipes disconnected and roof and immediate surrounds cleared before reconnection). Landowner consent is secured for all baiting on to private land, and on adjacent land if the baiting is to occur within 150 m of a dwelling. The first phase of aerial elimination work was sown over all available vegetation/habitat, including alpine herb fields, up to the beginning of continuous rock and ice. The second phase was sown to lower elevation, as our pre-monitoring (Nichols et al., 2021) and work from others (Glen et al., 2012; Christie et al., 2017) suggests possum and ship rat presence declines with increasing altitude.

Table 5 The history of 1080 to Zero treatments in the PFSW project[17].

Block	Phase: Date	Area Treated (hectares)
Perth-Barlow	Phase I: April 14 2019 Phase II: July 23 2019	9,376 6,437
Whataroa-Butler	Phase I: June 2 2021 Phase II: July 23 2021	14,570 14,077
South Ōkārito	Phase I: November 24 2021 Phase II: April 10 2022	14,672 14,076
Burster	Phase I: May 16 2023 Phase II: August 24 2023	21,626 18,818
Price	Phase I: October 21 2023 Phase II: December 19 2023	9,753 13,431 [18]

To date, this technique has been applied over 73,675 ha of the PFSW project area. Rock and ice are not included on the operational area. When the full catchment area is included, a total area of approximately 83,000 hectares has been targeted using the 1080 to Zero approach.

Initial predator removal in townships and farmland

On farmland and in and around townships, ZIP has used ground-based techniques to remove predators, including at Franz Josef and Ōkārito townships and the settlement of The Forks.

To remove possums, ZIP has deployed approximately 200 cage traps for periods of several nights to several weeks. As these are live-capture traps,

[17] The treatment is scheduled to be applied over the North Ōkārito block (approximately 10,000 hectares) from August 2024. It will not be applied in the Whataroa Farmland block (approximately 10,000 hectares). All treatments in Table 4 include oversows to reduce immediate incursion of the boundaries.

[18] The operational area for the Price block was larger in phase two as the section of the North Ōkārito block was included as a buffer to protect South Ōkārito from incursion.

they are either checked daily or are connected to our automated reporting system which notifies the trapper daily whether the trap is sprung or not. Cyanide (in the form of paste or strikers) has also been deployed in selected areas for periods of up to 7 days. A possum dog is also used regularly to assist with efforts to hunt remaining possums. Recently, thermal drones have been trialled in conjunction with dog-assisted hunting to detect and remove possums on farmland.

To remove ship rats, ZIP uses ZIP bait tunnels (ZIP, 2022a) or other commercial bait stations predominantly baited using brodifacoum pellets or blocks (other toxins such as pindone and 1080 pellets have also been used in small areas). At its peak, this network included 6,024 bait stations typically deployed on a 50 m x 50 m grid, or targeted to discrete patches of habitat as necessary. As at June 2024, the PFSW project area comprises a network of 3,678 bait stations over ~2,300 hectares (this includes a portion of the network within the farmland at the front of the Price block) (Fig. 9).

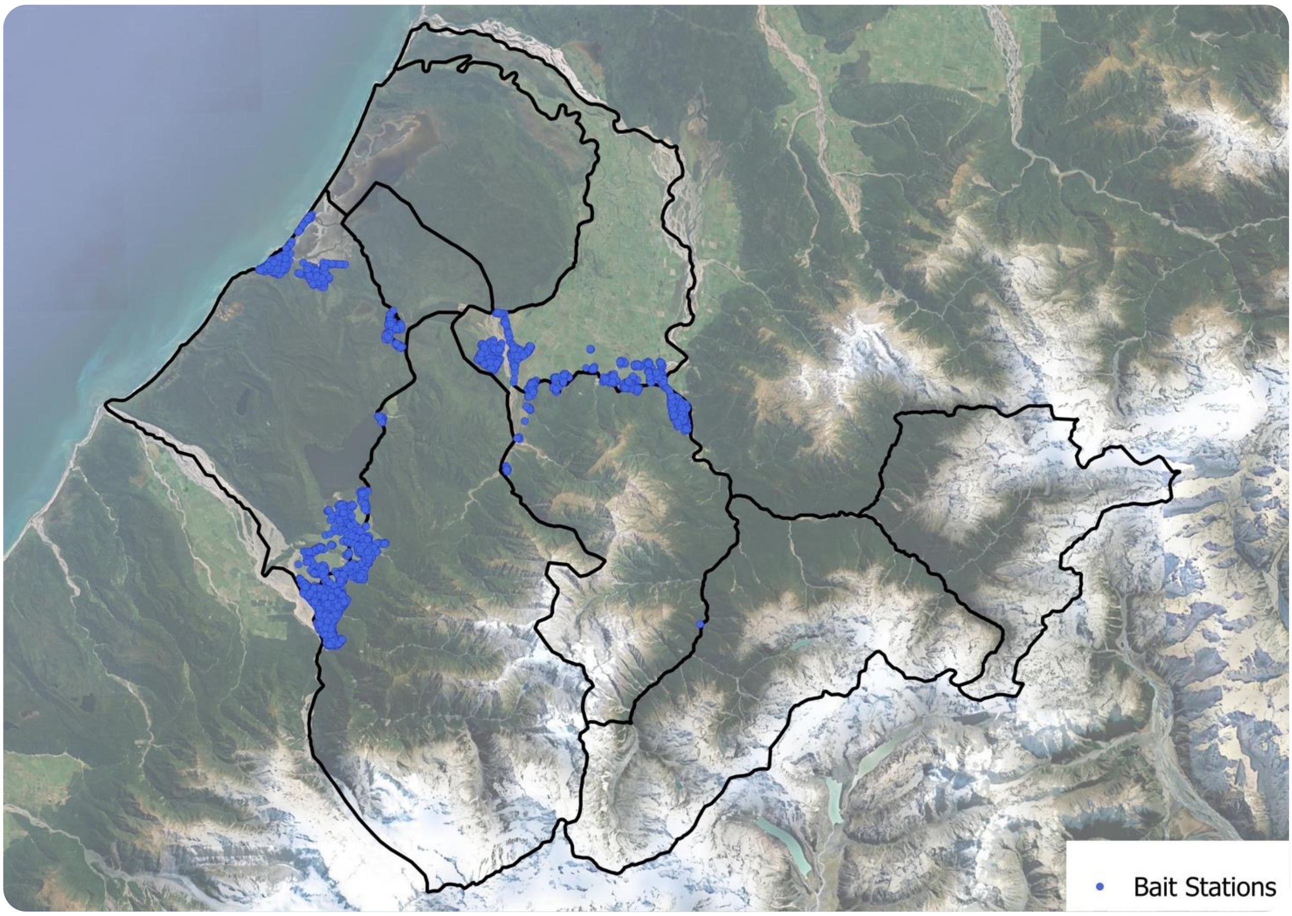


Figure 9 Current network (as at June 2024) of active bait stations in the PFSW project area

Bait stations are supplemented by the 1,115 ZIPinn and 128 DOC200 traps used for surveillance (as at June 2024). Traps are used where ground-based toxin is unsuitable, the private landowner has requested a non-toxic removal method, or in sensitive areas where additional defence is required. Humane kill traps provide additional benefits of instant capture of a predator, positive confirmation of predator type, and in the case of ZIPinn traps where the predator is captured without exterior damage to the body, sex and age of individual.

Stoats in rural areas and townships are removed using the network of ZIPinn and DOC200 traps (Fig. 7). Secondary poisoning from rodents that consumed brodifacoum may also supplement stoat removal (Alterio, 1996). However, stoats have variable and large home ranges (44–256 ha in South Island podocarp forest) (King and Veale, 2021; Miller et al., 2001) and therefore not all animals moving through the area are expected to be removed by these ground-based methods before they leave the area again.

Prevent predators re-establishing

When the surveillance system indicates that all of the survivors are likely to have been removed, then the next step is to prevent predators from re-establishing in the block.

Possum movement is known to be deterred by moving waterways (Cook et al., 2021), so incursion rates are low across river barriers in PFSW, and often coincide with very weak points in the river. Invading or surviving possums are relatively easily removed before the population recovers, as possums have a relatively slow reproductive cycle (Cowan and Glen, 2021). While possums are known to be fairly sedentary within their home range, individuals tend to make larger shifts in movement when alone after populations are reduced through control efforts (Ramsey et al., 2002; Sweetapple and Nugent, 2009).

Ship rat incursion is reduced by rivers that border PFSW blocks. However, some rats do cross waterways (ZIP 2019), and some river barriers in PFSW are stronger than others. Trapping is in place along the true left of the Waiau River (outside of the project area), and on the spit separating Ōkārito Lagoon from the Tasman Sea (a temporary internal boundary until the North Ōkārito block is treated), to reduce the invasion pressure on this boundary. Reinvading rats are detected within the project area by the camera network, ZIPinns, detection dogs (including in the case of community sightings/suspected incursion zones in the front country), and eDNA (still in development).

Stoats can swim long distances and often cross rivers (Veale, 2014). This, coupled with their large home range (King and Veale 2021) and rapid dispersal means that stoats may quickly reinvade into an area that they have been initially removed from.

The movements of detected individuals are modelled to help design an appropriate scale of response, taking into account location and the time elapsed since their detection. As such, responses to remove survivors and/or animals that had incurred into the treated blocks take the form of: smaller-scale follow-up aerial 1080 operations, toxins in bait stations, traps, and hunting. ZIPinn traps are used to reinforce protection of incursion points for rats and stoats; while cage traps are used to mop up surviving possums (Cook and Mulgan, 2022), and protect incursion points. Localised aerial operations are typically used to target emerging populations of ship rats, which incidentally remove stoats overlapping the treatment areas through secondary poisoning (Murphy et al., 1999; Le Lec and Nichols, *in prep*). These highly targeted aerial treatments can be categorized as boundary (or buffer zone) management, to reduce incursion risk of rats into the core zones; and 'spot' treatments within the core zones to mop up any survivors/dispersers from the buffer. And, more recently, possum-focussed targeted aerial treatments have been trialled in the very upper reaches of the Perth-Barlow block core zone to improve response coverage due to terrain limitations.

Stoats are directly targeted using toxic rodents, which mimic the secondary poisoning result using manufactured 1080-laced rodent carcass baits. While this work is still in development, initial trials have been promising (Nichols et al., 2022).

Photo Kea flying above Upper Barlow River, Chad Cottle.

Results and Analysis

As of June 2024, predators have been eliminated from four of the blocks, which are now being managed to prevent predators from re-establishing there. Those blocks are the Perth-Barlow, Whataroa-Butler, South Ōkārito, and Burster blocks. The total catchment area of these blocks is ~70,000 hectares (or 65% of the PFSW project area).

Data is taken from the network of cameras, ZIPinn traps, eDNA, and dog detections to measure the elimination status of each block. Trends of predator detections in the core and buffer zones are taken from camera data; while all other forms of detection data (eDNA, dog detections, and trap captures) help provide confidence in absence, and information on predator 'contaminated' zones.

In the Meaning of Elimination section to this document, predator elimination is described as a management approach designed to completely remove every individual resident predator within the *core zone* of a treatment area as well as other individual animals that subsequently incur before they re-establish in the area.

Under this approach, the *core zone* of the treatment area is almost always maintained as predator-free, while the *buffer zone* is subject to the sporadic presence of predators that crossed the boundary from non-treatment into treatment areas.

Two measures are being developed to determine elimination success: 1) one based on the depth of incursion by predators (to assign the buffer for each block), recognising that the majority of the management to maintain elimination will occur within the buffer; and 2) one based on the 'contaminated area' within the core when a predator(s) are detected, both in terms of scale of contamination and length of time required since last detection (or response action taken) to be considered 'free' of contamination.

While these measures are the subject of ongoing collaboration with DOC, PF2050 Ltd, and others in the predator-free community, we have used them as the basis for analysing the data from PFSW. We start with an in-depth look at the Perth-Barlow, the block with the longest management history; followed by the results as at June 2024 for the other managed blocks across PFSW.

Elimination measures – the Perth-Barlow example

We have followed a three-step process to implement the elimination measures, as described below using the Perth-Barlow block as an example.

Step 1: Decide on (i) the boundary of a treatment area that is vulnerable to incursions from outside the treatment area by a target predator, and (ii) an appropriate width of the *buffer zone* as it relates to the target predator species. The remainder of the treatment area is the *core zone*.

(i) The Perth-Barlow block shares a boundary with the Whataroa-Butler block and a boundary with another area outside of the project area. As the first block being treated in the PFSW project area, the Perth-Barlow block initially had a ~22-kilometre-long boundary vulnerable to predator incursion. At a width of 1,500 metres, the buffer zone covered a total area of 2,171 ha, as shown on Figure 10a[19]. The core zone comprised 1,663 ha of ship rat habitat and 5,913 ha of possum and stoat habitat.

After the Whataroa-Butler block was treated, the risk of predator incursion across the mid Perth River boundary was expected to decline (if not cease), and so the boundary with the Perth-Barlow block was reduced to ~11 kilometres, that is, the area outside the PFSW project area. At a width of 1,500 metres, this buffer zone now covered a total area of 1,590 ha, as shown on Figure 10b[20]. The core zone now comprised 2,648 ha of ship rat habitat and 8,084 ha of possum and stoat habitat.

[19] The buffer shown here has been 'clipped' to the extent of rat habitat where it has ended within the 1,500 metres.

[20] Again, the buffer shown here has been 'clipped' to the extent of rat habitat where it has ended within the 1,500 metres

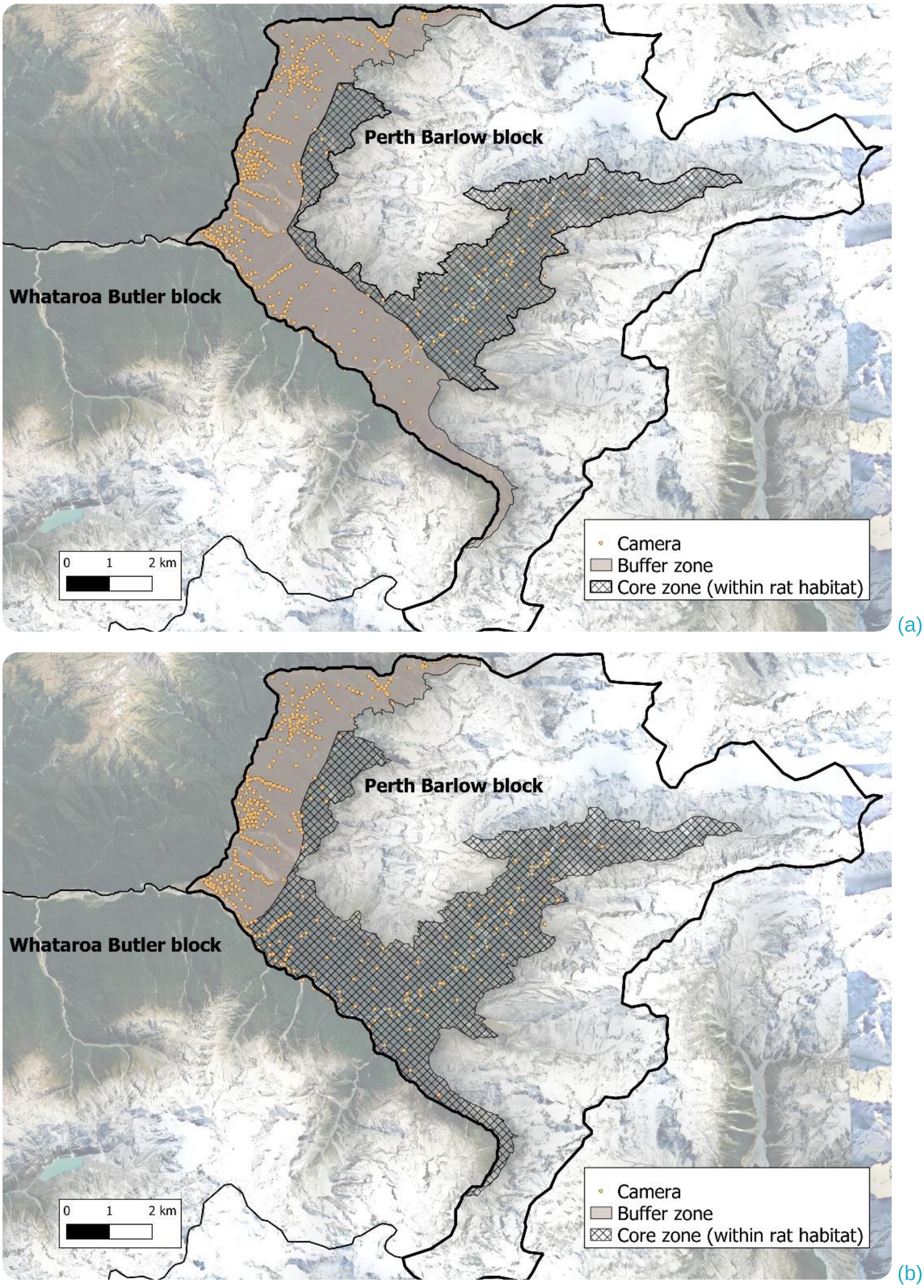


Figure 10 Boundaries, buffer zones and camera network in the Perth-Barlow block (a) before the Whataroa-Butler treatment and (b) after the treatment. Figures show all cameras (trail and ZIP) that have been deployed in the Perth-Barlow block.

(ii) Carpenter et al. (2023) showed that radio-tracked individual ship rats moved an average of 1,172 m (up to 1,500 m) into a low density (predator controlled) area over a period of six months; while Nathan et al. (2020) found that a mother ship rat translocated into a recently predator eliminated area moved 1,640 m during three months; with her offspring moving up to 675 m within the same vicinity. A plot of ship rat detections by distance from the boundary in the Perth-Barlow block (Fig. 11) also revealed a maximum distance post operation of 1,500 m (with an average of 750 m) (acknowledging that response interventions may have limited this dispersal distance). This distance has therefore been adopted by ZIP as the buffer zone for PFSW.

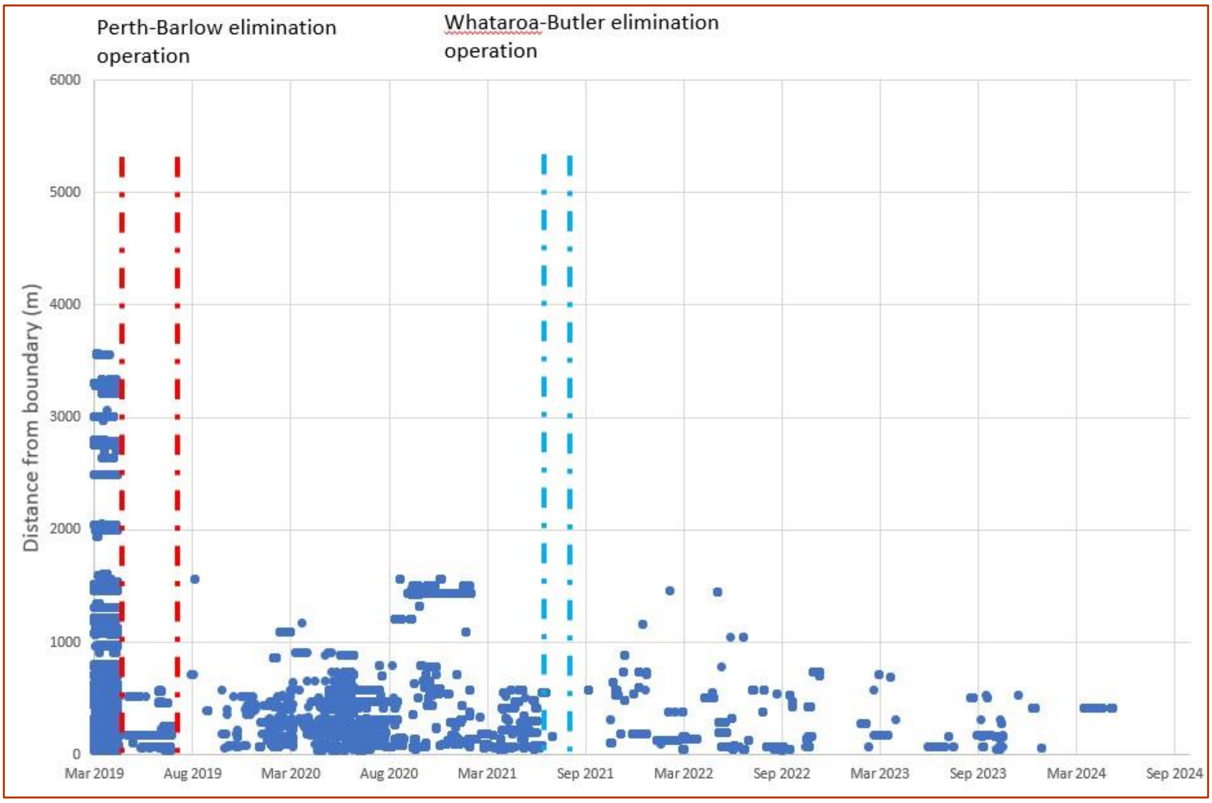


Figure 11 Depth of detections (y axis) of ship rats over time into the Perth-Barlow block from the boundary with the adjacent Whataroa-Butler block (treated) and the area on the true right side of the Barlow River (outside the PFSW project area, untreated).

Efford et al. (2000) found home range shifts of possums from uncontrolled sites into adjacent, newly controlled zones in the first year following control. However, only 1 out of 28 possums moved more than 200 m into the newly controlled zone during the first year. While possums often show larger movements in response to control efforts through roaming behaviour (Margetts et al., 2020), their aversion to crossing rivers reduces movements into the buffer zones to very low, slow-flowing sections of the river boundary. To keep it consistent with the buffer for ship rats, ZIP adopted 1,500 metres as the width of the buffer zone (not including any areas outside their potential habitat).

Few studies exist to help inform an appropriate buffer width for stoats, outside of known average home range estimates and juvenile dispersal movements. Work is ongoing across the wider PFSW project area in core zones that are much deeper (i.e., > 5km from the boundary) to determine whether the buffer approach is suitable for stoats. For the purposes of this report, we have used a buffer zone distance of 1,500 m to maintain consistency across all target predators.

Step 2: Establish a network of cameras inside the potential habitat of the target species within the project area that enables us to, with a very high degree of confidence, detect and eliminate all incursions of the target predator before it becomes established.

To date, a total sum of 368 trail cameras and 17 ZIP cameras have been deployed in the Perth-Barlow block, as shown in Figure 10. However, this figure has been subject to increases and decreases through time at specific locations of predator activity.

In late 2022, after the 1080 to Zero operation in the neighbouring Whataroa-Butler block, the network was reduced to 91 cameras (trail and ZIP). These are distributed at a density of 1 per 35 ha, biased mostly towards the rivers and rat habitat, and 1 per 105 ha in the narrow Teichelmann valley, upstream of Scone Hut. The Teichelmann valley increases in elevation quickly compared to the Barlow River side, and thus available habitat is compressed.

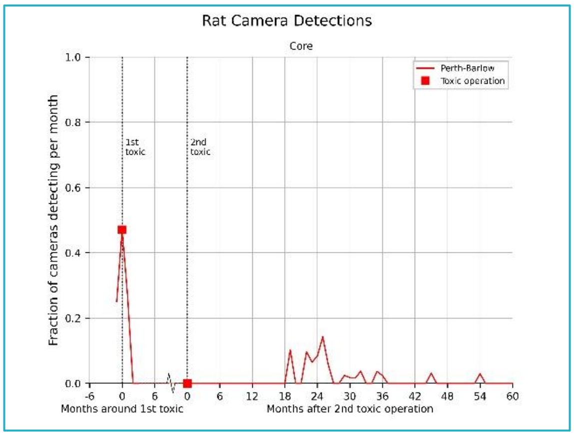
Step 3: Analyse detection data to identify ‘eliminated’ and ‘contaminated’ areas within the core zone, in order to measure elimination progress and determine further management interventions. Detection camera data is converted into occupancy trends (calculated by the percentage of available cameras that detected each species, per month), which are used to track presence/absence at cameras in the core zones. Buffer zone trends are also tracked to provide insight into incursion pressure and therefore the need for buffer management to prevent incursion into the core.

Detection trends in the core

Ship rats and possums (and stoats via secondary poisoning) were initially targeted through a 1080 to Zero aerial operation. After the completion of the second phase of this operation, detections of ship rats in the *core zone* were reduced from 47% to zero (all removed after the first phase), and remained at zero post operation for over a year (13 months) (see Figure 12a). The first core rat detections were in areas just beyond the buffer zone, midway up the Barlow River. It is not possible to know whether these were ship rats that had survived the initial operation and/or dispersed from the incursion buffer zone. These rats were eliminated using aerial spot treatments completed on 30th January 2021. No ship rats have been detected by cameras or through eDNA analysis in the Upper Perth valley (1,197 hectares) since the initial elimination operation was completed over five years ago. This demonstrates that a 1080 to Zero operation can result in a rat-free core zone.

Possum detections in the core zone were reduced from 92% to 12% after the 1080 to Zero operation (see Figure 12b). Targeted mop up of survivors (cage traps and dog searches) eventually reduced these detections to zero in 2020. However, starting in 2022, two detection locations in the upper reaches of the Perth valley suggested that there may be potential survivors persisting. Current analysis suggests the habitat further up the valley, which previously lacked camera detection effort, had harboured survivors who did not exhibit wide dispersal movements since the initial operation. No other areas in the core of the Perth-Barlow have seen possum detections since the 1080 to Zero operation. Increases in eDNA sampling and high elevation camera effort delineated contaminated areas in the valley, and a targeted aerial response was implemented in December 2023. One detection has since occurred outside of that treatment area as of May 2024, which could signal lonely dispersal behaviour, and is currently being responded to with ground-based efforts.

Detections of stoats in the core zone were reduced from 23% to zero after the aerial operation (all removed after the first phase) (see Figure 12c). Seven months later, at the start of juvenile dispersal season (from November 2019), stoats were detected on cameras primarily in the buffer zones, and later in both the core and buffer. We have had success in targeting stoats with toxic rodent carcass baits (Nichols et al., 2022). These baits mimic what occurs in aerial 1080 operations – rodents are laced with 1080, hand laid at sites of stoat detection, and subsequently found and consumed by stoats. In July 2020, after the initial invasion by stoats earlier in the year, toxic rodent carcass baits were hand-laid at 15 camera sites in the Barlow valley. Cameras monitoring the toxic baits showed stoats taking 7 out of 15 baits, and a subsequent reduction in stoat activity of 95%. Currently, the next stage of development and testing of rodent carcass baits is underway, with carcasses injected with 1080 solution at nearly the same toxicity (10 mg) as a 6-g cereal bait (9 mg). As seen in Fig. 14c, detections in the core have been few until more recently (2023-June 2024) where stoats that had invaded the core appear to be residing in the upper Perth valley core area, causing a spike in the trend. A targeted low density ZIPinn network deployed since late 2023 has since caught 5 individuals through June 2024. Work continues to determine if there is ongoing persistence of stoats in the area, and undertake targeted response actions to remove them.



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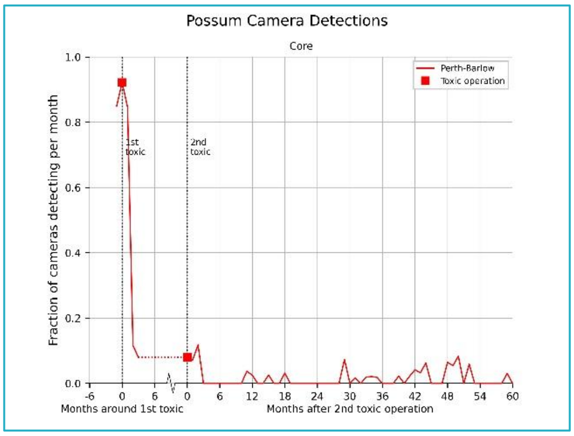

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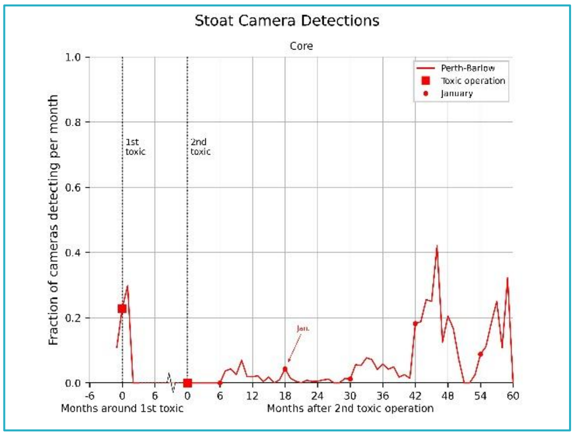


(c)

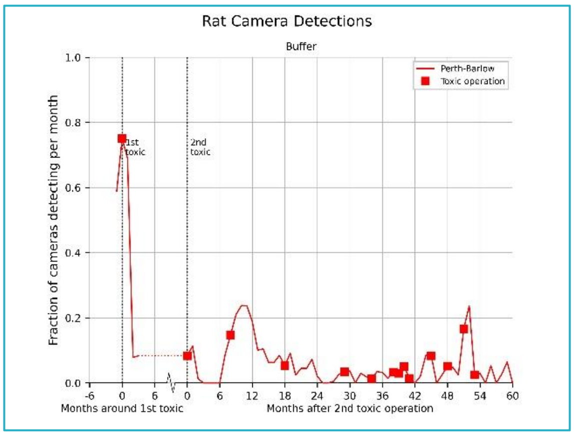
Figure 12 Detections of ship rats (a), possums (b), and stoats (c) in the core zone of the Perth Barlow block, March 2019–June 2024

Detection trends in the buffer

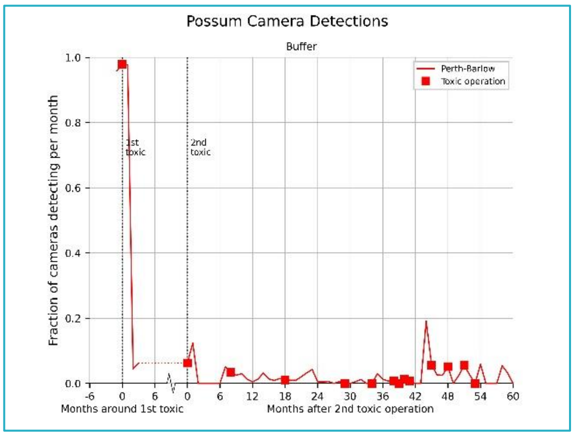
Detections of ship rats, possums, and stoats within the buffer zone were reduced substantially (if not to zero) after each of the first and second phases, but then increased within two months after completion of the second phase (July 2019) (see Figure 13 a-c). This detection pattern was likely driven by incursion (with some minor contribution from survivorship), given the significant reduction of resident populations within the core (see above) and the immediate proximity to the boundary and unmanaged predator populations. Completing the 1080 to Zero operation in the adjacent Whataroa-Butler block in 2021 reduced the detections of ship rats and possums in the corresponding buffer to virtually nil, with almost all incursion now being detected within the Barlow River buffer zone.

As an experiment, the area contaminated by rat incursion at the confluence of the Perth and Barlow rivers was allowed to expand in order to increase understanding about the rate of emergent population dispersal. This was always intended to be a short-term trial, but the timing coincided with COVID-19 lockdowns, which prevented ZIP from being able to implement a timely predator removal response for a period of three months, and enabled the rat incursion issue to grow significantly.

In response, an intensive network of approximately 1,777 bait stations was installed, containing brodifacoum toxic bait in pellet form, and later, wax block form. An additional 158 trail cameras were added in this ground-based response zone to monitor effectiveness. After the first 12 months of ground-based efforts, it became evident that this was an extremely expensive technique for eliminating ship rats in such a wet environment on difficult (steep) terrain, and would not result in complete coverage of the contaminated area. Consequently, a technique involving relatively small-scale aerial 1080 treatments was implemented to remove the ship rats and prevent them from re-establishing in the core zone.



(a)



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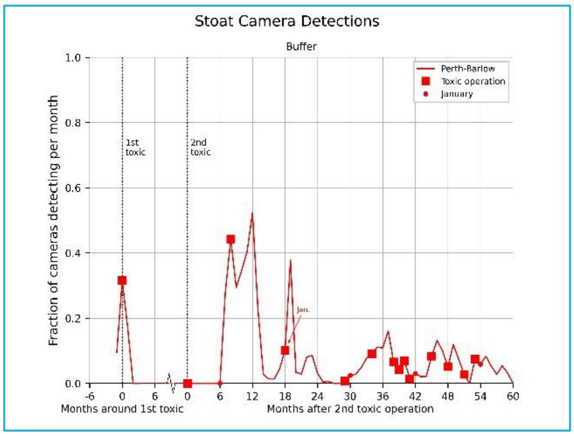

(c)

Figure 13 Detections of ship rats (a), possums (b), and stoats (c) in the buffer zone of the Perth Barlow block, March 2019–June 2024.

'Contaminated' vs eliminated areas

'Contaminated' areas are mapped spatially using any detections made by cameras, eDNA, dogs, and trap captures. Contaminated areas are further broken down into time periods since last detection following a response action, since this is the key metric when determining if that management intervention has successfully removed the incursion event.

Contaminated areas represent the area that a target detection may encompass, due to their activity as ranging animals (possums and stoats), and emerging populations (ship rats). The standards ZIP uses to define the contaminated area, and the length of time before a contaminated area is re-categorized as eliminated, are shown on Table 6.

The standards vary between species due to differences in their mobility, behaviour, and reproductive biology (Zero Invasive Predators, 2022b)[21].

[21] For example, any stoats that incur into the area have the ability to disperse rapidly, which is why the area considered contaminated after the detection of a stoat is larger than that for possums and

Table 6 The standards used to assess whether an area is contaminated or eliminated.

Predator Species	Area considered 'contaminated' following detection on a camera	Period of zero detections following response action to a detection before a contaminated area is re-categorized as 'eliminated'
Possum	500 metre radius (79 hectares) around the detection	6 months
Ship Rat		9 months
Stoat	1,000 metre radius (314 hectares) around the detection	1 month

When a rat is detected, the assumption, given the spacing of the camera network, is that there is likely more than one rat, and a population is beginning to emerge (Nathan et al., 2020). Spatial modelling of the growth and dispersal of emerging rat populations under a variety of plausible scenarios (i.e. different ages of sexual maturity, adult and litter survival rates) shows that in 97% of iterations, when two rats find each other, the emergent footprint of their offspring would be detected by the camera network in place within nine months. Few studies exist to help parameterize detectability of an emerging litter of ship rats, however, results from Nathan et al., (2020) and more recent analysis of a probable incursion and subsequent breeding event in the Brook Sanctuary (Nathan et al., *submitted* 2024) continue to inform and refine the modelling. Given this timeframe, and their potential spread, the area up to 500 metres in all directions from the detection site is considered contaminated with rats. Conversely, if no rats have been detected in an area for at least nine months, modelling suggests 97% confidence that, nine months prior, there were no rats breeding at that detection location or that the response actions taken have likely removed that emergent population.

Possums and stoats only breed once a year in this part of the country, and although they are capable of moving much greater distances than rats when searching for mates or invading a new area, detections are assumed to be individuals unless proven otherwise (e.g. by repeat detections after trapping the first individual).

The six-month window of contamination for possums relates to the expected wide-ranging movements of some lonely possums once their conspecifics have been removed, or after they incur into the area and seek to find mates. Typically, this time period allows for targeted removal of a 'roaming' individual (thus removing the 'contamination'); or for aggregation

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ship rats. Conversely, the standard period of time since last detection before a stoat-contaminated area is reclassified as predator-free is shorter than that for both possums and ship rats owing to their rapid movement across a landscape.

to occur,[22] which reduces the focus area of the response (whilst maintaining the 'contaminated' status).

The single month of contamination recognises that stoats (particularly males in breeding season, and juveniles dispersing) are capable of moving large distances in a matter of days. Thus, detections examined across timeframes over 1 month typically involve numerous detections by a few individuals (Nichols et al., 2022) and thus the focal point of contamination (and therefore response) shifts in line with those movement patterns.

As at June 2024,

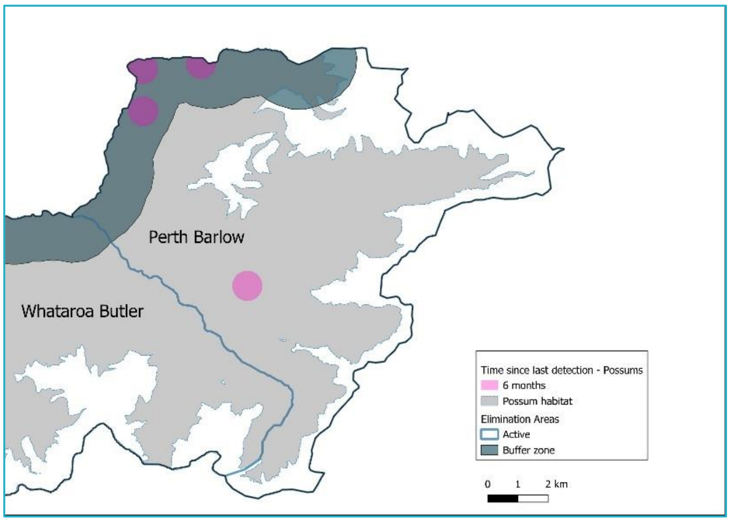
- 94% of the total catchment area of the Perth-Barlow block is free of possums, ship rats, and stoats (that is, 10,069 ha of 11,132 ha).
- 87% of available habitat for possums, ship rats and stoats is free of all three species (that is, 7,023 of 8,086 hectares)
    - 97% of the potential habitat for possums is free of possums (that is, 7,815 of 8,086 hectares)
    - 88% of the potential habitat of ship rats is free of ship rats (that is, 3,336 of 3,805 hectares)
    - 96% of the potential habitat for stoats is free of stoats (that is, 7,774 of 8,086 hectares).

The breakdown of the elimination status in core vs buffer zone, as of June 2024, is as follows:

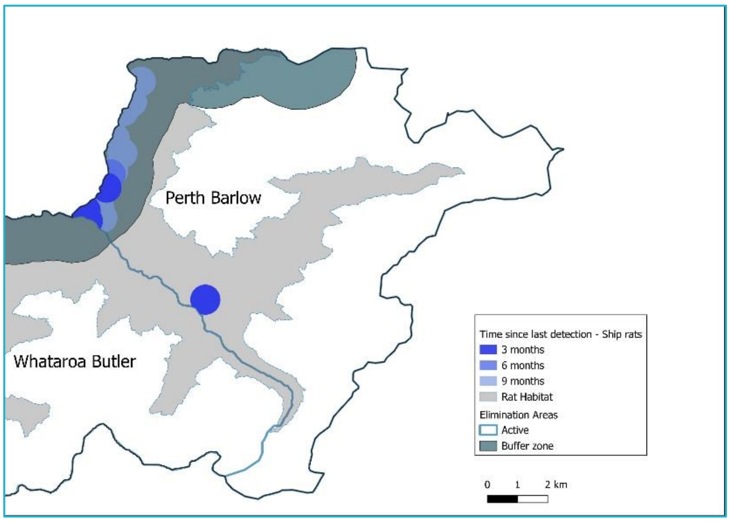
- 99% of the potential habitat for possums in the core zone is free of possums (that is, 6,308 of 6,386 hectares)
- 97% of the potential habitat for ship rats in the core zone is free of ship rats (that is, 2,528 of 2,604 hectares)
- 95% of the potential habitat for stoats in the core zone is free of stoats (that is, 6,074 of 6,386 hectares)

In map form (Fig. 14 a-c), it looks like this:

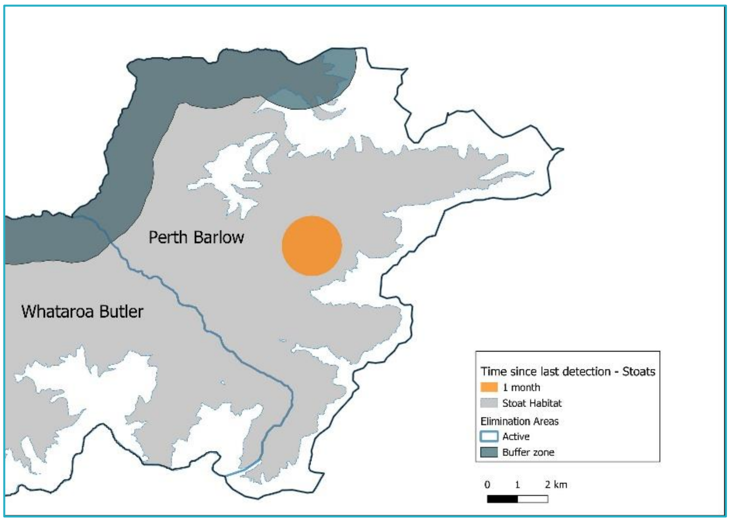
[22] For example, we have observed the shrinking of home ranges in places like the Perth-Barlow, where two survivors found each other, resulting in a few months of inactivity on cameras before being detected again (Cook and Mulgan 2022)



(a) Possums



(b) Ship rats



(c) Stoats

Figure 14 Contaminated area by species (possum (a), ship rat (b), stoat (c)) in the Perth-Barlow block, as at June 2024

Biosecurity implications

Since 2021, there have been nearly annual rat detections in the core zone, within 1 km of Scone Hut. Scone Hut is a popular site for people undertaking recreational pursuits, e.g. hunting, rafting, etc. While it is difficult to know whether these singular detections on cameras are invaders, survivors, or a combination of both; it is clear from increased eDNA, dog searching, and camera detections, they have not expanded into a wider population or a wider area (suggesting that they may be single events, and/or management interventions are working to prevent further spread). We currently assume these animals are invaders, potentially through human movement into the block. This underlines the importance of biosecurity management in areas of human transit, even in extremely remote areas.

Predator elimination results in the wider PFSW project

Using the elimination measures outlined above, the status of the combined Perth-Barlow, Whataroa-Butler, South Ōkārito and Burster blocks as of June 2024 is:

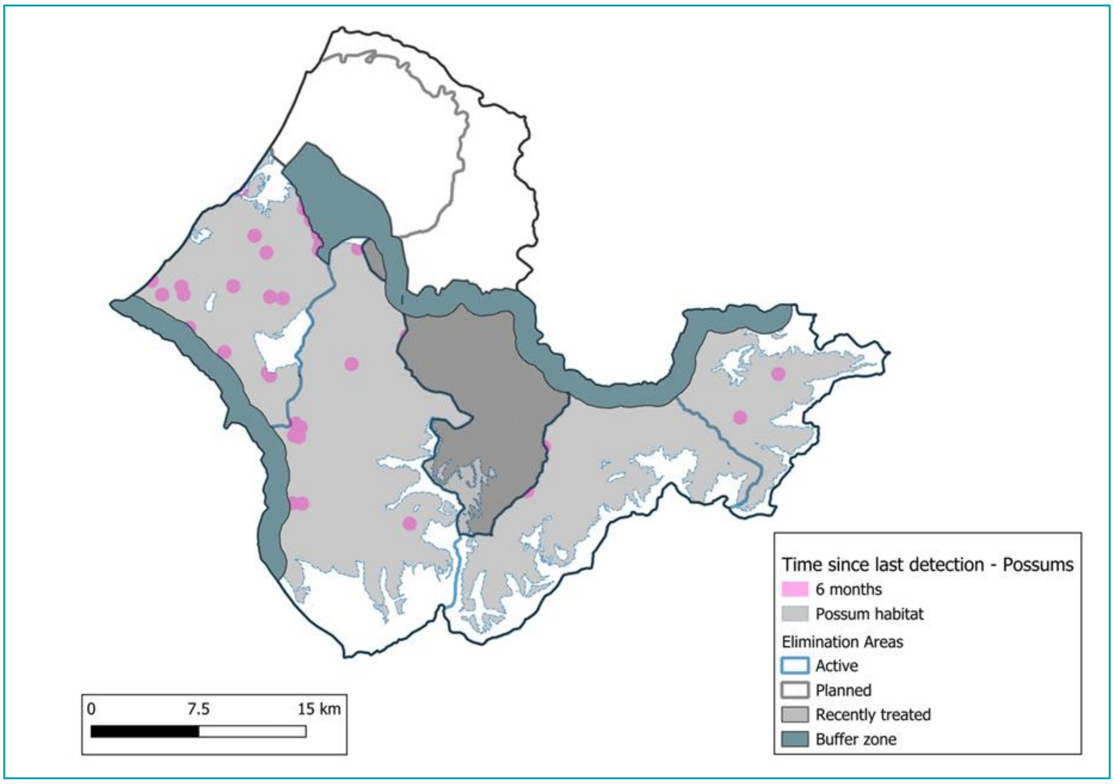
- 83% of the total catchment area of the four blocks is free of possums, ship rats and stoats (that is, 58,536 of 70,433 hectares)
- 78% of available habitat for possums, ship rats and stoats is free of all three species (that is, 43,405 of 55,303 hectares)
    - 95% of the potential habitat for possums is free of possums (that is, 52,716 of 55,303 hectares)
    - 80% of the potential habitat of ship rats is free of ship rats (that is, 32,079 of 39,995 hectares)
    - 92% of the potential habitat for stoats is free of stoats (that is, 50,685 of 55,303 hectares).

The breakdown of the elimination status in core vs buffer zones across all managed sites, as of June 2024, is as follows:

- 96% of the potential habitat for possums in the core zone is free of possums (that is, 46,718 of 48,535 hectares)
- 85% of the potential habitat for ship rats in the core zone is free of ship rats (that is, 28,649 of 33,719 hectares)
- 91% of the potential habitat for stoats in the core zone is free of stoats (that is, 44,265 of 48,535 hectares)

The eliminated and contaminated areas are shown in map form for each species in Figures 15a, 16a and 17a.

Figures 15b, 16b and 17b show the timelines of core detections of each predator species across the four managed blocks. The x-axis shows time before and after the first 1080 to Zero toxin operation corrected to align all blocks for comparison purposes.



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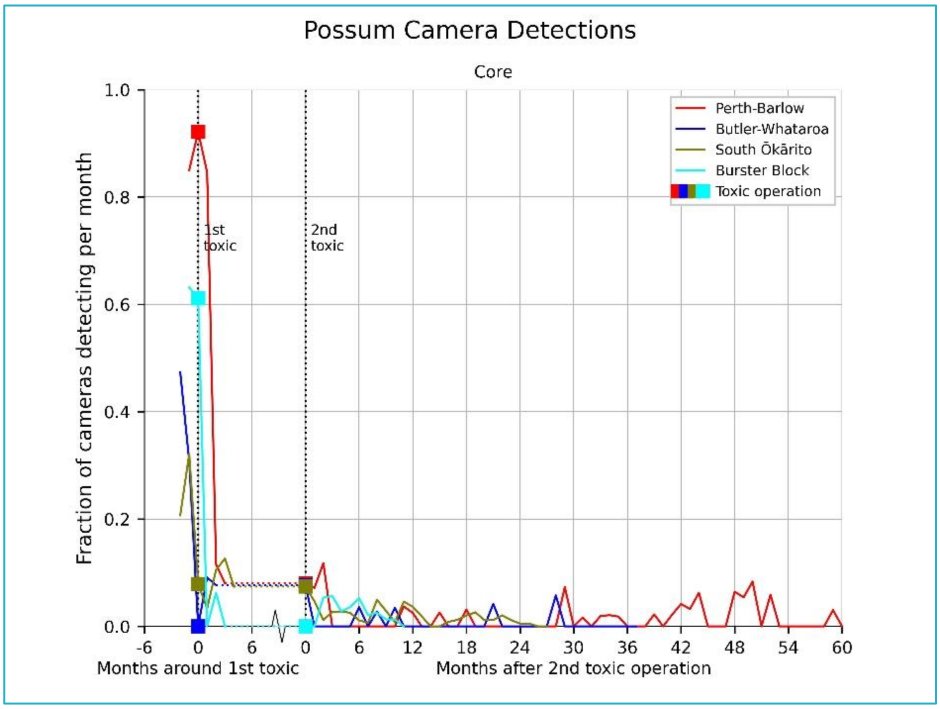
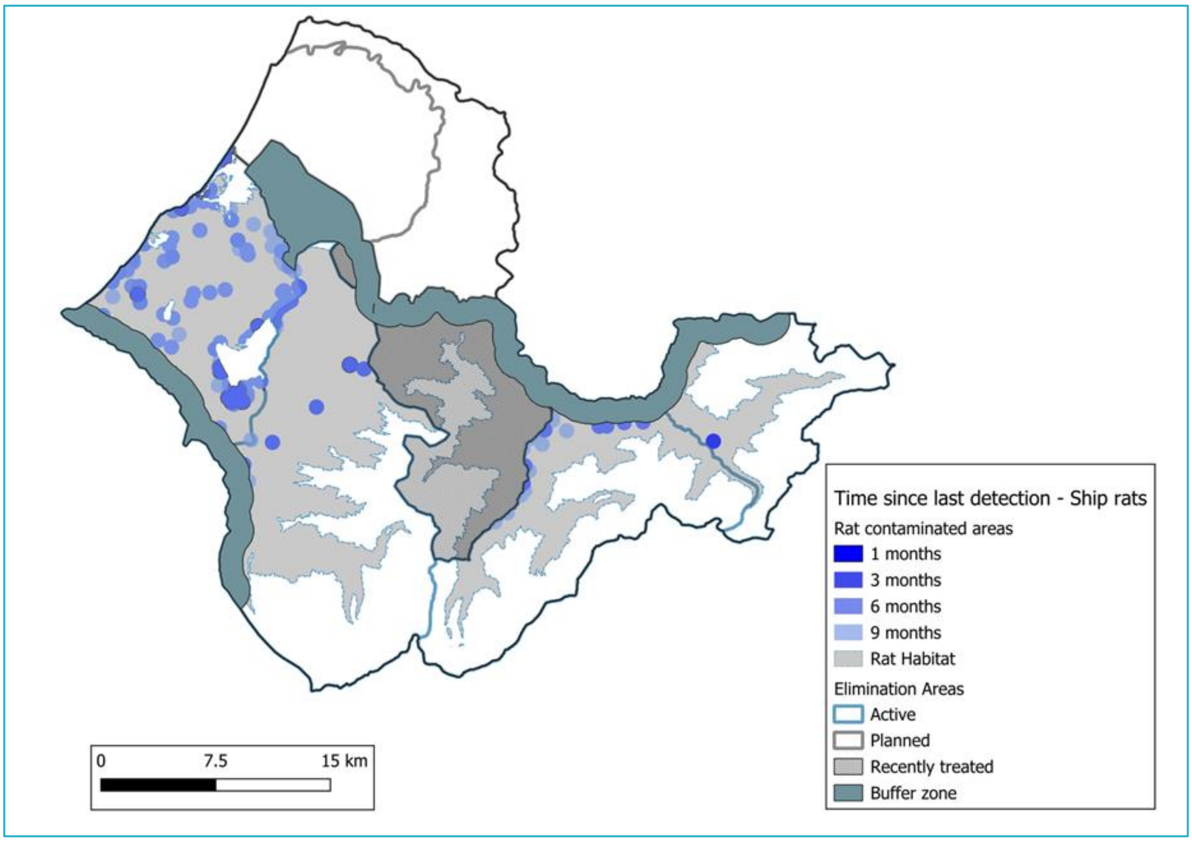


(b)

Figure 15 (a) Eliminated and contaminated areas in the core and buffer zones for possums with the last 6 months (cumulative) shown. (b) Core detection trends from the Perth-Barlow, Whataroa-Butler, Burster, and South Ōkārito blocks up to June 2024.



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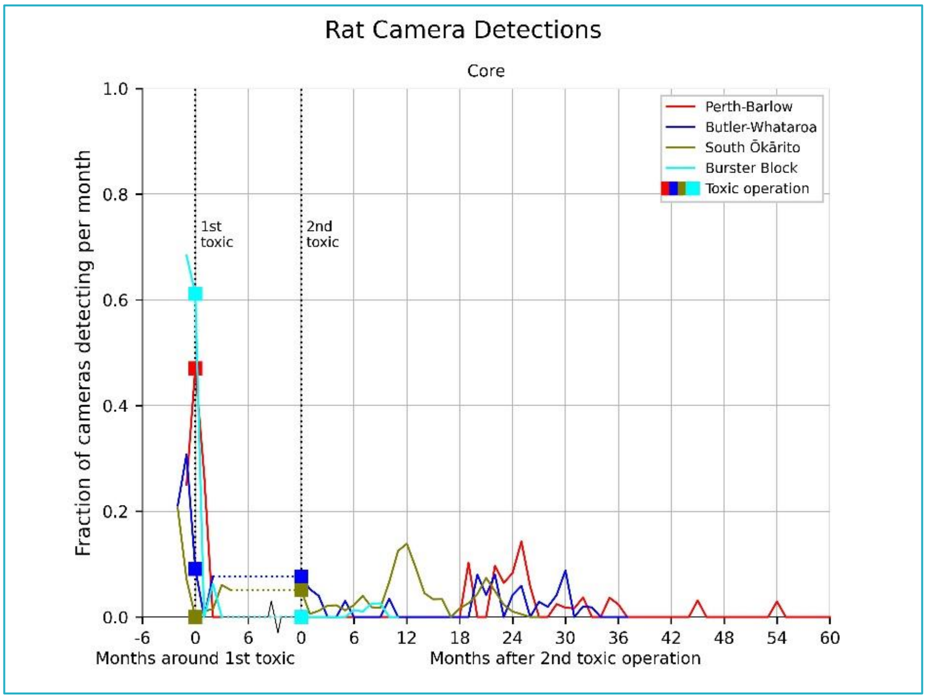
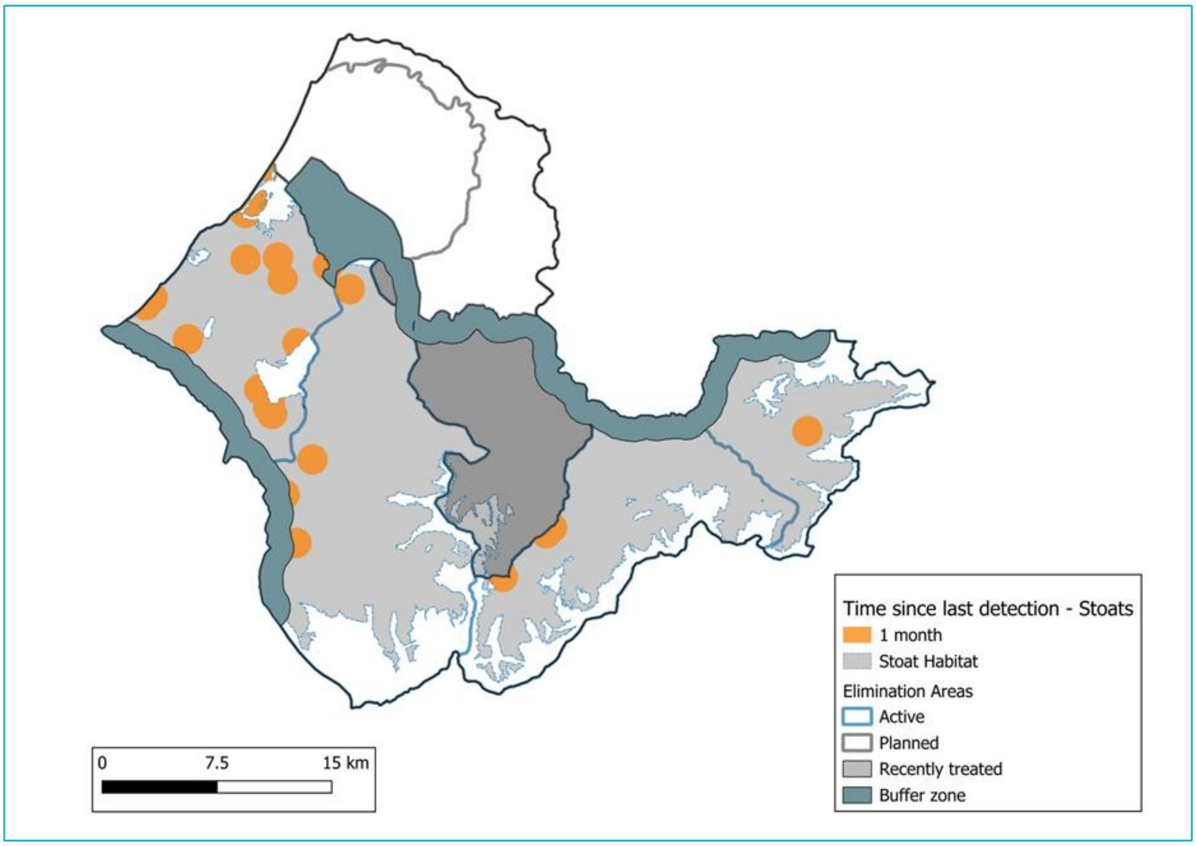
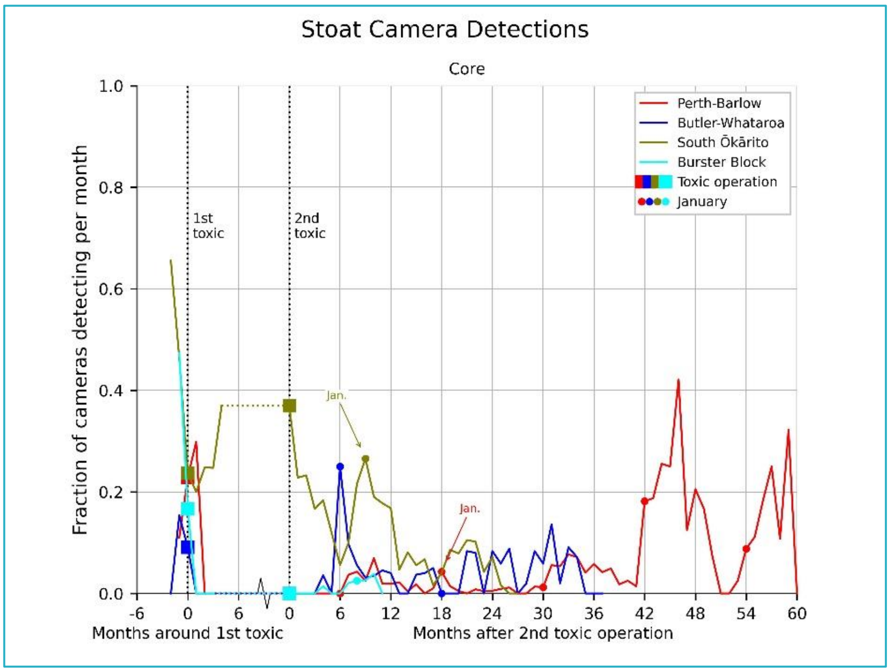


(b)

Figure 16 (a) Eliminated and contaminated areas for ship rats in the core and buffer zones with detection areas shown in 3-month increments (to reflect the rapid response that occurs). (b) Core rat detection trends in the Perth-Barlow, Whataroa-Butler, Burster, and South Ōkārito blocks up to June 2024.



(a)



(b)

Figure 17 (a) Eliminated and contaminated areas in the core and buffer zones for stoats, with the last 1 month shown. (b) Core detection trends in the Perth-Barlow, Whataroa-Butler, Burster, and South Ōkārito blocks up to June 2024.

The current percentage of cameras detecting target species in the core zones of each block (as of June 2024) are shown below.

Table 7 Current percentage of cameras detecting target species in the core zones of each block (as of June 2024)

Block	Ship rat	Possum	Stoat
Perth-Barlow	0%	0%	4%
Whataroa Butler	0%	0%	7%
South Ōkārito	1%	1%	2%
Burster	0%	1%	4%

Outcomes for native species

It is generally accepted that indigenous plants, birds and invertebrates benefit from the control of possums, ship rats and stoats, and that eradication is the most effective regime for achieving such benefits (Binny et al., 2020).

Many conservation projects specify, measure and report on achievement of the 'outcomes' of the project—that is the desired change(s) in the natural heritage of the project area (Department of Conservation, 1999)[23].

In the case of the PFSW project, the level of uncertainty about whether predator elimination was achievable, even as the project was initiated, meant that investment in the project has been largely focussed on implementing the actions required, including developing new knowledge, tools and techniques, to achieve elimination results.

That said, a range of sources indicate the PFSW project is very likely to be achieving beneficial changes in the natural heritage of the project area. The sources include: detections of native birds on trail cameras; records in the Kea Database; and observations by ZIP field rangers, locals, and other people[24]. The strongest evidence of the outcomes of the project are described in this section; other observations are described in Appendix 4.

DOC has recently begun an outcome monitoring programme in the PFSW project area that will track the trends of certain species over the next few years to quantify the ecological benefit of this work.

Native plants

Kiekie

Kiekie (*Freycinetia baueriana* subsp. *banksii*) is a common vine found on the West Coast all the way down to Milford Sound. Kiekie flowers and fruit provide food for short tailed bats, tūī, tauhou and kākā. Māori have many

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[23] For example, achievement of a target to increase the mean canopy foliage cover of Halls totara by >45% by a specified date (Department of Conservation, 1999).

[24] We acknowledge however that informal observations will not provide the same degree of certainty as a carefully-designed research project. That's partly because of the tendency of observers to: see either what they want/anticipate they ought to see or recognise, rather than what is actually happening; forget things or only recall part of what actually happened; or selectively report observations that they believe will be viewed favourably.

uses for kiekie, from food to weaving, and it is specifically listed as a taonga species for Ngāi Tahu[25].

Possums and rats consume the flowers and fruit [as do goats and other ungulates], and consequently, over large parts of its range kiekie is experiencing reproductive failure (de Lange, 2024). Today, the flowers and fruit are not often seen outside of pest-controlled sanctuaries (Predator Free Whangārei, 2022).

Though widespread in the South Ōkārito block, kiekie had not been seen flowering or fruiting for many years. However, after predator elimination work began in 2021, kiekie were observed to flower and fruit around Ōkārito township (Fig. 18) and in the wider block in 2023 (Naish, 2023).

Figure 18 Kiekie flowers (left) and fruits (right) in Ōkārito, around December 2022. **Photos**: Cameron Eddy (left), Chad Cottle (right).

Other native plants

Other native plant outcome observations that reflect the elimination/low numbers of possums and ship rats are:

- Clematis (*Clematis paniculata*), kāmahi (*Weinmannia* racemosa) and fuschia (*Fuchsia excorticata)* have all displayed noticeable prolific flowering over multiple consecutive seasons in the PFSW project area. Kāmahi in South Westland has been identified as one of the most important food species to native bird species studied in O'Donnell et al. (1994).

[25] Ngai Tahu Claims Settlement Act 1998, Schedule 97 – Taonga species.

- Uneaten miro (*Pectinopitys ferruginea*) berries are now a common sight on the ground, especially along river terraces and flats (Fig. 19)
- Supplejack (*Ripogonum scandens*) berries have also been noticed in larger numbers everywhere
- Lots of young rimu and kāmahi regeneration has been noticed in the forests in the South Ōkārito block

Figure 19 Abundant uneaten miro berries on the ground at Nolans Hut, Whataroa-Butler block, 24th May 2023. **Photo**: Chad Cottle.

Photo: Banded kea in the Upper Barlow Valley, Chad Cottle.

Native birds

Kea

Kea (*Nestor notabilis*) is a Nationally Endangered species (Robertson et al. 2021), and introduced predators such as stoats are a major threat to their survival (Kemp et al., 2023). Predator control operations significantly benefit kea populations but unfortunately 1080 also poses a risk to individual kea (Kemp et al., 2019).

Kea is widely recognised as one of the most intelligent of all bird species (Emery 2006, Auersperg 2011, and references therein)[26], with complex behaviours that can make it difficult to generalise population numbers from sample data.

Prior to starting work in the Perth-Barlow block of PFSW, technical experts estimated there could be 18 resident kea. Given the potential increased risk from human-influenced 'scrounge sites', the initial proposed treatment area was reduced and moved further away from Franz Josef, to reduce the potential to interact with human-influenced kea. However, the risk remained relatively unknown to technical experts, as the Perth-Barlow lies ~ 30 km away from Franz Josef, with 'scrounge adjacent' birds defined as

[26] They have many characteristics associated with high intelligence (Emery 2006): being a parrot, being omnivorous, exploiting multiple habitat types, being highly social, having relatively large brain size, maturing slowly, and living long.

resident within 20 km of a scrounge site, and ‘kea living remote from scrounge influenced sites’ > 40 km away (Kemp et al., 2019).

In 2018, 55 kea were banded, and of these, 30 were radio-tagged, in order to assess the survival of kea through the predator elimination (1080 to Zero) operation. From these catching trips, a population of 94 [95% CI; 67, 185] kea was estimated using a Lincoln-Petersen method (Sadinle 2009). The predator elimination operation was due to take place in 2018, but was postponed to 2019 due to heavy snowfall.

In order to mitigate risk to kea, ZIP trialled a novel approach using tahr carcasses to distract and lure kea to alpine sites above and outside the treatment area (Nichols and Bell 2019), combined with non-toxic aversion baits – cereal baits that mimic 1080 cereal baits, containing 2.7% anthraquinone to provide a secondary repellent effect (Nichols et al. 2020). Tahr carcasses proved highly attractive to kea, with 56% of those banded in 2018 visiting sites. Aversion baits proved successful at significantly reducing consumption of cereal baits in captive settings (Nichols et al., 2020). It is difficult to unpick which part of this combined approach has shown the most success (Young et al. 2023; and Yockney et al. 2022). Young et al (2023) used aversion bait in isolation with audio lures and found no improvement in survival over what could be expected for a partially scrounge-influenced kea population. And like Yockney et al (2022) and Nichols and Bell (2019), aversion bait was consumed in relatively small amounts if and when interactions were recorded. However, Young et al (2023) recorded 80% survival of birds that visited aversion baiting sites, and Yockney et al (2022) found no evidence of gross population change on cameras, with a slight increase in kea activity found post-operation with carcasses and aversion baiting.

In 2019, only 14 of the original 30 birds remained in the treatment area of the Perth-Barlow block, with transmitters intact, during the 1080 to Zero operation. The transmitter results post operation showed 12/14 radio tagged kea present in the operational area survived (86% [95% CI: 60%,98%]). Whilst Kemp et al (2019) cautioned that no published survival estimates for radio tagged kea exist for habitat 20–40 km from scrounge sites (such as the Perth-Barlow), we can definitively say that 86% survival is much higher than the lowest recorded standard aerial 1080 operation results for scrounge adjacent birds (56%) and more in line with the lower survival end for remote living kea (90%).

In alpine forests, kea are more easily monitored above the treeline; thus, ZIP is developing a measurement technique that can be used to generate a relative measure of kea abundance without the need to capture, band or VHF tag kea. This technique (known as the kea flock size metric) involves placing a camera in front of each tahr carcass at a standardised distance, recording the maximum number of kea (‘MaxN’) viewed in an image within a fixed time period[27], and averaging the 'MaxN' across all sites and time periods. The sampling is conducted at the same time each year (late August) to reduce seasonal effect on the results. The kea flock size metric is able to sample a larger proportion of the kea population, avoids small sample sizes of transmitter studies which reduce statistical robustness, and removes the bias introduced in banding or transmitter-based studies when more inquisitive birds are captured and tagged. As at June 2024, two sampling sessions have taken place in PFSW, with a third scheduled for August 2024. These sampling sessions have spanned multiple 1080 to Zero operations in the backcountry blocks of PFSW. The kea flock size (MaxN average) has grown from ~3 kea per image in 2021 to ~5.5 kea per image in 2023 (Figure 20).

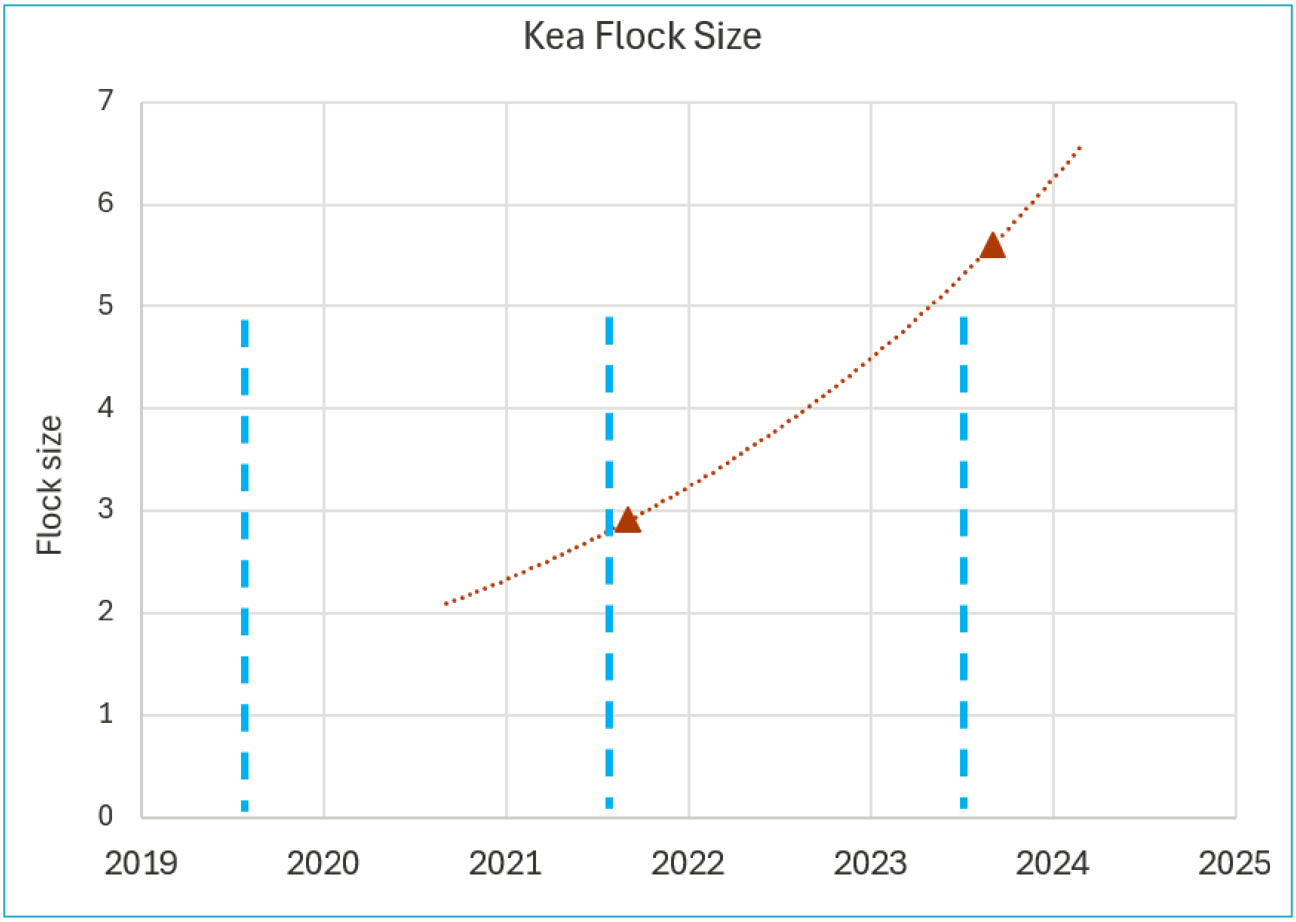


Figure 20 Kea flock size metric for PFSW. Predator elimination operations are shown for each of these blocks in blue dotted lines: Perth-Barlow 2019; Whataroa Butler 2021; and Burster in 2023.

Using the data from the flock size sampling sessions, and proportions of banded to unbanded birds (with a known total number of 373 banded birds

[27] The time period used is 12 hours if sites are spaced ~5 km apart. A rule we derived from movement data from banded birds (ZIP and DOC internal date) to reduce risk of double-counting kea

in South Westland, as of 2023); the current estimate for kea using the alpine areas of the PFSW project area is 450 ± 100 birds.

Within the South Ōkārito block, the percentage of trail cameras and ZIP cameras that detected kea has increased substantially between 2021/2022 to 2024 (Fig. 21).

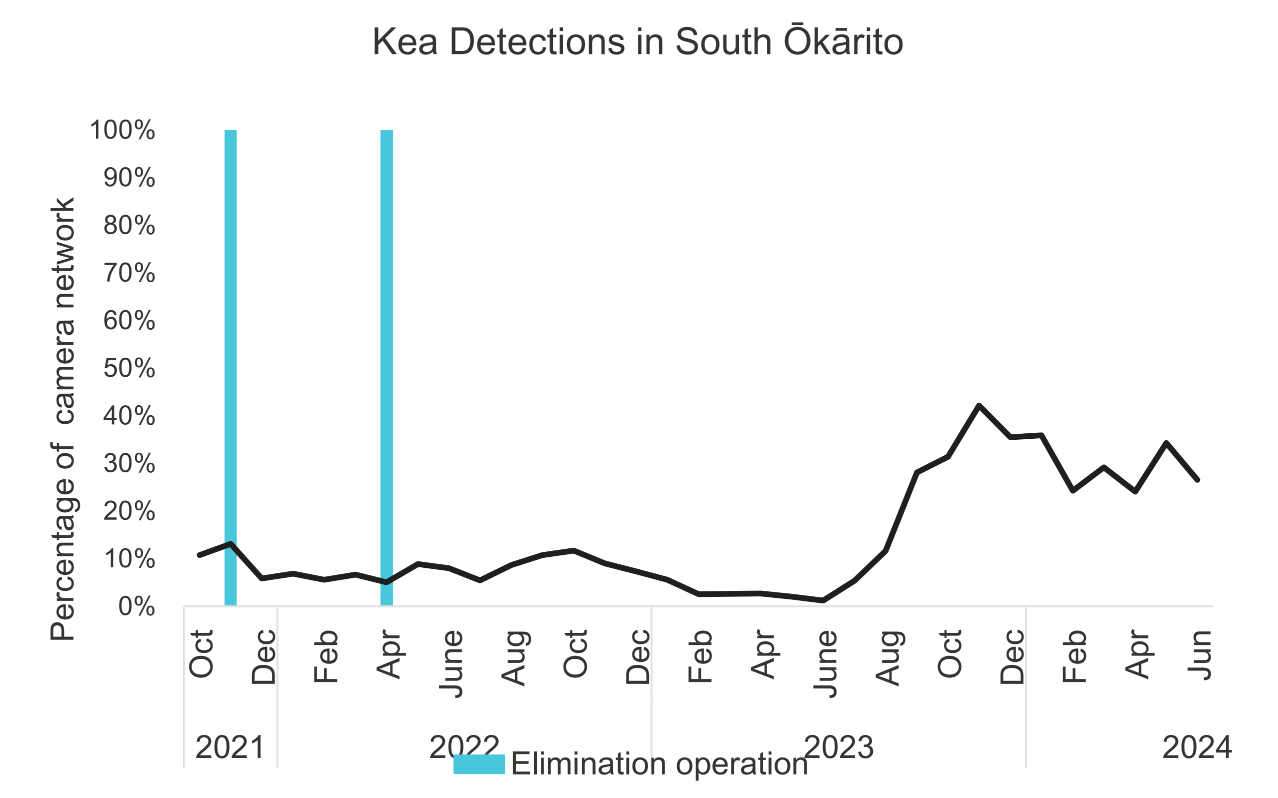


Figure 21 Percentage of cameras that detected kea in South Ōkārito 2021–2024.

The percentage of trail cameras and ZIP cameras that detected kea in the South Ōkārito block during the most recent month of data collection (June 2024) was 27% (Fig. 21). In 2022 (following completion of the predator elimination operation) this was 8%. June/July marks the beginning of the annual breeding season for kea (Kemp et al., 2018), thus these numbers are likely to represent a less active time for this species, as compared to peaks with adults and new fledglings from October/November.

The Kea Survey Tool[28], the DOC and Kea Conservation Trust kea population monitoring tool (and citizen science platform), provides another way to report patterns and changes in kea abundance and distribution in the PFSW project area. It uses the metric of *the chance of a kea encounter per observer per hour* to measure change in kea abundance and spatial patterns over time. An increase in chance of kea encounters

[28] https://survey.keadatabase.nz

per observer per hour within the PFSW footprint would indicate increases in kea abundance over time or before/after elimination.

Using the Kea Survey Tool, kea encounters were compared year on year (2021 to 2023) for each managed block in PFSW using a Fisher's exact significance test (data were not consistently recorded for blocks across the project area before 2021). Data was taken from all kea encounter blocks that fully or partially overlapped the PFSW area boundaries, as it is not possible to get more precise spatial resolution from the data base. As a result, some kea sightings may fall slightly outside of the PFSW area. Sightings are reported for Perth-Barlow and South Ōkārito as alpine and lowland forest examples (Fig. 22).

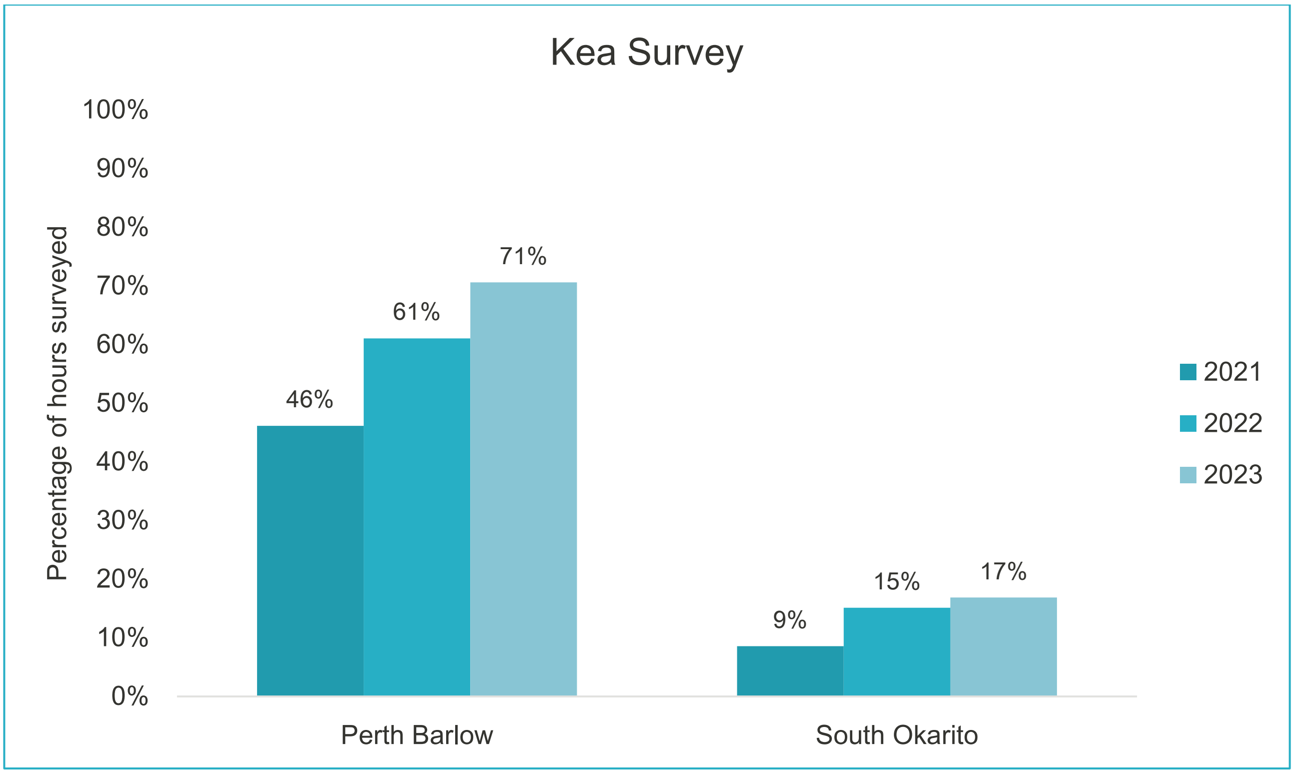


Figure 22 Percentage of hours surveyed with kea present in the Perth-Barlow and South Ōkārito blocks. 2021–2023

The results from a Fishers exact test analysis show a significant increase in kea encounters (comparing 2021 and 2023) in the Perth-Barlow block ($p = .0001$). There has been no statistically significant change in the South Ōkārito block ($p = .1437$), which can likely be attributed to the smaller dataset of kea hours; however, kea encounters in this site almost doubled from 2021 to 2023.

Kea sightings by the public and also by the ZIP team indicate an increase in kea numbers from 2019 to 2024. There has been a noticeable increase in the frequency of observations of large flocks of kea, including juveniles, by the ZIP team: For example, an encounter of 27 kea in the Perth River Valley was captured on video on 28th April 2020; a flock of 16+ kea was seen near the top of Dry Creek on 21st July 2022; and another flock of 28+ birds was seen near Abel Lake on 18th March 2023 (refer to Figure 23). While large flocks of kea can be seen from time to time in the Southern Alps, the consistency of these sightings is promising for the local population.

In 2023, locals in Ōkārito reported that kea have been more active near the coast than ever before.

Figure 23 A flock of kea at Abel Lake, Upper Perth River on 18th March 2023. **Photo**: Carey Lintott.

As noted in Young et al. 2023, it is not possible to attribute the kea population increase in the PFSW blocks solely to the use of tahr or anthraquinone; and it would be incorrect to view risk mitigation techniques in silo from the package of work that is predator elimination. Reproductive success increases following predator control; Kemp et al., (2018) showed kea reproductive rates were significantly higher due to predator control operations, increasing by a factor of 9.1 across Ōkārito (north and south blocks combined); even with a survival rate of 79% through the studied operation. In 2019, a 'double clutching' event occurred at multiple sites in kea habitat across the South Island. That is, where female birds raised two nests of fledglings in a single season. Given this was seen at not only sites in PFSW, but across kea habitat, it is likely there were multiple drivers of this event. However, the combination of all predators removed from the Perth-Barlow block during the 2019 nesting season, the double-clutching event, potential increases in food sources in the absence of pest competition (for kāmahi flowers and other fruiting species), and the expansion of predator elimination across subsequent PFSW management blocks has seen the local population increase substantially.

Korimako / Bellbird, Pīwakawaka / Fantail, Kakaruwai / South Island Robin and Ngirungiru / Tomtit

More than 10 million images in total have been recorded on the network of trail cameras since the inception of the project (up to June 2024). Although set up to detect possums, ship rats and stoats (Nichols et al., 2021; ZIP, 2018), cameras also record native birds that are active in the forest understory (Fontúrbel et al., 2020)[29]. The full list of commonly recorded native birds on trail cameras across the project area is provided below.

Table 8 Native birds commonly recorded on trail cameras across PFSW project area[30]

Native bird species [31]
Korimako / Bellbird (*Anthornis melanura*)
Matuku-hūrepo / Australasian Bittern (*Botaurus novaezelandiae*)
Pīpipi / Brown Creeper (*Certhia americana*)
Kotoreke / Marsh crake (*Porzana pusilla affinis*)
Pūweto / Spotless crake (*Porzana tabuensis plumbea*)
Pīwakawaka / Fantail (*Rhipidura fuliginosa*)
Mātātā / Fernbird (*Poodytes punctatus*)
Kākā (*Nestor meridionalis*)
Yellow-crowned kākāriki / parakeet (*Cyanoramphus auriceps*)
Kea (*Nestor notabilis*)
Kererū / Wood pigeon (*Hemiphaga novaeseelandiae*)
Rowi / Ōkārito brown kiwi (*Apteryx rowi*)
Kōtuku / White heron (*Ardea modesta*)
Ruru / Morepork (*Ninox novaeseelandiae*)
Tītipounamu / Rifleman (*Acanthisitta chloris*)
Kakaruwai / S.I. Robin (*Petroica australis*)
Ngirungiru / Tomtit (*Petroica macrocephala*)
Tūī (*Prosphenadera novaeseelandiae*)

[29] Fontúrbel et al. (2020) compared trail cameras and point counts for assessing forest bird diversity. They concluded a combination of trail cameras and counts provided a more comprehensive assessment of bird diversity than each method in isolation.

[30] Native bird species have also been detected using eDNA across the project area. A full list of native bird species detected using that method is provided in Appendix Three.

[31] This list is generated from the Classifier tool, used to efficiently classify trail camera images using quick key sorting (see https://zip.org.nz/products-list/2022/5/zip-classifier). Any native bird seen not on this list is sorted into a generic 'native non-target bird' folder.

Tauhou / Silvereye (*Zosterops lateralis*)
Weka (*Gallirallus australis*)
Whio / Blue duck (*Hymenolaimus malacorhynchos*)

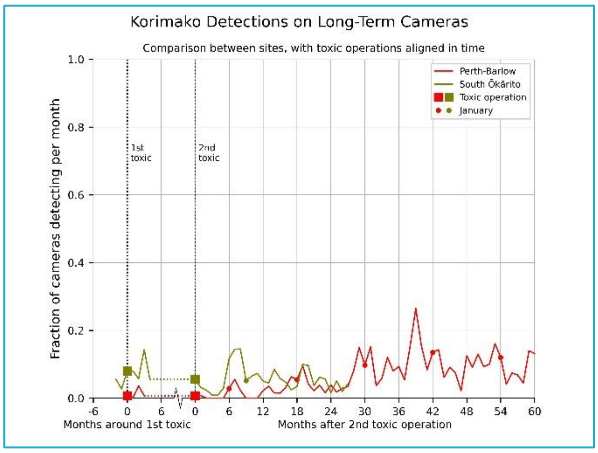
The species that are most frequently recorded on trail cameras across the project area are korimako / bellbird (*Anthornis melanura*), pīwakawaka / fantail (*Rhipidura fuliginosa*), kakaruwai / South Island robin (*Petroica australis*), and ngirungiru / tomtit (*Petroica macrocephala*).

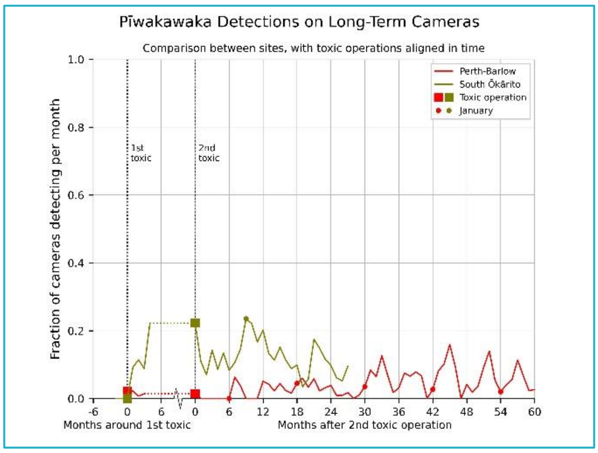
The data presented here has been standardized as much as possible, by using only established cameras (rather than high density response cameras that may be removed from the system with time). However, the camera networks were not completed in some blocks prior to the initial aerial treatment (smaller networks are used to determine coarse indices of target species presence). Additionally, camera monitoring only occurs for one month prior to any elimination operation undertaken in the PFSW project area. Thus, it is not possible to measure seasonal peaks in activity that are typical to each species before aerial treatment. Cameras are not specifically lured for birds; however, it is possible that some species may be attracted to the mayonnaise food lure.

That said, all trends are proportional to numbers of cameras; and cameras that are distributed on a much higher density for sensitive boundaries (such as around human habitation), are excluded.

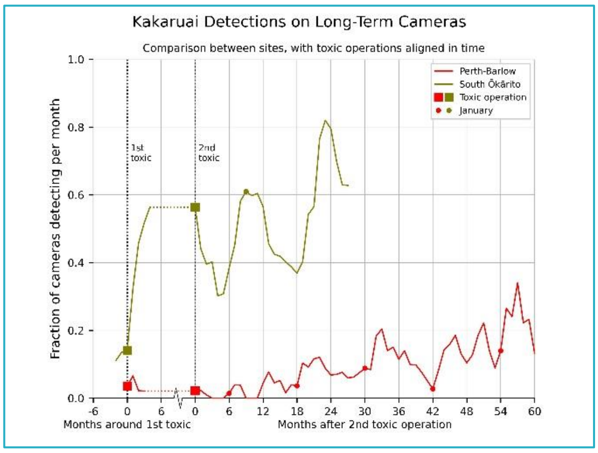
Here we are assuming that over time, the proportion of a network of cameras that detects a species of native bird is indicative of the trend in size of its population.

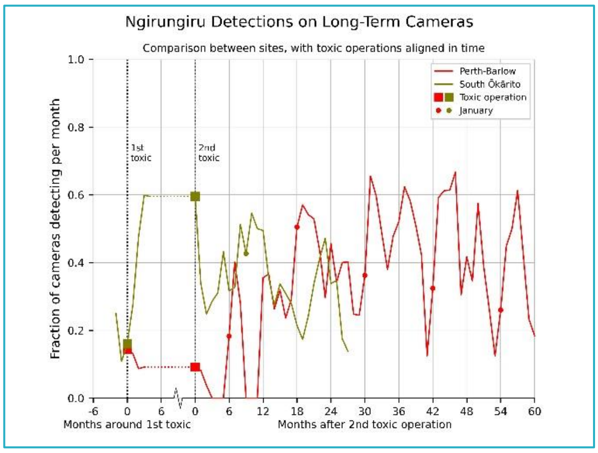
The majority of the networks of cameras in the Perth-Barlow and South Ōkārito blocks are trail cameras, which provide a strong basis for reporting on trend in population size, as shown in Figures 24 a-d. There are no equivalent graphs derived from the camera network in the Whataroa-Butler and Burster blocks, because these networks primarily consist of ZIP cameras. Native bird species are also detected by ZIP cameras, but in general these are hard to distinguish with thermal A.I images. The exceptions are kea (and kākā – although they are very sporadically detected by those cameras), and rowi, which are large and distinctive species that can be reliably identified.





(a) (b)





(c) (d)

Figure 24 Timelines of detections per month of korimako / bellbird, pīwakawaka / New Zealand fantail (a), kakaruai / South Island robin (b) and ngirungiru / tomtit (c) over the period 2019–2024 in the Perth-Barlow block and the South Ōkārito blocks.

In summary, the camera data indicates the following trends in detections of native bird species from before and after the initial predator elimination phase:

- Following predator elimination, summer peaks of korimako / bellbird and pīwakawaka / New Zealand fantail detections show an increasing trend each year in the Perth-Barlow block, between mid-summer and autumn months.
- Following predator elimination, there is an increasing trend of camera detections of kakaruai / South Island robin and ngirungiru / tomtit in the Perth Barlow block, with monthly fluctuations. Indication of a similar increase is occurring in South Ōkārito block now three years post 1080 to Zero operation. Interestingly, the Perth-Barlow detections are dominated by ngirungiru / tomtit, while the South Ōkārito cameras are dominated by kakaruai / South Island robin.

While it is difficult to know the exact drivers of seasonal peaks in forest bird activity, we know that in the South Westland forests, flowering and fruiting generally occurs between September and March (O'Donnell and Dilks, 1994). This coincides with typical breeding seasons of most species discussed here (Innes et al., 2022). We can speculate that summer/autumn peaks in activity seen on cameras is a result of both recruitment, and pursuit of seasonally available food within site. As described in Innes et al. (2022), the peaks may in part also be due to natal dispersal[32] of species from across the project area and beyond.

As of June 2024, the Department of Conservation has begun annual bird counts and other outcome monitoring in the North Ōkārito block (prior to 1080 to Zero aerial treatment). This work will allow further comparison with cameras that incidentally detect the above bird species.

Rowi

Rowi / Ōkārito brown kiwi (*Apteryx rowi*), New Zealand's rarest kiwi species, has a conservation status of 'Nationally Vulnerable'. With a total population of less than 1,000, rowi are found exclusively in the Ōkārito Sanctuary (within PFSW) and in the Omeroa Range (immediately south of PFSW) on the West Coast. Predation by stoats saw rowi numbers plummet until the 1990s when DOC intensified its conservation efforts to prevent extinction. Through predator control and initiatives like Operation Nest Egg, the rowi population has stabilized, although they remain highly susceptible to stoats even at extremely low densities (https://www.nzconservationtrust.org.nz/).

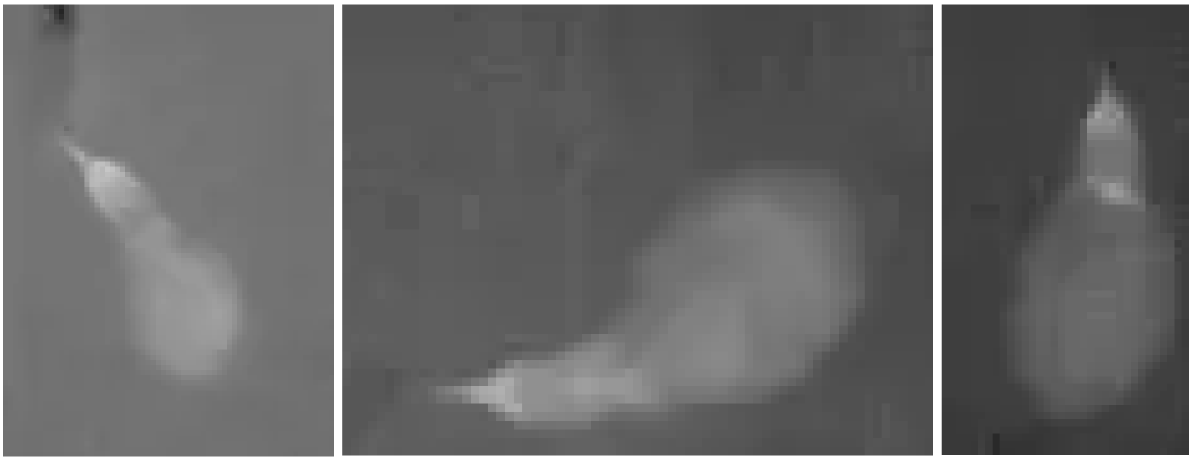


Figure 25 Rowi detected on ZIP cameras in the South Ōkārito block.

Rowi are regularly detected on trail and ZIP cameras in the South Ōkārito block (Fig. 26). The percentage of trail cameras and ZIP cameras that detected rowi in the South Ōkārito block during December 2021 was 16%, in December 2022 it was 10%, and in December 2023 it was 21%.

[32] That is, the movement from the birth site to the first breeding site.

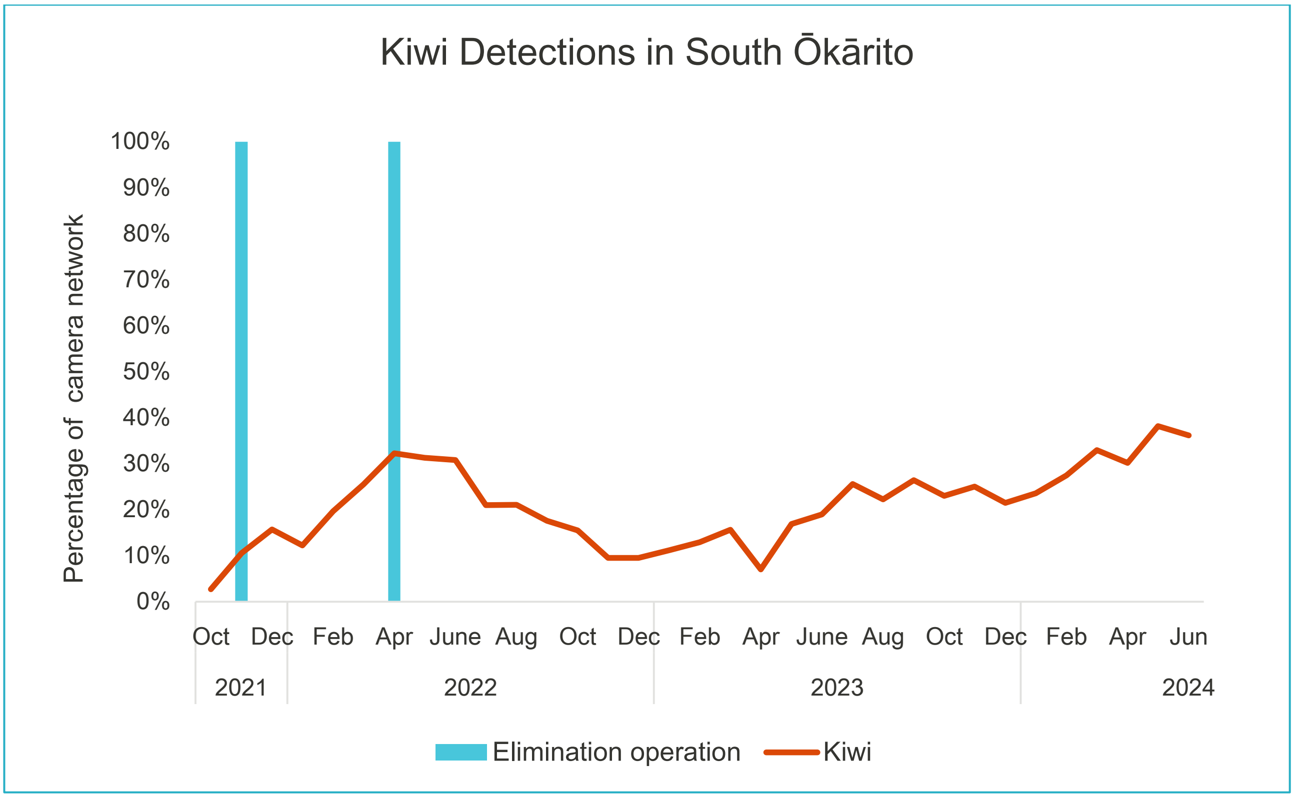


Figure 26 Percentage of cameras that detected rowi in the South Ōkārito block, 2021–June 2024

The month prior to the 1st toxic operation shows very few detections. This is most likely an artificial result due to rowi being less active during the breeding season, and the relatively low-density camera network (1 per 250 hectares) at that time, before the camera density was increased (to 1 per 35 hectares) post operation. As with all bird species recorded on cameras here, the changes in detections may be due to a variety of environmental and behavioural factors. Consequently, we can't explain the dip in rowi detections after the second toxic operation—nevertheless, the dip was temporary. Rowi have relatively slow breeding rates, and thus increases in population size are expected to be gradual.

Rowi / Ōkārito brown kiwi chick survival in the wild is typically low, largely due to stoat predation, even when stoats are at low densities. The Ōkārito Sanctuary has been the site of an extensive egg-hatching and chick-rearing program since the mid-1990s. Over the past few years, DOC has monitored rowi chicks in situ, in order to help understand the impact of the predator elimination activities by ZIP and develop a population growth model. Modelling has demonstrated that to maintain the population, chick survival to 6 months old should be 13%, and 26% chick survival will achieve the population increase target of 2% per annum (the national target for kiwi).

Prior to the rowi monitoring work done alongside the ZIP predator elimination operations, only 22 wild hatched rowi successfully reached six months of age in all the years of intensive work on this species. Two out of the last three years (to 2023/24 season) have seen chick survival to 6 months old of over 50% in the South Ōkārito block of the PFSW project (Table 9).

Table 9 Stoat predation results from monitoring of rowi chicks in the predator elimination managed area of the Ōkārito Sanctuary (Department of Conservation, 2024).

	2021/2022	2022/2023	2023/2024
Number of chicks monitored	11	22	18
Mustelid predation	2	9	1
Mustelid predation likely	-	6	
Rowi deaths by other causes	3	4	5
Number of chicks that survived 6 months	6	3	11
Survivorship in the South Ōkārito block	55%	14%	61%

As at June 2024, only one of the chicks from the 2023/24 breeding season have died due to stoat predation in the South Ōkārito block, which is likely to be due to a combination of the results of aerial 1080 spot treatments (which targeted rats, but removed stoats via secondary poisoning), ZIPinn trapping, and the deployment of rodent carcass baits.

Kākāriki

The PFSW project area is a home to yellow-crowned kākāriki (hereafter, referred to as kākāriki), which are rare or uncommon in most places on the mainland. This species has a threat classification of At Risk – Declining. The presence and abundance of kākāriki is often a good natural indicator of the overall health of a forest or ecosystem (McLennan, 2017). There appears to be no record of kākāriki from DOC's tier one monitoring (5 min bird counts) across monitored plots in the PFSW project area between 2018 and 2021.

In 2018/19, kākāriki were rarely seen by the ZIP team in the Perth-Barlow block. Since the completion of predator removal in 2020, the ZIP team has regularly seen flocks of kākāriki calling and flying overhead in the Perth-Barlow and Whataroa-Butler blocks (particularly in the upper Barlow River area).

The increased sighting of kākāriki is particularly significant as the ZIP field team spend much less time in the Perth-Barlow and Whataroa-Butler blocks these days, but still regularly see large numbers of kākāriki there. For example, 23 kākāriki were seen in the lower Perth River around Hughes Creek in September 2023.

Figure 27 Kākāriki, seen in a flock of 15 birds in Upper Barlow Swamp, 24th May 2023. **Photo**: Bradley Shields.

Prior to 2022, kākāriki were observed in the forest canopy; since then, our trail camera network (which is effectively looking at the forest floor) has begun recording them (refer Figure 28). Typically, kākāriki in South Westland are observed foraging in the canopy (O'Donnell et al., 1994); so, it may be unique to record them on cameras on a forest floor. In addition, a pair of nest-searching kākāriki were seen in the Burster block in July 2023, which is an area where kākāriki sightings are rare.

Figure 28 Kākāriki detected by trail cameras, September 2022.

Increased observations of kākāriki are not just limited to the remote Perth-Barlow and Whataroa-Butler blocks. Since mid-2023, kākāriki have been heard calling from Ōkārito Township and in the vicinity of the nearby Ōkārito Trig Walk by both members of the ZIP team and locals. For example, an Ōkārito local reported that on Christmas Day 2022 he had, for the first time in 24 years of living there, seen kākāriki (Ian Cooper, pers. comm., 27 December 2022). A feature article in the Grey Star (28 May 2024) highlighted the 'return of the kākāriki', citing numerous locals in Ōkārito who reported significant positive change in the number of kākāriki sightings in the area.

Karoro

Karoro, otherwise known as southern black-backed gulls (or 'black-backs') are one of the most abundant and familiar large birds in New Zealand. They occur in open habitats from coastal waters to sub-alpine areas, and are common around landfills and ports.

It is generally recognised that a risk of using toxins to control introduced predators is that native birds may occasionally also be harmed. Consequently, 1080 operations are carefully planned and managed to minimise the loss of non-target species, particularly threatened native species.

In November 2021, during a PFSW aerial 1080 operation in the South Ōkārito block, approximately 550 karoro died as the result of consuming poison bait.

The ZIP team was shocked and saddened by the deaths of these birds, and we acknowledge the upset this incident caused for mana whenua Te Rūnanga o Makaawhio.

The ZIP review of the incident found the primary cause of this incident was a lack of general knowledge about the vulnerability of karoro to 1080 cereal baits. In addition, ZIP was also unaware of the presence of karoro colonies on the extensive Waiau riverbed.

DOC audited ZIP's compliance with the conditions of the permissions associated with the operation. The audit concluded that, with the exception of not providing some minor details in some post-operation reports, ZIP fully complied with the conditions of the permission to apply 1080 bait.

ZIP minimised the risk of further deaths of karoro during subsequent aerial 1080 operations, by: (i) undertaking an aerial survey of the riverbed to identify the locations of any bird colonies, and (ii) using trickle sowing and hand-laying techniques to enable bait to be precisely applied in areas of rat habitat (and thereby minimise the quantity of bait on the riverbed).

Fortunately, while this incident had a significant short-term impact on the local karoro colonies, it had very little impact on the national population of more than one million birds.

Comparison of bird observations with outcomes documented elsewhere

Several studies have documented biodiversity outcomes of pest management actions undertaken at landscape-scale predator suppression sites, predator-free fenced sanctuaries, and off-shore islands (Jones et al., 2016; Binny et al., 2020; Byrom et al., 2010; Innes et al., 2019; O'Donnell and Hoare 2021)[33]. It should be noted that ecological recovery can take time. Recovery times can range from a few years to decades depending on habitat and species characteristics (Walker et al., 2021). In many of the blocks of PFSW, it is still early days in terms of ecosystem recovery.

Table 10 compares some of the documented outcomes for native birds with what has been observed in the PFSW project area.

Table 10 Comparison of indicators of the benefits of the PFSW project with outcomes observed at other ecological restoration projects in New Zealand.

Biodiversity Outcomes	**PFSW Observations**
1. 'Deeply endemic' bird species have higher recovery rates than 'least deeply endemic' species in	There has been an increase in sightings of the following deeply endemic species: kākāriki /

[33] However, there is currently no information on the biodiversity outcomes of pest management actions undertaken at unfenced landscape-scale (> 10,000 ha) predator-free sites, that we can compare with the PFSW project.

eradication-focussed ecosanctuaries (Binny et al., 2020)	yellow-crowned parakeet and kea. Also of the less following endemic species: tūī, korimako / bellbird, and kererū / New Zealand pigeon.
2. Large endemic species, such as kererū / New Zealand Pigeon responded positively at the population level to mammal control (Fea et al., 2021)	There has been an increase in sightings of kererū / New Zealand pigeon, particularly in the Perth-Barlow block. More recently (February 2024), flocks of approximately 25 birds have been seen moving across the South Ōkārito block.
3. Kakaruwai / South Island robin apparently benefit from pest mammal eradications (Miskelly et al., 2021)	The camera network indicates an increasing detection trend of kakaruwai / South Island robin in the Perth-Barlow and the South Ōkārito block.
4. Ngirungiru / tomtit appear to do better in the absence of predatory mammals, and were recorded more often after eradications (Miskelly et al., 2021).	The camera network indicates an increasing detection trend of ngirungiru / tomtit in the Perth-Barlow and initially in the South Ōkārito block (competition by robin may be a factor here).
5. Pīwakawaka / New Zealand fantail appear to do better with the removal of predatory mammals (Miskelly et al., 2021)	The camera network indicates initially an increasing detection trend of pīwakawaka / New Zealand fantail in the Perth-Barlow and South Ōkārito blocks, but again, competition may be a factor.
6. After several years of sustained eradication-focussed control managers can expect populations of introduced bird species to decline (Binny et al., 2020)	No observations of this to date, nor have we analysed trail camera data to determine whether this is indeed the case.
7. Dijkgraaf (2002) found encounters with frugivorous birds in particular increased following suppression operations; and surmised this was likely due to an increase of available, uneaten ripe fruit.	Frugivorous birds of South Westland include kererū / New Zealand pigeon, korimako / bellbird, kākāriki / yellow-crowned parakeet, tauhou / silvereye, kākā and tūī (O'Donnell and Dilks, 1994). There has been an increase in sightings of kererū / New Zealand pigeon, korimako / bellbird, and kākāriki / yellow-crowned parakeet.
8. Rowi kiwi survival rates should increase in the absence of predators, and in turn the population should grow	Not only are rowi being seen increasing on the South Ōkārito camera network, detections have been found as far as the Whataroa River (Price boundary) and further into North Ōkārito than previously seen

Benefits and Significance

To date, the PFSW project has delivered four main benefits:

1. Demonstrated that predator elimination is achievable at the landscape scale on the mainland of Aotearoa New Zealand
2. Enhanced the ability for nature to thrive in the project area, and provided opportunity to reintroduce species that were formerly present – improving the resilience of the ecosystem
3. Developed new tools and techniques that can be used for a wide range of conservation management purposes (i.e. not just to eliminate predators)
4. Identified the critical factors that underpin a successful landscape scale elimination project.

Predator elimination is achievable

Until the mid-1960s, it was unknown whether it was possible to eliminate predators from off-shore islands. Since then, through the efforts of many people, predators have been eliminated from many, increasingly larger, offshore islands; the largest in Aotearoa New Zealand is Campbell Island *Motu Ihupuku*, which is 11,300 hectares.

In 2016 the Government adopted the goal for New Zealand to be Predator Free by 2050. At that time, elimination on the mainland had been achieved at relatively small fenced and partly fenced eco-sanctuaries; the largest is Sanctuary Mountain Maungatautari, which is 3,400 hectares. Whether elimination could be achieved at landscape scales, with at most only very limited use of fences, was unknown.

It has been five years since work began to eliminate predators from the PFSW project area. In that time, it has become apparent that elimination is indeed possible at the landscape scale on the mainland of Aotearoa New Zealand.

Within the PFSW project area, the Perth-Barlow, Whataroa-Butler, South Ōkārito, and Burster blocks are being managed to prevent predators from re-establishing in the blocks. These four blocks cover a total of 70,433 hectares (65% of the PFSW project area). As of June 2024, 83% of the total catchment area of the four blocks are free of possums, ship rats and stoats (that is, 58,536 of 70,433 hectares).

For context, the seven ring-fenced and partly-fenced eco-sanctuaries in Aotearoa New Zealand total 10,297 hectares (Innes et al., 2019).

While the measures of elimination are still being refined, and we continue to learn and optimise elimination methods with each new block, it is clear to us that PFSW is demonstrating what predator elimination looks like on the mainland. That being, the removal of the resident predator populations and then the constant management of incursion (constant detection and targeted response) to maintain a ‘predator-free’ core where re-emergent populations of predators cannot persist. With work ongoing in PFSW (e.g. North Ōkārito and Whataroa blocks to be completed in 2025), we expect to further enhance our ability to maintain predator elimination and grow the predator-free core of the project area.

There is always a risk that possums, ship rats and stoats may incur into the predator-free areas. However, incursion is a risk that also applies to other predator free areas such as ecosanctuaries and offshore islands (Connolly et al., 2009; Innes et al., 2019; Russell et al., 2010; Elliott et al., 2010). As the protected core zones expand, with adjacent management blocks treated across PFSW, the scale of predator-free zones will increase, and the risk of incursion deep within these core zones will decrease.

Enhancing natural resilience

Owing to the very limited investment in outcome monitoring, it is not possible to scientifically conclude (Allen et al., 2023), that the native plant and animal observations described in this document are due to the results of the actions undertaken to eliminate predators from the PFSW project area.

Towns et al. (2018) describes the eradication efforts on Mercury Island in terms of increasing *resilience* – the system’s ability to recover from disturbance, which has biological, social and cultural factors. This summarizes the objectives of the PFSW project efforts well.

The observations seen in PFSW and reported here are consistent with those seen at other eco sanctuaries such as Zealandia and Kapiti (Innes et al., 2019). Increases in both camera records and anecdotal observations of fauna such as kakaruwai, kākāriki, and rowi, and flora such as kiekie and kāmahi are consistent with the responses seen from pest density-impact functions outlined by Norbury et al. (2015).

Given the risk that 1080 poses to individual kea (Kemp et al., 2019), it is notable that the kea population in the Perth-Barlow, Whataroa-Butler, South Ōkārito, and Burster blocks does not appear to have declined, and is very likely growing. This is despite the use of aerial 1080 in operations to remove predators from across these blocks, and repeated targeted aerial treatments to prevent remaining or invading ship rats from establishing in blocks.

Landscape-scale, unfenced predator-free areas such as PFSW are potentially useful habitat for native animal species that have been translocated from other areas. In January 2024, twelve whio were released into the upper Perth Valley and Whataroa catchments. This translocation significantly increases the former whio population. Increasing the size of these predator-free areas may even allow some of the most vulnerable native species (such as kākāpō) to be introduced with minimal risk of stoat predation.

Photo: Whio in the Perth Valley, Naomi Aporo.

Developed new tools and techniques

Achieving the results and outcomes outlined in this Impact Report required dedicated investment in research and development, above that provided for operational implementation. That funding enabled ZIP to build an integrated team of complementary skills and expertise, to focus on developing the necessary toolset. Based on an R&D philosophy of 'try-sense-respond', this team has been able to successfully prototype, test, refine, and implement new knowledge and tools within the PFSW Project.

Some of the tools and techniques developed by ZIP to achieve elimination in PFSW include:

- an aerial 1080 technique ('1080 to Zero'), that reliably removes 99.9% of all possums, ship rats and stoats
- a kea risk mitigation approach utilising tahr carcasses, aversion bait, and strategic deployment of 'mitigation stations' that, when used in 1080 to Zero operations, appears to reduce the risk to the kea population (compared to the existing risk assessments at the time of those operations)

- a truck platform for drone sowing operations that enables bait to be sown efficiently
- remote reporting communication systems, that notify the team that predators have been detected or trapped
- a low-powered remote-reporting camera, that uses artificial intelligence to classify predators that it detects (described on page 20)
- an automated liquid dispenser, used to lure, prefeed, or biomark target animal pests (described on page 23)
- an effective ship rat and stoat trap (‘ZIPinn’), that eliminates escapes and does not damage the carcass of the trapped animal (described on page 23)
- a rodent-specific bait station, that keeps toxic baits fresh and minimises risk to non-target species
- rodent carcass baits (a targeted stoat response tool), that mimic the secondary poisoning effects of aerial 1080 operations on stoats but can be deployed in a targeted fashion (without the need for the aerial operation itself)
- an image classification tool (software), that makes it easier and more efficient to manually review trail camera footage.

Identified the critical success factors

Four fundamental factors underpin the success to date of the PFSW project:

1. Establishing a presence within the local community. Building genuine relationships with resident landowners and businesses based on trust and mutual respect, which provides the opportunity to adapt plans and implement actions that reflect the values of those people and the community.
2. Being embedded in the elimination work at place. Gathering the critical understanding of the context and the challenges, enabling an agile and grounded response, including through the development of new tools and techniques.
3. Having a high calibre team with wide-ranging capabilities, who are: closely connected and support each other and others that they work with; willing to work hard; and comfortable with adapting to new challenges, often at short notice and with limited or emerging data/information at the time.
4. Having the trust and confidence of partners and funders to remain alert to opportunities and responsive to grasp them, without a constraining administration burden.

A note on cost

The PFSW Project has a $47.3M total budget to fund the elimination of predators from 107,000 hectares within the project footprint – approx. $450 per hectare. This budget covers all elements of the project, including predator elimination activities, maintaining the predator-free status of each block as the project progresses, and the research and development undertaken along the way. The project has been implemented by ZIP, who have built and maintained the capability and capacity to operate this landscape-scale project within this funding envelope.

Based on lessons learnt, the track record of success, and expected R&D improvements, if the PFSW project was to be initiated now, we forecast it would cost $400 per hectare – a total budget of ~$42M. This per hectare cost (which includes staff time) is roughly broken down to:

- $110 for detection network establishment and maintenance
- $160 for 1080 to Zero (and associated kea risk mitigation)
- $130 for survivor mop up and initial incursion management/response

The PFSW Project is a project that will sit under the 'Tomorrow Accord'; an agreement between philanthropy and the NZ Government which states, if philanthropy contributes significant funding to the initial implementation of 'transformative' ecological projects, the Government agrees to assume responsibility for maintaining those gains into the future. Maintaining the PFSW Project as predator-free is forecast to cost $30-$40 per hectare for the first year after completion. Ongoing R&D effort is focussed on driving that cost as low as possible, to ensure a sustainable future for the project's legacy.

Final Comments

Predators have been established on mainland Aotearoa New Zealand for a long time, and our biodiversity is in crisis as a result.

The PFSW project has demonstrated that elimination on mainland Aotearoa is possible, making significant progress towards the elimination goal across the full project footprint over a period of little more than 5 years. There is still a lot to learn (especially around maintaining predator elimination), and development of new tools and techniques will be needed to continue refining and optimising elimination methods, and adapt to changes beyond our control. A recent example of this was the sudden reduction in capacity of the SWARM satellite network used to transfer data from ZIP cameras (as a result of strong solar flares emitted by the Sun).

ZIP is confident however that we will innovate, develop and adapt solutions to these recent challenges, just as we have done to resolve other previous ones.

Rats regularly incur across the Perth and Barlow Rivers, which are the boundary to the Perth-Barlow and Whataroa-Butler blocks. Consequently, this results in relatively frequent spot treatments. To reduce this pressure, we are investigating a proposal to expand into the Upper Whataroa catchment (~9000ha) which lies outside the current PFSW boundary, in order to reduce the cost of preventing ship rats from re-establishing in the core PFSW project area.

The Actions section (page 23) advised that, ideally, the ZIP 4-step approach to elimination would be repeated in an adjacent landscape-scale area, in order to increase the size of the core zone and reduce the ratio of length of the boundary vulnerable to predator incursion relative to the size of the total area. A potential next step for a predator-free Te Tai Poutini South Westland would be to expand the current PFSW project southwards, to the strong natural boundary provided by the Weheka Cook River; an additional area of ~65,000 hectares.

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Appendix 1: A Note About Mice

The camera network detects mice (which are not a target species of the PFSW Project). The main results are briefly summarised here.

Detections have increased in the Perth-Barlow, Whataroa-Butler, South Ōkārito, and Burster blocks after completion of the 1080 to Zero operations, as shown in Figure 29.

However, it is interesting to note that pre-operation mouse occupancy was highest in the Burster block prior to the 1080 to Zero operation there (corresponding with the peaks in other sites at the same time). This suggests there were other drivers of mouse abundance (aside from the removal of ship rats, possums, and stoats) in the system in the 2023 season.

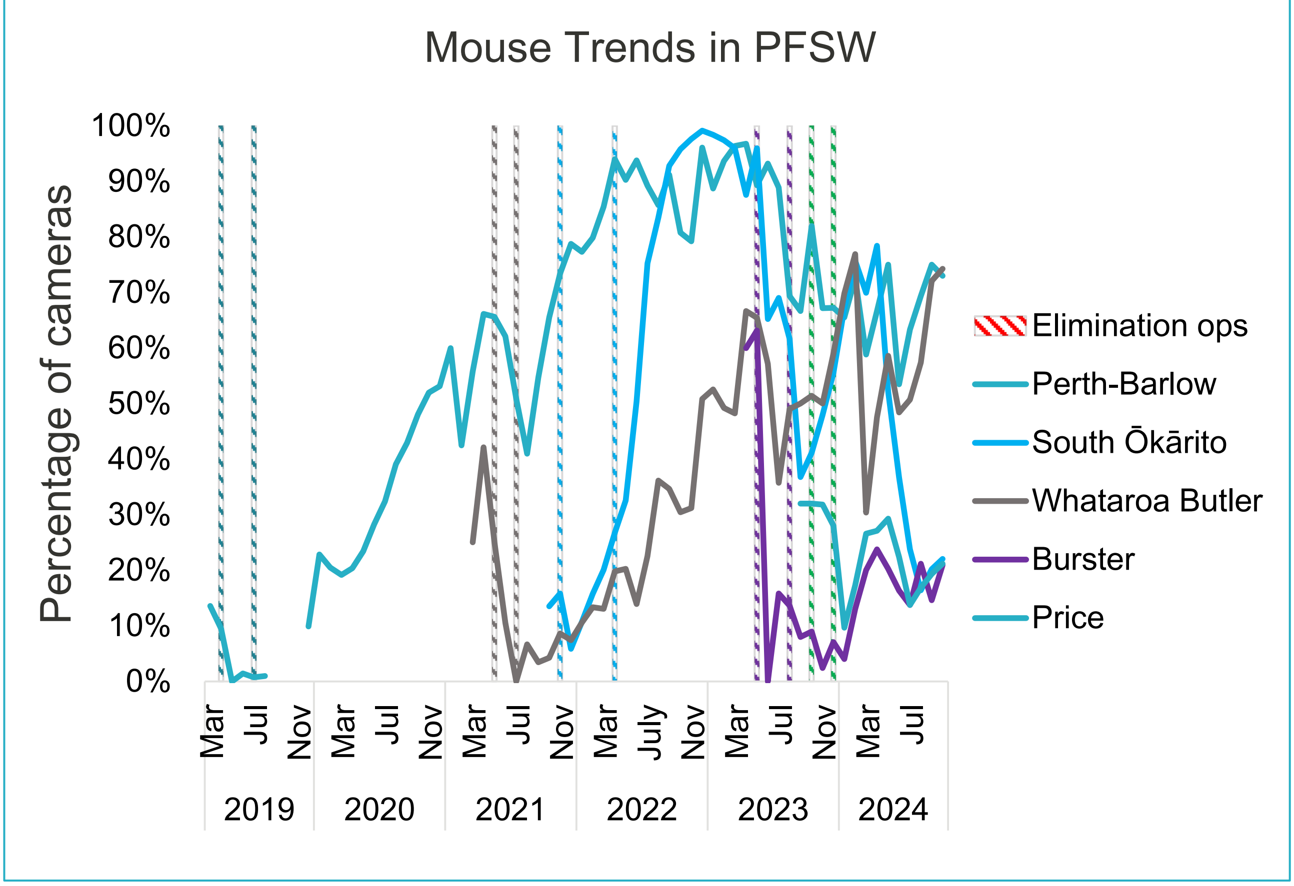

Figure 29: Timelines of mouse detections in the Perth-Barlow, Whataroa-Butler, South Ōkārito, and Burster blocks. Elimination operations correspond in colour with each of the different blocks. Note, there is a data gap in the Perth-Barlow trends Aug.–Dec. 2019.

Appendix 2: Correspondence of LCDB cover classes

Merged Cover Class shown in Figure 2	LCDB Cover Class(es)	
Indigenous Forest	54 69	Broadleaved Indigenous Hardwoods; Indigenous Forest
Indigenous Wetland	45 46	Herbaceous Freshwater Vegetation; Herbaceous Saline Vegetation
Indigenous Scrub	47 50 52 58	Flaxland; Fernland; Manuka or Kanuka; Matagouri or Grey Scrub;
Sub-Alpine Scrubland	55	Sub-Alpine Shrubland
Tall Tussock Grassland	43	Tall Tussock Grassland
Alpine Grasses	15	Alpine Grass / Herbfield
Built-Up Area	1 3 2 6	Built Up Area (Settlement); Transport Infrastructure; Urban Parkland / Open Space; Surface Mine or Dump;
Exotic Vegetation	30 40 41 51 56 64 68 71	Short-Rotation Cropland; High Producing Exotic Grassland Low Producing Grassland Gorse or Broom; Mixed Exotic Shrubland; Forest – Harvested; Deciduous Hardwoods; Exotic Forest;
Water	20 21 22	Lake or Pond; River; Estuarine Open Water;
Sand, Gravel, Rock, Snow, Ice	10 12 14 16	Sand or Gravel; Landslide; Permanent Snow and Ice; Gravel or Rock;

Appendix 3: Native bird species detected using eDNA

Common name	Scientific name
korimako / bellbird	*Anthornis melanura*
riroriro / grey warbler	*Gerygone igata*
kākāriki / yellow-crowned parakeet	*Cyanoramphus auriceps*
karoro / Southern black-backed gull	*Larus dominicanus*
kawau pū / black shag	*Phalacrocorax carbo*
kawaupaka / little shag	*Microcarbo melanoleucos*
kea	*Nestor notabilis*
kererū / wood pigeon	*Hemiphaga novaeseelandiae*
kōtare / sacred kingfisher	*Todiramphus sanctus vagans*
ngirungiru / tomtit	*Petroica macrocephala*
ngutu pare / wrybill	*Anarhynchus frontalis*
pīhoihoi / Australasian pipit	*Anthus novaeseelandiae*
pīpipi / brown creeper	*Mohoua novaeseelandiae*
pīwakawaka / fantail	*Rhipidura fuliginosa*
pukeko	*Porphyrio melanotus*
pūtangitangi / paradise shelduck	*Tadorna variegata*
ruru / morepork	*Ninox novaeseelandiae*
tauhou / silvereye	*Zosterops lateralis*
tūī	*Prosthemadera novaeseelandiae*
warou / welcome swallow	*Hirundo neoxena*
whio / blue duck	*Hymenolaimus malacorhynchos*

Appendix 4: Other Observations of Native Birds

In September 2022, trail cameras detected our first camera records of titipounamu / rifleman (*Acanthisitta chloris*) in the South Ōkārito block.

The ZIP team now frequently observe titipounamu / rifleman within the South Ōkārito block, including a group of five adults in 2023.

Figure 30: Titipounamu near Cockabulla Creek in the Ōkārito Sanctuary, June 22nd 2023. **Photo**: Bradley Shields.

The number of kererū (*Hemiphaga novaeseelandiae*) has also increased, and is noticeable when in the backcountry. In April 2021, a local hunter observed seeing a flock of 30 kererū near Nolan's Hut in the Butler-Whataroa block. During 2022, the ZIP field team reported seeing multiple large flocks in the Perth-Barlow and Butler-Whataroa blocks, with one flock of up to 80 birds.

The numbers of tūī and korimako around the settlements of Stony Creek and Ōkārito have increased noticeably in the last two years. Flocks of 40+ tūī were seen in Ōkārito in October 2023.

Figure 31: Twenty tūī in flax plants in Ōkārito Township, 2023. **Photo**: Chad Cottle.

The ZIP team has frequently observed pīpipi/brown creeper (*Mohoua novaeseelandiae)* within the South Ōkārito block, including multiple groups of five or more adults in a group, or foraging in close proximity. Large counts of pīpipi have also been recorded. For example, 31 birds were counted feeding in low scrub over 350 m, on June 9th 2023 in the Perth-Barlow block. In South Ōkārito, 23 birds – one flock of 15 and one flock of 8 - were observed near the Pakihi Walk Lookout on June 19th 2023, and multiple observations of 12+ birds were recorded across the South Ōkārito Sanctuary during 2023.

Figure 32: Pīpipi / brown creeper in the Upper Barlow valley, Perth-Barlow block, 2022.
Photo: Bradley Shields.

The trail cameras in the South Ōkārito block have also detected cryptic species of native birds including matuku-hūrepo / bittern (*Botaurus poiciloptilus*, Figure 33), which has a threat status of Threatened – Nationally Critical. Other cryptic species detected, all of which have a threat status of At Risk – Declining, include kotoreke / marsh crake (*Zapornia pusilla*, Figure 34), pūweto / spotless crake (*Zapornia tabuensis*) and mātā / fernbird (*Poodytes punctatus*). These camera records may be of great added value to the learnings by the Department of Conservation using GPS trackers to measure activity patterns.

Figure 33: Matuku-hūrepo / bittern detected on a trail camera.

Figure 34: Kotoreke / marsh crake detected on trail camera.

Whio / blue duck (*Hymenolaimus malacorhynchos*; threat status of Threatened – Nationally Vulnerable) have been observed by the ZIP team in the Perth River valley since 2019. Initial surveys immediately pre- and post the 2019 1080 to Zero operation showed six pairs of birds in the Perth-Barlow block. Further surveys would be useful to measure the growth of the population since predator elimination commenced.

A group of 4–5 ducklings were seen in the Upper Barlow River (Perth-Barlow block) in late 2019. Along the Perth River, two ducklings were seen near First Creek in 2020, and two ducklings were seen near Scone Hut in 2022. In July 2023, four adult whio were seen in the Elizabeth Stream area (Perth-Barlow block).

Pīwauwau / rock wren (*Xenicus gilviventris*) were surveyed prior to the 2019 Perth-Barlow operation. These counts showed 47, and 29, individuals across two monitoring sites (upper Perth catchment and Barlow valley, respectively); as well as 50 and 44 individuals across two monitoring sites in a nearby non-treatment area (Lord River and Aciphylla Creek). Counts taken using different methodology in January 2024 within a smaller portion of the upper Perth valley (Perth-Barlow block) found >30 birds; meaning numbers appear to have remained stable for this area.

Finally, a pīwauwau was reported on Ōkārito Beach in February 2023 and re-sighted in March and April. While there have been various word of mouth stories of pīwauwau seen here over the last few decades, this is the first documented record of pīwauwau on the beach since the 1960s. This is an exciting observation given that pīwauwau species has a threat status of Threatened – Nationally Endangered.

Figure 35: A pīwauwau on Ōkārito beach, 9th March 2023. **Photo**: Chad Cottle.

Appendix 5: Community Reports

> “Amazing the changes that we have noticed, particularly over the last 18 months…all of our guests are so blown away and excited to hear what’s going on.”

Paula Sheridan, Ōkārito Boat Tours, February 2023

> “I am hearing so much more birdlife out on my tours than I have ever heard before”.

Ian Cooper, Ōkārito Kiwi Tours, November 2023

> “The bird life on my recent trip into the backcountry was certainly some of the best I have experienced, particularly in the Perth Valley from Nolans hut. We spotted a couple of groups of kea, but most noticeable was the kereru; lots and lots of them! Congratulations and keep up the good work.”

Mark Winter, CFO My Food Bag, February 2022

> “So awesome -life in Ōkārito is now one filled with maniacal tui’s, flocks of (granted not our native species but still!) redpolls, green and gold finches and yellowhammers in the fields, we had a first sighting of a pair of kākāriki from the boat (Alex and Helen from DoC) and yesterday morning we had a bittern fly over us in the boat (spotted by none other than keen-eyed Bradley :)) but as I later walked down The Strand and chatted with a friend another bittern casually flew all the way up the main road til it turned the corner -head height -just cruised on by....a few minutes later I was joined in the Plants Nursery by a young fern bird who just wiggled and darted about the plant stock and came out to perch and watch what I was up to....of course just after that a kotuku went striding past down the road....how can you not love what’s happening around here?”

Paula Sheridan/Swade Finch, Ōkārito Boat Tours, December 2023

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