Collective action to eradicate rats and mustelids from a large, peopled landscape: A social-ecological approach

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Research Report:

Collective action to eradicate rats and mustelids from a large, peopled landscape: A social-ecological approach

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EXECUTIVE SUMMARY

The control or eradication of introduced mammalian predators is one of the most urgent tasks for conserving native wildlife in Aotearoa New Zealand (Elliot et al., 2010; Innes et al., 2010). Predator Free Wellington (PFW) is a collaboration between several key organisations, community groups and the wider public which seeks to eradicate mammalian predators (rats, possums and mustelids) from Wellington City to enable native biodiversity to thrive. In 2019, PFW began a large-scale eradication of rats and mustelids from the urban landscape of Miramar Peninsula; this has driven a significant reduction in the presence of predator mammals in the area.

This report seeks to:

1. Harness the social and ecological learnings from this pioneering eradication effort.
2. Examine the evidence of both social and ecological outcomes resulting from the project.

This report is underpinned by four primary sources of material that inform these aims:

- Key informant interviews that provide an in-depth exploration of PFW's methods for mammalian predator eradication and engaging community action, as well as information on social and ecological outcomes
- Documentation supplied by PFW about their methods and structure and their annual reports
- PFW Engagement Field Officers' reflection and action sheets
- Existing data sets and reports that provide evidence of social and ecological outcomes.

This report outlines the social-ecological approach that PFW has taken for the eradication. PFW's strategy had two interconnected arms – the technical plan and the community engagement plan. A 'remove and protect' model was the basis for the technical plan (Bell, Nathan & Mulgan, 2019). This model requires the complete removal of predators from an area and then protecting that area against reinvasion, including establishing a virtual barrier. PFW had a general communication plan to build their presence in the community, a targeted strategy to engage community environmental groups as collaborative partners and a tailored engagement strategy to recruit landholders' participation within each community.

In this report we have positioned PFW's operation within the Collective Impact Framework (Cabaj & Weaver, 2016; Kania & Kramer, 2011) which includes the process of organising and implementing both the technical aspects of a project and engaging people.

PFW Ltd. (the core team) was an independent organisation that acted as the back-bone entity of the collective and managed the many facets of the project. Such an independent entity is uncommon in community restoration collaborations in New Zealand (McFarlane, 2021; Salignac et al., 2018). Providing funding, resources, labour, technical expertise, building the capacity of the PFW team and the wider community, and promoting evidence-based learning were key functions of the core team that underpinned the impact of the project.

Evidence for ecological outcomes

The biodiversity on Miramar Peninsula has shown some signs of recovery since PFW began its eradication of predators in July 2019, but the full impact of this intervention will only be evident over the coming decades. The ecological outcomes observed include:

- Mustelids (*Mustela nivalis* and *M. erminea*) and Norway rats (*Rattus norvegicus*) were declared eradicated in January 2021 and abundance of ship rats (*R. rattus*) has been dramatically reduced. The abundance of mice has not decreased in recent years.
- The abundance of native forest birds increased by over 50% following predator eradication The increase was largely driven by a 49% increase in the mean number of tūī (*Prosthemadera novaeseelandiae*).
- The abundance of tūī, riroriro (*Gerygone igata*) and pīwakawaka (*Rhipidura fuliginosa*) were significantly higher in 2021 compared to 2017.
- There was no evidence of improvements in the abundance of tauhou (*Zosterops lateralis*), kōtare (*Todiramphus sanctus*), or kererū (*Hemiphaga novaeseelandiae*).
- Kororā, little penguins (*Eudyptula minor*), breeding was unchanged over the last seven breeding seasons, suggesting no benefits from the removal of rats and mustelids at this stage.
- Tree wētā (*Hemideina crassidens*) increased by over 100% at sites where rats were considered absent.
- The number of beetles and cockroaches decreased at sites where rats were considered absent.

- The recovery of native flora was not examined here. However, recovery is likely to be happening. Te Motu Kairangi-Miramar Ecological Restoration have planted thousands of natives on the Peninsula and Wellington City Council invest in planting natives across the city and support volunteer planting projects
- Recovery of coastal bird populations can be assessed once Greater Wellington Regional Council repeats their baseline Coastal Bird Survey from 2017-18.

Evidence for social outcomes included:

- In a Wellington study, people who participated in trapping were more likely to report lower levels of depression, anxiety and stress and stronger feelings of social cohesion than those who did not participate in trapping. However, this research does not prove a causal relationship, and planned repeat surveys will assist in unpacking this pattern.
- PFW achieved equitable deployment of traps and bait stations across the landscape, irrespective of the socio-economic context or the amount of tree canopy cover in neighbourhoods. This is an uncommon occurrence with social imbalances in environmental outcomes common globally (Hart et al., 2022). A community-by-community approach to recruitment of private businesses and householders was a key feature that promoted these equitable outcomes, and it may ultimately lead to equitable improvements in biodiversity over time.
- Surveys indicate an increase in support for predator eradication in Wellington City since 2017 (prior to eradication). Although 93% of Wellingtonians surveyed supported predator eradication in 2021, only 44% of people currently participated in predator control. This attitude-action gap may have consequences when PFW hands over the responsibility for biosecurity maintenance to the community.

Some of the ecological outcomes reported here differ from what might be expected after undertaking predator control. Riroriro and pīwakawaka are increasing in Miramar but these species do not generally respond well to predator management (Fea, Linklater & Hartley, 2020; Miskelly, 2018). In contrast, Kererū are as yet found in low numbers on Miramar Peninsula. Kererū have been at low numbers on the Peninsula for many years and have a low reproductive rate (Casey, 2001), so may take longer to re-establish. The recovery of native bird populations is also limited by habitat quality, especially in urban areas such as Miramar Peninsula which has little native forest.

While some evidence of social outcomes has been presented here, there is much more to explore. There are many potential social and economic benefits of the eradication effort for which we have little evidence (Russell & Stanley, 2018; Wilson et al., 2018). Social outcomes are a key reason for investment in biodiversity restoration (Shanahan et al., 2018) and can motivate participation where concern for the environment is low (Russell & Stanley, 2018). Further, additional knowledge is needed to inform the transition to community-led biosecurity maintenance. In particular, how can community engagement be sustained at the level necessary to maintain biosecurity? Do the socio-ecological benefits associated with the eradication support community engagement?

The PFW project is an opportunity to partner with mana whenua, to learn from Indigenous knowledge and to uphold Indigenous rights and interests (Lyver et al., 2019; Wehi & Lord, 2017). PFW have long expressed a desire to develop a true partnership approach to running its projects, but progress along this pathway is still in the very early days. Research that explores the nature of the relationship to date, potential challenges to implementation of a partnership approach and potential pathways forward would be valuable.

PFW's landscape-scale eradication effort on Miramar Peninsula is an exemplar of collective action which involves a long-term collaboration between community and across-sector organisations to achieve greater impact than the groups could otherwise accomplish. PFW developed a social–ecological approach, deemed necessary to address complex conservation issues, such as predator eradication, in peopled landscapes (Berkes, Colding & Folke, 2003). In addition, the project demonstrates the full range of amplification processes described by Lam et al. (2020a) as PFW worked to scale-up the existing community-led predator control activities on Miramar Peninsula.

The learnings from this research can inform the next phases of PFW's plan in Wellington City and have particular relevance for achieving the PF2050 goals. The learnings also have long-term implications for improving large-scale community engagement in ecological restoration projects locally, nationally and internationally. The strategy's used by PFW to interweave technical expertise and community engagement could be applied to other 'wicked' problems that require a systems approach, such as developing a regional response to address aspects of climate change which could culminate in community-wide behaviour change.

REPORT SCOPE AND STRUCTURE

The goal of this report was to harness the social and ecological learnings from Predator Free Wellington's work in mammalian predator eradication in Wellington City. The research agenda was shaped by two research partners (Predator Free Wellington Limited and Biological Heritage National Science Challenge) from the outset (Garnett et al., 2009) to ensure the research has greater impact and relevance academically and for practitioners and society (Jolibert & Wesselink, 2012). Co-design principles governed the entire process (as per Wilk et al., 2020) and included being open and transparent, sharing and aligning expectations of the projects aims and goals, and being flexible and reflective.

Predator Free Wellington as an exemplar of collective action in predator eradication

There is a need for exemplars to demonstrate the value of collective approaches to pest management at a landscape scale (Duncan & Diprose, 2020). There is little published literature on collective approaches and the resulting social and ecological outcomes from mammalian predator eradication in peopled landscapes. Even though a large number of community groups make valuable contributions to predator management in Aotearoa New Zealand (Peters et al., 2015). This report presents Predator Free Wellington (PFW) as an exemplar of a collective, landscape-scale predator eradication project in Wellington City, a project that amplifies the work of community-led initiatives already operating on the Peninsula. This report describes:

- Predator Free Wellington's social-ecological pathway to predator eradication
- Key learnings and innovations that arose from the project
- The social and ecological outcomes for which we have evidence.

The report is structured into four sections:

- Section 1, background of the project and outline of the methods used in this report
- Section 2, Predator Free Wellington's pathway to impact
- Section 3, evidence of the social and ecological outcomes of the project
- Section 4, final Discussion.

SECTION 1: BACKGROUND

1.1 Mainland eradications to avert biodiversity loss

The control or eradication of introduced mammalian predators is one of the most urgent tasks for conserving native wildlife in Aotearoa New Zealand (Elliot et al., 2010; Innes et al., 2010). Multi-species eradication of introduced mammalian predators, such as possums (*Trichosurus vulpecula*), mustelids (*Mustela erminea, M. nivalis* and *M. furo*) and rats (*Rattus rattus and R. norvegicus*) has been achieved on over 100 (10%) of New Zealand's offshore islands (Parkes et al., 2017; Towns et al., 2013) and from fenced and open wildlife sanctuaries on mainland New Zealand (Bombaci et al., 2018). The predicted challenges of climate change suggest small islands cannot exclusively be relied upon for biodiversity conservation (Courchamp et al., 2014). In addition, for ecological processes to be restored at a landscape scale, invasive predators need to be controlled in the areas outside of sanctuaries (Adams et al., 2016; Ives et al., 2016). Beyond designated sanctuaries on mainland New Zealand, until 2016, New Zealand mainland mammalian predator management had largely focused on control rather than eradication. This approach carries a significant long-term cost as reinvasion must be continually managed.

In 2016 the New Zealand Government announced Predator Free 2050 (PF2050) - an ambitious project to rid New Zealand's 26.4-million-hectare mainland of damaging introduced predators (possums, mustelids and rats) by 2050 (Department of Conservation, 2017; Hill, 2012; Innes et al., 2010; Owens, 2017; Russell et al., 2015). This would represent a global first as eradication of these species has not previously been achieved in large-scale, peopled landscapes, in particular, rats have never been eradicated from urban areas (Peltzer et al., 2019; Russell & Stanley, 2018). The social-ecological and technological advances required for this to be successful could improve large-scale predator management worldwide and over the long-term (Kopf et al., 2017).

The scale of effort required to reverse the biodiversity decline in New Zealand exceeds the capacity of national and local governments (Department of Conservation, 2020a). In light of this, community-led ecological restoration projects, which seek to improve biodiversity outcomes, have become of strategic significance in New Zealand for over 20 years (Peters et al., 2015; Rykers, 2019). Predator control programmes on mainland New Zealand have been undertaken by thousands of community groups, formed largely from volunteers. The Department of Conservation (2020b) reported over 5000 community groups and iwi or hapū registered to conduct predator control across the country, and 4373 projects are registered on an online platform for monitoring trapping (Trap.NZ; accessed April 2022). Traditionally these projects focus on an area of local land with relatively little landscape-scale coordination between projects (Glen et al., 2013; Guerrero et al., 2015; Norton, 2018, Perring et al., 2018). Greater co-ordination of groups and scaling up the effort to cover broad geographical areas is considered essential for meeting the PF2050 goals (Brooks et al., 2013; Lam et al., 2020a; Russell et al. 2015). Although, a number of groups have begun building collaborative relationships, their lack of training, capacity and consistent funding can constrain their efforts (Doole, 2020; Peters, 2019).

1.2 Predator Free Wellington

Predator Free Wellington Limited (PFW Ltd.) is a charitable company that was established in 2016 and listed in 2018 to support the vision of Wellington becoming the first 'Predator Free'[1] capital city in the world, thus relieving the stress of predators on native biodiversity and allowing it to recover. The vision would be achieved by eradicating rats, possums and mustelids from Wellington City, a total area of 30,000 hectares. PFW Ltd. is aligned to the New Zealand government's Predator Free 2050 initiative. The PFW collective was a collaboration between PFW Ltd. and several key organisations who had a shared concern about the impact of introduced mammalian predators on Wellington's native biodiversity and chose to work collectively and share authority, decision-making and accountability to address the problem (Weaver, 2018). PFW Ltd.'s initial focus (Phase 1) was to co-ordinate the landscape-scale eradication of rats and mustelids from Te Motu Kairangi, Miramar Peninsula (800 ha) (Figure 1.1), to provide proof of their concept's effectiveness, and then develop a strategy to extend the concept throughout Wellington City (Phase 2 to 5, Figure 1.1). Phase 1 began in 2019 and is the main focus of this report.

Eradicating predatory mammals from peninsulas is considered a stepping stone from island eradications towards achieving eradications across New Zealand's mainland (Russell et al.,

[1] Possums, rats and mustelids were the target mammalian predators. Management of other mammalian predators, such as dogs and cats, was not included in the scope of PFW Ltd.'s project nor within that of PF2050.

2015). Miramar Peninsula (800 ha), on the south-eastern side of Wellington City, has a population of nearly 20,000 people and offers a microcosm of Wellington City, with a variety of biological ecosystems and a diverse range of communities (Predator Free Wellington, 2020). The Peninsula is geographically well positioned to be defensible against predator reinvasions across the isthmus which separates Miramar from the rest of the city (Figure 1.1). Predator eradication is already a familiar concept on the Peninsula. Possums were eradicated in 2006 after a three-year programme (Greater Wellington Regional Council, 2021). Well established community-led efforts to control other introduced predators are undertaken by volunteer groups such as Predator Free Miramar, Forest and Bird, Te Reo O Te Taio’s Places for Penguins, and Te Motu Kairangi-Miramar Ecological Restoration and private land-holders.

Figure 1.1 Map showing the five phases of PFW’s eradication plan for Wellington City. Phase 1 covers Miramar Peninsula which is separated from the rest of the city by the isthmus which houses Wellington Airport. The phases move consecutively westwards and then northwards across the city to Phase 5, on the northern city boundary. Figure courtesy of Predator Free Wellington Ltd.

1.3 Methods

A mixed methods approach was used in this report to draw on both qualitative and quantitative data to address the core aims of this report. The first aim was to harness learnings from the PFW project that could assist other organisations as they embark on collective effort. To this end, first, we examined the structure and processes involved in PFW with a particular focus on the predator eradication from Miramar Peninsula. We did this in the context of the Collective Impact Framework (Cabaj & Weaver, 2016; Kania & Kramer, 2011), which describes a systems approach to address 'wicked' problems (including environmental problems) through cross-sector collaborations between communities and organisations to find solutions for such problems on a large scale (Cabaj & Weaver, 2016; Kania & Kramer, 2011). The second aim is to examine the evidence for key social and ecological outcomes that have emerged from the project, which required both qualitative and quantitative data sources.

This data sources used to address both aims here include (explained further below):

- Key informant interviews that provide an in-depth exploration of PFW's methods for mammalian predator eradication and engaging community action, as well as information on social and ecological outcomes
- Documentation supplied by PFW about their methods and structure and their annual reports
- PFW Engagement Field Officers' reflection and action sheets
- Existing data sets to provide evidence of the social and ecological outcomes.

Key informant interviews

These interviews provided an in-depth form of data collection and analysis. They were held to engage in-depth with work-stream leaders (who have specialised knowledge and/or oversight of various teams), employees of PFW and key stakeholders.

Potential interviewees were approached via an email which explained this research project and the relevant ethics information and suggested an off-site place to meet, at their convenience, if they were willing to participate. Interviews were conducted and notes of the interview were taken by Dr Julie Whitburn. Informed consent for participation in the interview was confirmed at the beginning of each interview. Human ethics approval for the research was obtained from the Human Ethics Committee of Victoria University of Wellington (Reference number: 30086) and the research abides by PFW's Privacy Declaration for Visitors.

A semi-structured design was used for the interviews to explore:

1. The interviewee's position or association with PFW and PFW's work from their perspective
2. Their insights into what had worked well or challenges they faced and key innovations and evidence-based learnings
3. What could help inform future practice.

A series of questions relating to these lines of inquiry served as a starting point for the conversation while allowing the discussion to flow spontaneously (Appendix 1). These interviews allowed the identification of emerging themes and insights while helping to form a broad understanding of the project (Whyte-Jones, 2016).

Raw data from the interview notes were compiled into an Excel workbook to create an analysis grid with categories that correspond to the conditions outlined in the Collective Impact Framework or potential social outcomes suggested from the literature. Distinct ideas were collated under each category while maintaining the anonymity of the interviewee. Other categories and themes that did not fit within the Collective Impact Framework were informed by the responses themselves. Verbatim quotes were not included in the report, unless from published works, because they would too easily reveal the identity of the individual from the PFW team.

PFW documentation

PFW provided documentation such as:

- Predator Free Wellington 2018 Communications and Marketing Plan (PFW, 2018, unpublished document)
- Miramar Eradication Project Biosecurity Incursion Detection (PFW, 2019, unpublished document)
- Graphics that detailed the structure of PFW and the relationships between stakeholders
- Copies of their Impact Reports (Predator Free Wellington, 2019, 2020a, 2020b, 2021)
- PFW Engagement Field Officers' reflection and action logs, from March to October 2019 for the Miramar recruitment (PFW, 2019, unpublished raw data). A reflections'

log, was intended to help Engagement Field Officers (EFOs) process their experiences and identify strategies and solutions to challenges as they recruited landholders. Raw data from the officers' reflection sheets were entered into an Excel workbook. Similar ideas from the raw data were collated into categories such as, landholders' reasons for not participating or difficult situations that arose and how they were handled.

Quantitative data sets

Evidence of ecological outcomes was drawn from:

- Trap.NZ (Trap.NZ, raw data; accessed April 2022) for predator catch data for the Miramar predator eradication
- Greater Wellington Regional Council's annual Five-Minute Bird Count surveys (GWRC, unpublished raw data)
- Places for Penguins breeding data (Places for Penguins, unpublished raw data)
- Victoria University of Wellington data on wētā and other invertebrates (Hartley, Balls & Nelson, 2021).

Evidence of social outcomes was sourced through:

- Existing research on wellbeing outcomes associated with participation in ecological restoration (Shanahan, 2020)
- Wellington City Council's community online surveys investigating Wellington residents' participation in and attitudes towards predator eradication deployed in 2017, 2019 and 2021 (Wellington City Council, 2021)
- PFW's Chew Card survey, which was a brief on-line survey deployed by PFW in association with a Wellington wide 'Chew Card Tuesday' event held in April 2021. The survey measured social cohesion and residents' perceptions of wildlife (PFW, unpublished raw data).
- Data on tree canopy coverage Morgenroth (2021), New Zealand Deprivation Index for each suburb on Miramar Peninsula (Environmental Health Intelligence New Zealand, 2018) and data from PFW on density of traps and bait stations deployed on Miramar Peninsula.

The interpretative narrative describing PFW's Pathway to Impact in Section 2 is based on these spreadsheets, drawn from the interviews and documentation supplied by PFW, but is not directly attributed to individuals.

SECTION 2: PREDATOR FREE WELLINGTON'S PATHWAY TO IMPACT

2.1 Collective action in predator eradication

Collective action (Ostrom, 2009) is an approach used to address 'wicked' problems which are socially complex, changeable and difficult to solve using traditional processes (Rittel & Webber, 1973). Collective action is a systems approach that accommodates differing viewpoints, values and goals (Bradshaw, 1996), and acknowledges that the ethic of environmental stewardship varies across communities and cultures (Virapongse et al., 2019). This inclusive, collective approach can encourage the collaboration and social cohesion necessary for landscape-scale eradication of mammalian predators (Bradshaw, 1996).

There is a diversity of collective approaches to eco-system regeneration in New Zealand that seek to amplify the impact of community-led restoration projects on biodiversity outcomes (McFarlane et al., 2021). These collectives consist of community networks, tangata whenua-led collectives, project-based collectives, agency-led collectives and partnership collectives that vary in their composition, structure, purpose, activities and level of impact (McFarlane et al., 2021). Predator Free Wellington (PFW going forward) is a project-based collective that takes a landscape-scale approach to predator eradication in Wellington City. PFW involves a long-term collaboration between community (groups, businesses and house-holders) and across-sector organisations (local government, NGOs) to achieve a common purpose (Appendix 2 details the structure of the PFW collective).

It is useful to position the PFW collective's work within an established framework for collective action to help describe and understand the social-ecological system. However, it is important to note that this approach does simplify the nuances of reality. The Collective Impact Framework, first developed by Kania & Kramer (2011) and updated by Cabaj & Weaver (2016), aligns well with the PFW approach.

The Collective Impact Framework includes both the process of organising and implementing the technical aspects of a project and the engagement of people (Weaver, 2018). It identifies three pre-conditions and five inextricably linked conditions that lead to positive social and ecological outcomes for collective enterprises (Cabaj & Weaver, 2016; Kania & Kramer, 2011; Weaver, 2014, 2018). The three preconditions of the Collective Impact Framework include a sense of urgency about the issue in the community, an influential leader and adequate initial funding to establish the project (Weaver, 2014).

The five conditions are (Figure 2.1):

i. A **common agenda for change**, which includes having a shared vision and understanding of the problem and a joint approach to solving it through agreed upon actions. Having a common agenda enables participants to focus on the goals (Kania & Kramer, 2011) and direct available resources where they can best be utilised (Braun et al., 2016).

ii. An action plan that outlines and coordinates the **mutually reinforcing activities** for each participant and thus avoids overlap and gaps in the work.

iii. An agreed upon way of **measuring and reporting results** across all the participants that can inform collective evidence-based learning.

iv. **Open and continuous communication** across the many participants to build trust, assure mutual objectives, and create common motivation. This condition has evolved within the framework to include the critical importance of meaningful community engagement and to consider mechanisms to achieve this engagement. These include amplifying the community voice through feedback opportunities and incorporating that voice into the project goals and actions (Brady & Splansky Juster, 2016; Raderstrong & Boyea-Robinson, 2016; Wolff, 2016).

v. An independent **backbone organization** (or convening structure) with staff who have the specific skills to serve the entire initiative and coordinate participating organisations and agencies. Purpose driven, independent back-bone organisations are rarely present in community conservation initiatives (McFarlane, 2021; Salignac et al., 2018). However, their existence is a major advantage as they can guide the development of a vision and strategy, coordinate aligned activities, establish shared measurement practices, build public will, advance policy, and mobilize funding (Holmgren, 2018).

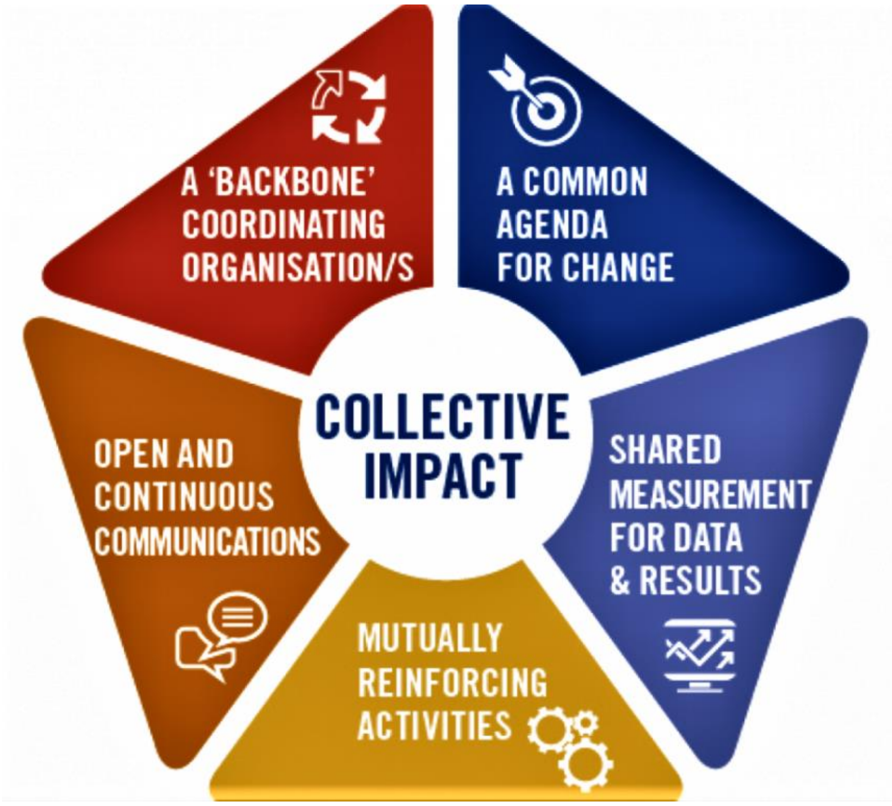

Figure 2.1 Collective Impact Framework demonstrating the five conditions that lead to positive social and ecological outcomes. Figure from: https://customsitesmedia.usc.edu/wp-content/uploads/sites/308/2018/08/17130559/collective-impact-graph.png

The Collective Impact Framework evolved to include principles of practice thought to contribute to population-level change (Brady & Splansky Juster, 2016; Rodrigues & Fisher, 2017). These principles include cultivating system leaders, tailoring initiatives to the local context, including the community, using data to learn, equity and fostering relationships on trust and respect.

Strong systems focussed leadership is consistently recognised as an important factor in successful ecological restoration projects (Brooks et al., 2013; Shanahan et al., 2021). A review of community-based conservation projects identified that successful leaders are likely to be innovators, communicators, learners, bridge-builders, and system thinkers (Timmer, 2004). Likewise, successful collective restoration projects require adaptable, inspiring leaders, motivated by the cause and committed to overcome obstacles in order to see the project through) and who are able to genuinely engage with other people's ideas with the intention of incorporating them (Brady & Splansky Juster 2016; Cabaj 2014; Weaver 2016; Salignac et al., 2016). Effective leaders can give credibility to a project and are able to tap into their existing networks to make connections to broaden the membership of the collective or to secure resources or funding (Weaver, 2018). An important aspect of leadership is to identify and train emerging leaders to cultivate these system leadership skills.

2.2 Collective action on Miramar Peninsula

The situation on Miramar Peninsula, and in Wellington City, was ripe for such a collective approach. The three preconditions (outlined by the Collective Impact Framework, Hanleybrown et al., 2012) or triggering moments (Brook, 2013; Seixas & Davy, 2008) which initiate action and support successful outcomes were present (Hanleybrown et al., 2012). That is:

i. A sense of urgency for change was apparent. The pressure on native biodiversity, the presence of community groups already involved in predator control and the potential for substantial funding, with the announcement of PFNZ 2050, may have been among the catalysts for people to come together on PFW's project.

ii. An influential champion, the Project Director of PFW, was appointed to lead the PFW collective. The Project Director is passionate about the project with a systems-oriented approach and the skills to bring cross-sector leaders together and maintain the momentum of the project (Perring et al., 2018; Timmer, 2004).

iii. There was adequate initial funding invested by the Foundation Partners (Appendix 2) to establish the project, identify stakeholders and plan the eradication.

2.2.1 PFW Ltd. as the backbone entity of the collective

The core PFW Project Team (that includes the Project Director, Project Coordinator, Communications/Digital Manager and Stakeholder Engagement manager) was created, funded and staffed as an independent organisation and served as the backbone or galvanising entity of the collective (Adams et al., 2016; Duvall et al., Coates, 2017; Kania & Kramer, 2011). The role of the core PFW Project Team, and in particular the Project Director, was to plan, manage, and maintain the focus and momentum of the project. The key tasks of this team, as outlined by the Collective Impact Framework (Figure 2.2) were to:

(i) Bring together a diverse group of stakeholders and build a collective identity within a community that had its own set of values and motivations for participating in the project.

(ii) Facilitate the development and implementation of a **common agenda** among key stakeholders. First by promoting PFW Ltd.'s vision, "…to create the world's first predator free capital city where communities and native biodiversity thrive (GWRC, 2016)" and second by developing a common understanding of the mammalian predator problem on Miramar and a joint approach to solving it.

(iii) Coordinate the varied **mutually reinforcing activities** required to carry out the predator eradication and the agreed upon **shared measurements** needed to track progress and inform practice as the collective proceeds towards the shared goals.

(iv) Maintain **open communication** with and between stakeholders, including employees and the wider public, to help build trust and respect with and between the constituent groups and with the wider public and to reassure the groups of their mutual objectives and common motivation.

(v) Support the work of the work-stream managers, foundation partners, researchers and other stakeholders

(Brady & Splansky Juster, 2016; Cabaj & Weaver, 2016; Hanleybrown et al., 2012; Kania & Kramer, 2011; Seixas & Davy, 2018; Weaver, 2016).

The core PFW Project Team facilitated other key aspects of the project, in particular securing consistent funding and building the capacity and capability of the collective.

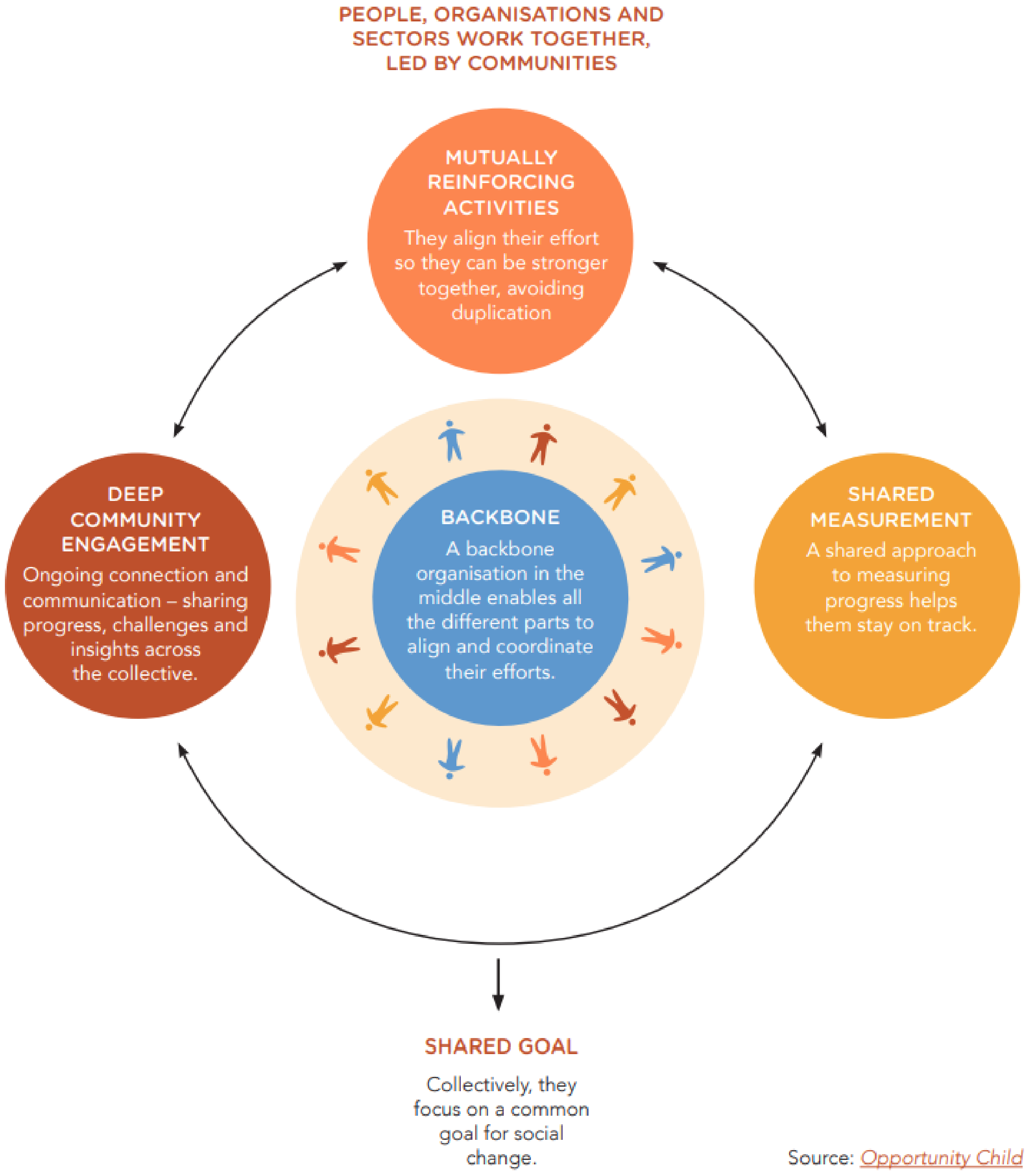

Figure 2.2. Collective Impact Framework, demonstrating the role of the backbone entity. Figure from Opportunity Child, Rodrigues & Fisher (p. 16, 2017).

Funding & resourcing

The ability to mobilise funding and resources is crucial to sustain projects in the long-term (Perring et al., 2018; Seixas & Davy, 20018; Sirimock & Rusdianto, 2020; Shanahan, 2021). The core PFW Team coordinated funds and promoted investment opportunities from diverse sources to support the common priorities and strategies of the collective. This includes the initial funding through the Foundation partners, a subsequent grant from PF2050 of $7.6 million through 'Jobs for Nature', Wellington Community Trust funding for the barrier structure across the isthmus, donations from local businesses (such as in-kind donations of peanut butter to bait the traps from Fix & Fogg), money raised at events such as Taps & Traps sponsored by Parrot Dog brewery and resources supplied through community trap-building workshops.

Supporting communities through the bulk funding of PFW rather than funding individual groups means community groups can concentrate on their field work and team building rather than fundraising. It can also reduce the competition for limited restoration funding between community groups (Rodrigues & Fisher, 2017; Hanleybrown et al., 2012), and this was likely the case for PFW.

Providing money, resources and staff for the field operations meant there was no cost to householders and no requirement to service traps. This can encourage participation from those people who otherwise might not be involved (Adams et al., 2016; Kaine et al., 2021).

Partnership with the Greater Wellington Regional Council (GWRC) and contracting their technical leadership, field staff and vehicles significantly reduced the administrative burden on the core PFW Team and meant administrative infrastructure such as health and safety policies or insurance associated with the field work were already in place.

Building capacity in the PFW team and community.

Voluntary environmental groups' or community partnerships' ability to achieve their social and ecological objectives can be limited through a lack of training, capacity and inconsistent funding (Braun et al., 2016; Doole, 2020; McFarlane et al., 2021; Peters, 2019). Other limitations, such as the groups' ability to monitor and verify social and ecological outcomes (Perring et al., 2018) can also impair their capacity to contribute to the outcomes in New Zealand's Biodiversity Strategy (Jones & Kirk, 2018). Capacity and capability building may be the most important elements that can carry a project forward and sustain it over the longer term (Seixas & Davy, 2008; Sirimorok & Rusdianto, 2020). A collective's investment in capacity building covers technological or scientific improvements (Miller et al., 2017), increasing a team's and/or a community's knowledge and skills, providing access to expertise, funding and resources. A particular advantage of working as a collective is the ability to increase a community's capacity by building stronger relationships, better communication and adaptive leadership skills (Cabaj & Weaver, 2016).

An important way to build a team's capacity is through **strategic or adaptive learning -** that is using data and observations to learn, adapt and improve (Rodrigues & Fisher, 2017). This shifts the focus from reactive problem solving to co-creating solutions (Senge, Hamilton, & Kania, 2015). Adaptive learning can be carried out in a way that allows participants to learn from their efforts and make changes to their strategy. These strategies can then be tested and if found successful incorporated into the ongoing approach (Phillips & Splanksy Juster, 2014). Therefore, adaptive learning relies on a culture that fosters relationships, respect and trust across participants (Soderquist, 2016). Adaptive learning also includes incorporating scientific research experiments into the projects (Gellie et al., 2018).

PFW promoted capacity building within the project by:

- Bolstering the practical science necessary to achieve the eradication both through evidence-based learning and scientific trial and error (for example, when trying to catch the last rats who evaded traditional methods), and through deliberately embedding scientific research experiments into the project.
- Employing staff to recruit landholders and carry out the field work – initially PFW employed 26 field staff but this increased by 42 with the 'Jobs for Nature' grant in 2020.
- Investing in professional development for its staff. Employees of PFW are provided with a wide range of skills to enable them to succeed in their work. For example, field operators received dog aversion training, other health & safety training, technical training in equipment use and deployment, 'Thinking under fire' and leadership training.
- Developing career pathways for staff and promoting within the organisation as employees develop the appropriate skills and experience.

- Maintaining open communication at all levels of the collective. For example, Friday meetings of work-stream leaders and the core project team provide a key integration point for whole project. It is an opportunity to update the entire team about progress, challenges and work together to create solutions. These meetings are a strategy to avoid silos forming in different parts of the collective. In the afternoon the leaders socialise any plan with the operations team so they can provide feedback and then implement any changes the following Monday.
- Upskilling community trapping groups and providing them with resources, which is crucial to the success of collectives such as PFW (Brooks et al., 2013). The upskilling can be in refining trapping or monitoring methods but also PFW works to identify key individuals with leadership skills and includes them at the decision-making level. In addition, this supports them to undertake more specialised work such as running training events (for example, 'Extra for Experts" training).
- Building the ability of householders to participate in the project through PFW communications and one-to-one conversations with Engagement Field Officers (which educate and invite participation and can correct misinformation that might prohibit participation).

2.3 Predator Free Wellington's approach to eradication

The eradication of mammalian predators in large-scale peopled landscapes had not been attempted before (Peltzer, 2019) and all eventualities could not be anticipated. Therefore, PFW took an adaptive management approach, which entailed being open to evidence-based feedback about what was or was not working and adapting technical or engagement aspects of the project when appropriate. The two interconnected arms to the PFW's strategy, the technical plan and the community engagement plan, were aligned to tackle the eradication. Sections 2.3.1 and 2.3.2 draw on the data collected through the key informant interviews and material supplied by PFW to describe how the collective worked together to implement the technical operation and the community engagement plan.

2.3.1 The technical operation

The technical operation was led by the technical Project and Operation Leads from Greater Wellington Regional Council's (GWRC) Biosecurity team. A 'remove and protect' model was the basis for the eradication (Bell, Nathan & Mulgan, 2019). This model requires the complete removal of predators from an area and then protecting that area against reinvasion. In effect this creates mainland 'island' eradications within larger landscapes. Members of the local community can provide useful local knowledge (Phalen, 2009). PFW's technical operation was informed by local knowledge from the community groups such as knowledge of the site, community needs and logistical information related to carrying out predator control. Key learnings from the technical operation can be found in Text box 1.

Remove

A precise GPS grid (Figure 2.3) was constructed over the entire peninsula for the placement of traps (in wooden tunnels), bait stations and monitoring devices (chew cards or wax tags) with the goal of having a trap within the home-range of every rat. This means there would be a 100% chance of every rat coming across one of these devices. Bait stations and traps, 6000 devices in all, were placed on private property, in bush reserves, parks, coastal and commercial areas.

The field operation is summarised in Table 2.1 and given in detail in Appendix 3. Members of the PFW collective were coordinated to implement the field operation to avoid replicating efforts and avoid gaps. PFW field staff cut tracking lines and deployed and serviced the trapping network. Places for Penguins continued to take responsibility for predator trapping in the area around their penguin nest boxes. Predator Free Miramar took on additional responsibilities beyond their house-hold trapping network and took sole charge of predator eradication in the northern end of the peninsula, an area over 100 hectares. Some members of the public who had traps on their property continued to monitor their devices and reported the findings to PFW.

PFW Ltd. invested in Trap.NZ (https://www.trap.nz) to record all their trap and bait station data, which provided consistency in data recording (i.e., fulfilling the condition of shared measurement). Trap.NZ is used nationally as a predator trapping and monitoring data management system that is convenient for field operators because data can be entered using a phone application while on location. Trap.NZ was used to generate reports, graphs and maps which helped PFW understand which traps are most effective or which areas needed more attention and this information was conveyed to the field team.

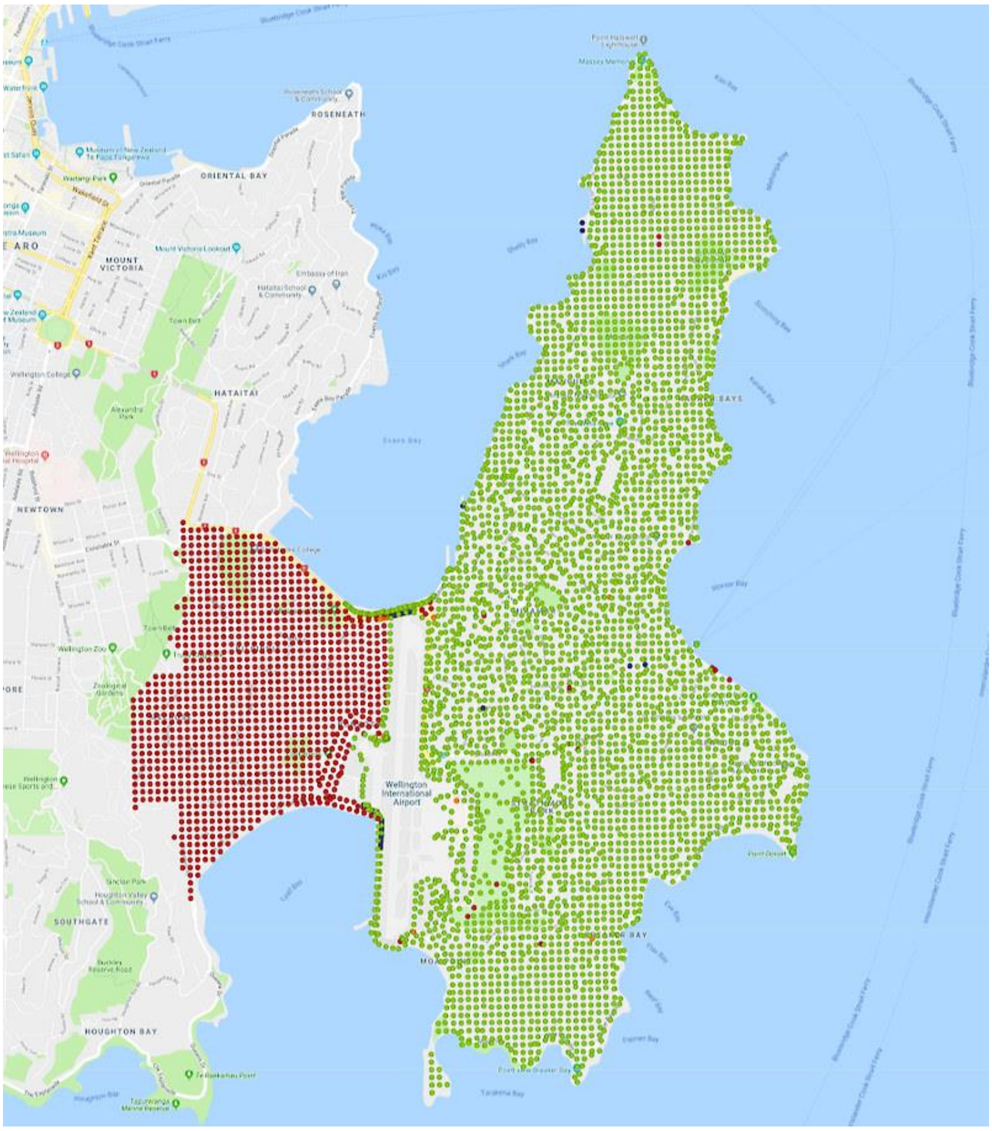

Figure 2.3 Map of the trapping network across Miramar Peninsula. Green dots indicate the position of traps or bait stations on Miramar Peninsula. Red dots are traps or bait stations in the buffer zone across the isthmus separating the Peninsula from the rest of Wellington City (PFW, 2019).

Table 2.1 Summary of the PFW tools used to eradicate rats and mustelids.

Animal predator	Habitat	Grid	Trap/Bait station	Pre-feed in traps	Bait	Last animal caught
Weasels (*Mustela nivalis)* and Stoats (*Mustela erminea*)	Found within 500 m of coast, in mix of bush and coastal habitat	Traps, 100 m x 100 m across the peninsula and adapted to 50 m x 50 m around coastline Bait stations, 50 m x 50 m	BT200 double set run through trap boxes, replica of DOC 200. Protecta Sidekick bait stations (ground based).	Pre-feed, 100 g fresh rabbit meat, for three weeks. Refreshed weekly. Traps locked with cable ties & treadle plate screwed down.	Rabbit meat	January 2021
Norway Rats (*Rattus norvegicus)*	Urban environments, feeding on food scraps, compost and back-yard garden vegetables. Near freshwater streams and coastal habitats. Most commonly trapped around buffer zone	Traps, 100 m x 100 m Bait stations, 50 m x 50 m			Traps: When bait take slowed, traps were baited with peanut butter and set. Bait stations: Brodifacoum rodent pellets	January 2021
Ship Rats (*Rattus rattus)*	Highest density in areas of undisturbed vegetation, especially escarpments and weedy banks. Favoured vegetation includes cape ivy, taupata, karo, blackberry, honeysuckle, ivy. Lowest density in developed urban areas. They are tree and ground dwellers.	Traps, 100 m x 100 m traps, Bait stations, 50 m x 50 m bait stations were effective in highly urbanised areas. Habitat approach, in dense weedy areas. The very last rats are difficult to catch and PFW catered to individual preferences and trialled new techniques.				Some ship rats remain as at 30 June 2022, especially in undisturbed, dense vegetation, particularly escarpments and weedy banks

Catching the last rats. By January 2021 Miramar Peninsula was declared free of mustelids and Norway rats and the ship rat population was dramatically reduced (PFW, 2021). However, the last ship rats on the peninsula are proving to be elusive. Intensive monitoring, bait-take analysis, use of cameras and certified rat detection dogs helped the team identify areas where rats persisted. Areas of known rat activity areas were then blanketed with devices.

Through scientific trial and error, the architecture of bait stations was adapted to try to lure the remaining rats into the bait stations and tracking cameras were strategically deployed to monitor the rats' behaviour during these attempts to catch them (for further details, see Appendix 3).

Proof of freedom from ship rats. Over time, areas of the peninsula have been declared ship-rat free. This began in the urban zone in June 2020. Freedom from rats was ascertained by analysing bait take, monitoring with chew cards and wax tags, installing 80 monitoring cameras across the urban zone and having the certified rat detection dogs scour the coastline. The public have been included to help provide proof of freedom. For example, PFW is undertaking chew card surveys in targeted areas on the peninsula (for further details, see Appendix 3). As at 30 June 2022, pockets of rat activity remain on the peninsula, considerably longer than the end of 2019 that was originally predicted.

And Protect

The GWRC Biodiversity Team determined (through predator surveys in the Kilbirnie area, Crisp et al., 2018) that the isthmus, separating Miramar Peninsula from the rest of Wellington City, and the coast (Figure 1.1) were particularly vulnerable to reinvasion. This information led to an expansion of the coastal defences (traps and bait stations) and the implementation of a virtual barrier across the isthmus. A virtual barrier is a system that excludes predators that may attempt to enter the peninsula (Bell et al., 2019). Significant investment was made into aligning many different stakeholders affected by this plan to understand their needs and incorporate them into the barrier design. The final barrier was in place by October 2019 and consisted of a combination of traps and bait stations every 50 m across the isthmus and 4 lines of traps along the coastlines. The Phase 2 eradication will add another layer of protection for the Peninsula.

Alongside the tracking network, engaging the general public to protect the peninsula from reinvasion is crucial. They are the eyes and ears on the ground. PFW set up a "live intelligence centre' where the public can report a sighting or evidence of predators[2]. PFW responds within 24 hours to these notifications to build trust in the organisation and keep the community engaged in reporting and in the project. A recent stoat incursion (April 2022) tested the biosecurity plan. The stoat was sighted twice by field operators, picked up on a monitoring camera and reported by a member of the public. The multiple sightings provide encouraging evidence that the multiple layers of protection can work. PFW Ltd. have a fixed term contract for their project and are planning for the biosecurity maintenance to become completely community-led in future.

[2] Phone line (0800 NORATS) or email (hello@pfw.org.nz).

Text box 1. KEY LEARNINGS FROM THE TECHNICAL OPERATION

Rat home-range

When aiming for the total eradication of rats, considering the variations in individual rat behaviour and the extremes in home-range size for the few remaining rats were even more important than understanding population averages. Research by Henry Mackenzie from Victoria University of Wellington (Makenzie, 2021) demonstrated that the size of the home-range of urban ship rats was smaller than that expected based on research into rats living in rural areas. He also found that the home-range of individual rats overlapped.

This research meant that the traps placed in the 100 m x 100 m grid, might be beyond the range of some ship rats. That is, rats may not come across the traps in their wanderings.

The outcome of this research was to change to a finer placement of traps in likely habitats, narrowing to a 10 m x 10 m grid in some instances.

Moving to a habitat approach to the placement of devices

Henry's research, camera traps deployed by PFW, catch data, and observations from the field team identified the most likely places to find rats. They showed open areas, such as grass berms, did not attract rats, even if rats were present in the surrounding area. Ship rats were at their highest density in areas of undisturbed, dense vegetation - particularly escarpments and weedy banks - and commonly around the boundary between bush fragments and urban areas, where they have access to shelter and food. In addition, areas with dense tangles of cape ivy (*Senecio angulatus)*, a vigorous exotic plant that can grow 2-3 m high and inhabits scrubland near the coast, was a popular habitat for rats.

The outcome of these findings was to a move from the strict grid-based placement of traps to consider the surrounding habitat as well. Traps and bait stations were therefore placed close to the grid points but in areas with some cover. Targeted weed control, in particular of cape ivy, would remove much of the shelter in the remaining ship rat strongholds and may help catch those last rats.

Innovative remote reporting

Kurtis Papple and Dylan Hobbs developed the Trapscan QR code. The code can be attached to a trap or bait station and provides an easy and innovative way for the community to help monitor the biosecurity network. Remote reporting tools are intended to enable quick response to breaches, protect areas from reinvasion and promote community participation. This was tested over Easter weekend 2022 around the Seatoun coast.

Outcome. There were no responses from the community via the QR codes. This could mean that there was no evidence of incursions or trap damage because instances of zero rat activity are commonly unreported in PFW's Chew Card surveys. However, it may mean that the public did not get on board with the QR scans and potential rat activity went unnoticed. More comprehensive testing is needed to understand the effectiveness of QR codes.

Helpful hints

Keep a learning log - record learnings and responses to challenges as you go. Learning logs are a useful tool used by PFW to reflect on their work but also to share learnings with others.

Wax tags were a more effective than chew cards for monitoring rats (0.45 detections per sightings compared to 0.3 for chew cards) and were effective for longer. This suggests wax tags are more suitable for monitoring low densities of rats or as an early detection method for reinvasion. Adding peanut butter just above a wax tag encouraged interactions.

Chew cards. PFW's 2020/21 Impact Report provides further information on deploying chew cards at scale. https://www.pfw.org.nz/2020-21-impact-report/

2.3.2 Community engagement

Engaging the wider community is a critical factor in the long-term success of collectives (Brooks et al., 2013; Cabaj & Weaver 2016; Hanleybrown & Splansky Juster, 2015; Raderstrong & Boyea-Robinson 2016). Everyone in a community, especially in urban areas, contributes, consciously or unconsciously, to the state of the environment and recognising this can be critical to the success or longevity of restoration projects, including predator eradication (Egan et al., 2011). Community support can enhance participation throughout a project and increases the possibility that the community will be involved in the longer-term (Amed, et al., 2015; Fox & Cundill, 2018; Lambert, 1999; Phalen, 2009).

A variety of social strategies that depend on the local context have been identified that are key to engaging a community in ecological restoration. These include: promoting active community participation, supporting local livelihoods, respecting people's values and perspectives, evidence-based learning in all aspects of the project, providing environmental education and supporting local groups (Fox & Cundill, 2018; Raderstrong & Boyea-Robinson 2016). PFW were aware they could not achieve their goal without the support of the wider community and invested as much rigor into their engagement plan as they did into their technical plan.

The eradication project, and in the longer-term, biosecurity maintenance required increasing levels of support and participation from different sectors of the community on Miramar Peninsula including:

- The general support of the wider community, including mana whenua
- The active participation of community environmental groups in the field work and as advocates for the initiative
- Support and permission to position and service traps on private land (large landholders, businesses, schools and private residences).

2.3.2.1 Engagement with the wider community

PFW wanted to create an environment where their ideas would take hold in a way that allowed the possibility of new norms around predator eradication to develop, as well as achieving a high level of community buy-in (Harwood, 2015). To achieve this, Predator Free built their presence in the community by:

- Developing a brand, including logos and uniforms, so field workers would be easily identified and associated with the project.
- Participating in community events such as fairs, the annual Kotahi festival and the Miramarvellous festival (Figure 2.4). These events were an opportunity to communicate PFW's mission and to hear from members of the community. Amplifying the community's voice is a key condition to facilitate collective impact (Raderstrong & Boyea-Robinson, 2016).
- Tailoring events that tied in with PFW's objectives and desired outcomes (Allen, 2009). For example, organising community clean ups of rubbish and collaborating in a rat-proofing compost workshop in Strathmore in association with Sustainability Trust, to remove habitat for rats and create more attractive and healthier surrounds for people in the community.
- Participating in strategic opportunities that aligned PFW with PF 2050, such as the Fight for the Wild Documentary film & podcast series which explored the ambitious goal PF2050 goal and promoted community led projects (including PFW) that can help turn the tide of biodiversity loss.

Figure 2.4 The Predator Free Wellington stand at Newtown Fair.

The Communication and Marketing Plan was designed to align with PFW's eradication and social goals, to encourage recruitment and to present a consistent narrative to the stakeholders and public. Communications can influence factors that motivate change in people's understandings, beliefs and attitudes around predator eradication (Allen & Horn, 2009), such as understanding the importance of the project, the actions people can take and the significance of predator eradication to the broader community. The dominant themes of the Communication and Marketing Plan included:

- PFW's vision and approach to make Wellington the first predator free capital city in the world.
- Emphasis on increasing native biodiversity in Wellington City, rather than the number of predators killed
- The potential lifestyle, economic and environmental benefits to Wellington from the project.
- Everyone has a part to play and can make a difference in their neighbourhood.

Investment in digital marketing (in particular, Facebook) was an essential part of the engagement/communication strategy. The Communications and Marketing Plan recognised that advertising on social media had several advantages - an unparalleled reach into the community, the ability to target relevant sectors and expand an audience, and the potential to build online relationships. Social media was a way to move beyond top-down communication and amplify the community's voice (Raderstrong & Boyea-Robinson, 2016), that is the online community could engage with the PFW team and provide feedback. Facebook, and subsequently the social networks of PFW's followers could also be used to report progress and outcomes and drive action, including recruitment. The latter became especially important when Covid-19 hit New Zealand in 2020 and Wellington City went into lock-down. PFW had to pivot and move the one-to-one recruitment process to online recruitment.

Feedback from the Facebook platform was used to inform the engagement strategy going forward. For example, posts featuring photos of native plants or wildlife posts received several hundred 'likes' and 'shares' on Facebook, compared to around 30 'likes' for posts about technical matters. Therefore, the communications team frequently uploaded wildlife posts to keep the online community engaged.

PFW's website was created to be a hub for information on PFW and predator trapping in general. It provides a registry for suburban trapping groups, a place to record successes and challenges and resources for teachers and activities for children. Communications were designed to be accessible to everyone. One example of this is the format of PFW's annual Impact Report. An accessible version was designed and published on the PFW website. The latest 2020/21 Impact Report had over 1000 people read it for at least 3 - 4 minutes within two weeks of being published (PFW, pers. comm., 17.12.2021), probably reaching a larger audience than the traditional style of corporate document usually disseminated to shareholders.

Environmental education was a critical part of PFW's strategy to engage the wider public. The Predator Free Schools project, launched early 2018, was a significant opportunity to educate and engage young people in the eradication. Twenty-one schools on and near Miramar Peninsula have participated in the programme. Zealandia's educators coordinated and delivered a predator tracking and trapping programme for kura kaupapa (primary schools where Māori values are taught and te reo Māori is the language of instruction), primary and intermediate schools in the Miramar project area. Papa Taiao (a sustainable learning enterprise) delivered the Predator Free Schools programme to secondary schools in Wellington.

2.3.2.2 Partnership with Māori

Miramar Peninsula includes the rohe (area) for both Taranaki Whānui ki te Upoko o te Ika and Ngāti Toa Rangatira Iwi. The PFW project is an opportunity to partner with mana whenua, to integrate Indigenous knowledge and to uphold Indigenous rights and interests (Eufemia et al., 2019; Hemming et al., 2017; Lyver et al., 2019; Wehi & Lord, 2017). Mana whenua have representatives on the PFW Board of Trustees but beyond this progress along the pathway to partnership is still in the early days. PFW welcomes a kaupapa Māori approach when opportunities arise. For example, the mana whenua board members are currently employing a tuakana teina approach reflecting a shared learning experience, in this case between two people.

PFW builds on existing, often personal relationships, to invite participation and strengthen relationships with Māori. Currently PFW are collaborating with the Taranaki Mounga project. Rangatahi (young people, youth) associated with that project have been invited to a wānanga (meeting/forum) in Wellington where they can strengthen their links with their iwi in Wellington and develop a relationship with PFW. Rangatahi can then stay on for one week to develop skills in predator eradication. These kinds of initiatives offer opportunities to build connections and trust in PFW, the project and the people, and to demonstrate reciprocity. PFW Ltd. are not yet where they want to be in their relationship with Māori, and are working to explore potential pathways to develop a meaningful partnership going forward.

2.3.2.3 Partnering with community environmental groups

Collective impact efforts are most effective when they build on existing community efforts (Bradley et al., 2017). There were three community environmental groups established on Miramar Peninsula and hundreds of households already involved in trapping before PFW Ltd. formed (Henry, 2019; Appendix 2). PFW's core project team used a targeted strategy to engage community groups as collaborative partners and where appropriate place decisions and the implementation of the work into their hands. This is considered a key strategy to successfully partner with community groups (Phalen, 2009; Raderstrong & Boyea-Robinson, 2016; Shanahan, 2021).

Members of the PFW core team meet regularly with leaders or key individuals from backyard and reserve trapping groups. The purpose of these meetings is to build relationships between PFW and these groups and strengthen the connections between the groups themselves. It is an opportunity to acknowledge and appreciate the groups' efforts, to give updates on PFW's plans and importantly to hear from the group leaders themselves. A key aim of hearing from the group was to understand the trapping group's goals, the kind of support they need, opportunities for growth and ultimately their interest and capacity in collaborating with PFW's plan in their area, while supporting them to maintain their identity and a sense of ownership of their work.

Meetings with Phase 2 trapping groups' leaders provide an example of the meetings' usefulness. Early in Phase 2, concerns were raised that recent plantings of natives done by the group would be trampled by PFW field staff as they cut and laid trapping lines in the same area. PFW and the group leaders worked together to create a solution. They decided a knowledgeable PFW staff member would carry out a pre-assessment of the area and would flag these high-value plants to protect them. This outcome served to allay the group's concerns and deepened their trust that PFW valued their work, goals and priorities, which are crucial elements in building effective collaborations (Raderstrong & Boyea-Robinson, 2016).

The relationship between PFW Ltd. and community groups had reciprocal benefits. Alongside recruiting the groups to collaborate with PFW, PFW could add to the effectiveness of the groups by providing resources (e.g., funds, chew cards, trapping tunnels and technical knowledge) and train them to be more effective (e.g., how they are trapping - different lures, how to identify signs of predators, monitoring, leadership skills). Dan Henry, the lead of Predator Free Miramar wrote:

> *"But having [the PFW technical leads] and their team of 30 odd passionate and professional trappers, checking their 50 m by 50 m network of nearly six thousand bait stations and traps across the peninsula each week, provides a great deal of security that our work is well-supported!"* (p. 16, Henry, 2019).

2.3.2.4 The community-by-community approach to recruitment

Predator eradication must reflect the values, context and culture of each community if it is to successfully engage with community members (Allen & Horn, 2009; Egan et al., 2011; Raderstrong & Boyea-Robinson, 2016). This includes being sensitive to issues around equity and social justice (Brady & Splansky Juster, 2016). PFW's strategy before beginning work in a new suburb is to first identify and build relationships with key groups or individuals in that suburb, such as existing trapping or environmental groups, community centres, schools or churches. PFW then works with their community partners to engage community members at the grassroots level. This helps PFW to understand the local context, identify the community's particular needs and determine how those needs are aligned with PFW's objectives. PFW can then tailor their approach for the local context (see an example in Text box 2).

The precise nature of the trapping grid meant the placement and servicing of some traps and bait stations needed to be on private land (homes and businesses). Once an approach to a particular community was developed, large and small land-holders were recruited to participate in the project. The Stakeholder Engagement Manager identified large land holders on the Peninsula and began to build relationships with them, explaining the project and hearing landowners concerns before any technical work began. PFW obtained all the permissions they required from large land-holders, at times at the expense of the land-holder themselves. For example, Wellington International Airport provided staff members to accompany the field officers when they deployed and serviced the traps and bait stations on airport land to meet the requirements of aviation law.

Three Engagement Field Officers (EFOs) worked to obtain permission from householders and businesses to place and service traps and bait stations on private land. This process took the EFOs six months of full-time work, door-knocking, conversations and cups of tea to obtain the 3000 permissions necessary to complete the trapping network. The professional training and personal characteristics of the EFOs (such as being personable, empathetic, humble, knowledgeable) and their ability to problem-solve and take initiative resulted in 99% of households they approached agreeing to participate (PFW, 2020b). The investment in this time-consuming and expensive endeavour gave rise to other important outcomes. Information gathered from EFOs' conversations, and recorded in their reflections' sheets, was invaluable to understanding people's perspectives on the project. The conversations revealed reasons individuals chose to participate or not to participate and their excitement or concerns about the project.

EFOs used these learnings to educate people about the project, correct misinformation and answer their concerns. These learnings also informed the communications strategy and influenced the development of public messaging to clarify the methods of predator control, reassure the public about their humaneness and safety and address concerns around the impact of poisons. It was also an opportunity to promote the positive feedback – people's delight in seeing native birdlife.

Text box 2. KEY LEARNING TO ENGAGE A COMMUNITY

Each community is a unique opportunity to engage

An example of tailored engagement. The hills of Strathmore Park are home to a socially unique community. The area is ethnically diverse with relatively fewer European people and relatively more Māori, Pacific Peoples and Middle Eastern people than the rest of Wellington. There is a large amount of social housing with 400 homes out of 1400 owned by Kāinga Ora, the government agency responsible for state housing (Martley, 2020) and the area is rated as decile 8 (indicating a high level of economic disadvantage) in the New Zealand Deprivation Index (Environmental Health Intelligence New Zealand, 2018).

PFW's Project Director made the first approach to the two community centres in the area. The community centres' co-ordinator suggested attending the regular morning tea to meet some of the local people, promote PFW's work and identify community needs that might align with the eradication work. PFW demonstrated their willingness to give to the community through co-hosting a workshop on rat-proofing compost bins and supporting street clean-ups.

Many people in the area were concerned about rat infestations in their homes and on their properties. This was their main motivation to participate in the project, rather than to achieve biodiversity gains. They were also concerned about the cost and the methods PFW used. This learning informed the redesign of the pre-visit flyer delivered to letterboxes to make the key message front and centre: we will kill your rats, its free and its safe. It also informed the strategy of the Engagement Field Officers.

Meeting people where their needs are can have unexpected outcomes. For example, one Strathmore resident, Daniel*, became involved in volunteer trapping because rats in his ceiling were keeping him awake at night. Daniel became a central part of the volunteer team in Strathmore, supported and resourced by Predator Free Miramar. He became an advocate for the project and was able to access properties of neighbours who were wary of the PFW team coming onto their property and help them deal with rat infestations on their property. Daniel, who had faced a number difficulties during his life, developed new skills that could be useful when seeking employment.

*Name changed to protect resident's privacy

2.3.2.5 Summary

Section 2 has outlined the social-ecological approach that PFW has taken for the eradication on Miramar Peninsula. A 'remove and protect' model was the basis for the technical plan (Bell, Nathan & Mulgan, 2019). PFW had a general communication plan to build their presence in the community, a targeted strategy to engage community environmental groups as collaborative partners and a tailored engagement strategy to recruit landholders' participation within each community. We demonstrate how the initiative fulfils the five conditions of the Collective Impact Framework (Kania & Kramer, 2011). PFW's core team functioned as the backbone organisation, managing the project and guiding the development of a common agenda for change. They co-ordinated mutually reinforcing activities and an agreed upon way of measuring outcomes and maintained open communication with the stakeholders.

Collaborative initiatives have been criticised for being too top-down and engaging the most powerful organisations and partners in a community to agree on the common agenda (Raderstrong & Boyea-Robinson, 2016; Wolff, 2016). Thus, failing to meaningfully engage those in the community most affected by the issues. This approach can disregard community knowledge and compromise community ownership of the project. Which in turn can lead to solutions that are not informed by community needs and may not be appropriate in a particular situation (Raderstrong & Boyea-Robinson, 2016; Wolff, 2016). PFW Ltd. was established by the Foundation partners with an established agenda and technical plan to undertake the eradication.

Engaging with the local community before forming the common agenda, perhaps through a social impact assessment, community meetings or focus groups, would have provided an opportunity to amplify the community voice, including that of mana whenua, and enable the wider community to meaningfully share in decision making. Nevertheless, PFW's Communication and Marketing Plan outlined a pathway to inclusive community engagement. This pathway involved collaborating with community environmental groups early in the project, building PFW's presence in the community and encouraging participation and input from all sectors of the community such as schools, householders and businesses.

SECTION 3: SOCIAL AND ECOLOGICAL OUTCOMES

3.1 Introduction

The management or eradication of mammalian predators from urban areas can have a variety of inter-related ecological and social outcomes (Russell & Stanley, 2018; Wilson et al. 2017). In addition to demonstrating the effectiveness of a project, measuring and communicating outcomes ensures that participants' efforts remain aligned and provides participants with opportunities to learn from each other's successes or failures (Kania & Kramer, 2011). Shared measurement and communication are two of the conditions of the Collective Impact Framework (Kania & Kramer, 2011).

A second framework, proposed by Brooks et al. (2020) and modified by Shanahan et al. (2021) is a useful way to examine and understand the relationship between the social and ecological outcomes of conservation projects. This social-ecological systems framework has been used here to demonstrate the potential direct and indirect effects and feedback loops of predator eradication on people and the ecosystem (Figure 3.1). The outcomes selected for this model have been identified from the literature and are those for which there is some evidence available.

The framework shows how the social and ecological outcomes can be interlinked and highlights the possibility of positive or negative feedback loops. For example, more biodiverse environments can have a greater impact on psychological wellbeing than areas with less biodiversity (Fuller et al., 2007; Cox et al., 2017), although not always (Luck et al., 2011; Dallimer et al., 2012). Conversely, unintended consequences of predator control, such as poisoning non-targeted species, could have a negative impact on people's attitudes towards the predator eradication.

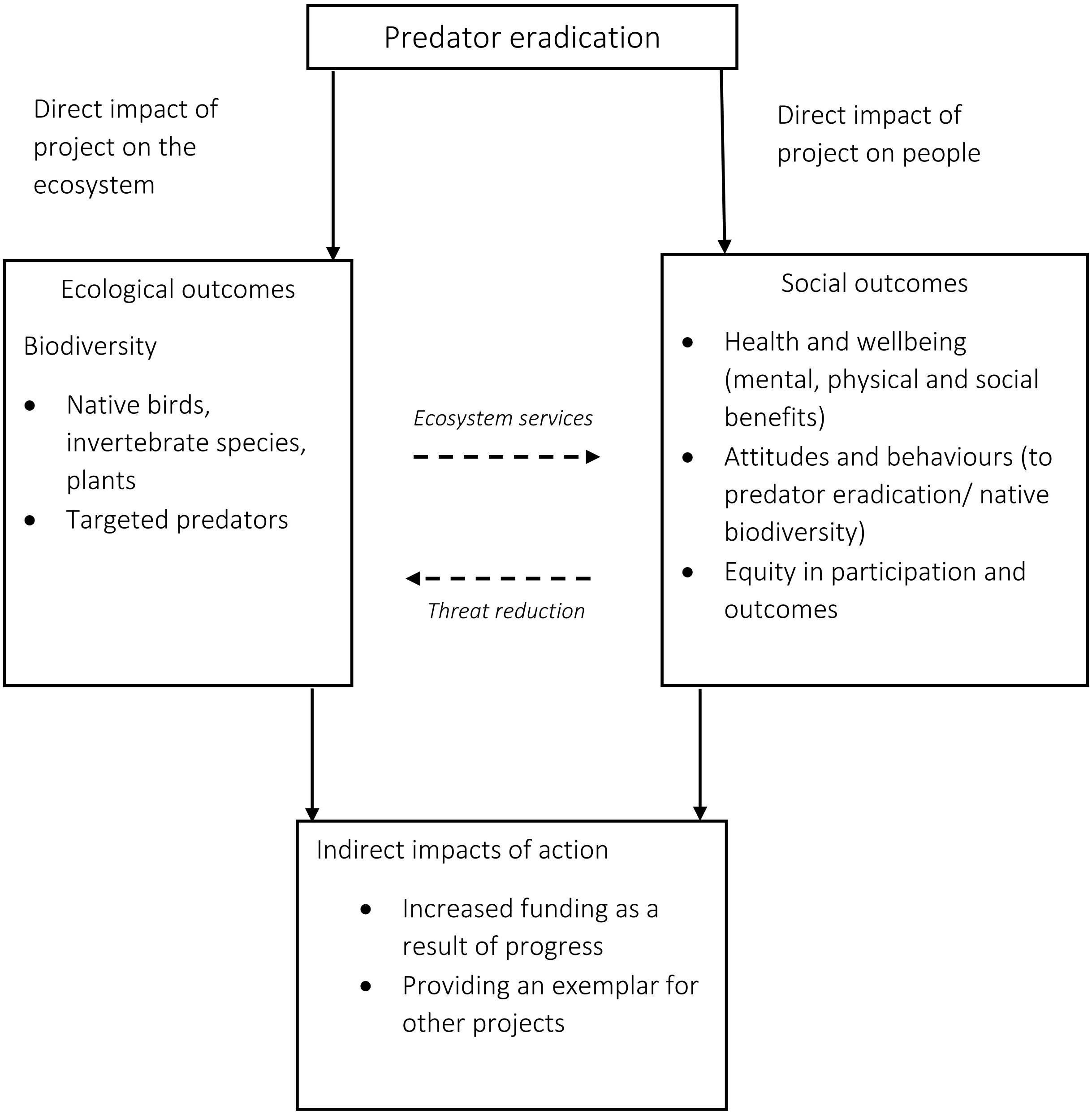

Figure 3.1 A framework demonstrating the potential social and ecological outcomes from predator eradication, adapted from Brooks (2020) and Shanahan et al. (2021).

Next, we use existing ecological and social science literature to introduce the potential ecological and social outcomes highlighted in the framework (Figure 3.1), that might be expected from PFW's work in Wellington. This is followed by a consideration of the evidence for social and ecological outcomes from PFW's work.

3.2 Ecological outcomes

The management or eradication of mammalian predators can benefit native biodiversity by eliminating the threat of introduced predators and reducing browsing on plants and their seeds thus allowing their habitat to recover, when it reduces predator numbers below their damage threshold (Norbury et al. 2015). The extent to which biodiversity can recover depends on the existing biodiversity at the site (which determines what species might rebound) and the type of landscape (which affects animal behaviour) (Russell & Broome 2018).

Predator control in 'mainland islands' (Saunders & Norton, 2001) and eradication from predator-proof fenced sanctuaries (Innes et al., 2012; Miskelly, 2018) and other eco-sanctuaries (Binny et al., 2021) has led to localised biodiversity gains mirroring those found through offshore island eradications (e.g., Tiritiri Matangi, Galbraith & Cooper, 2013). Other community efforts, such as the Kiwi Coast project in Northland, have reported changes in species diversity and relative abundance after suppressing mammalian predators (Kiwi Coast Trust 2018; Ōtanewainuku Kiwi Trust 2020; Parihaka Community Landcare 2020). Two meta-analyses of New Zealand conservation projects demonstrated that large, deeply endemic bird species (who have evolved in New Zealand longest) appear to have the strongest responses to predator management compared to more recently arrived natives (Binny et al., 2021; Fea et al., 2018). Binny et al. also noted that, at least within eco-sanctuaries, some invertebrates benefit from predator control - Orthoptera, which includes the endemic wētā, and Isopoda - but others such as Coleoptera (beetles) did not.

Monitoring ecological outcomes provides essential information to refine and improve best practice methods (Wortley et al., 2013). Monitoring can help justify the cost of predator eradication and the cost to animal welfare (Dubois et al., 2017), is needed to meet the requirements of project funders (Sporle, 2007; Peters et al., 2015) and providing evidence of progress can be an important motivating factor for collectives to continue their work (Weaver, 2016).

Although there is a growing awareness that biodiversity monitoring is needed, few community-based restoration groups monitor biodiversity outcomes or publish their data (McFarlane et al., 2021; Russell & Stanley, 2018; Sullivan & Molles, 2016). This can be because the community group or collective is in the early stages of development or perhaps lack the capacity or the capability to do so (Braun et al., 2016; McFarlane et al., 2021). Although monitoring toolkits designed for community environmental groups exist, they are not widely used (Peters et al., 2016). The ecological outcomes that are measured are limited, and generally focus on reporting the more easily measured indices, such as the number of traps set and rats killed or the level of volunteer involvement, rather than evaluating increases in abundance and diversity of native species which is their ultimate goal (Jones & Kirk, 2018; Russell & Stanley, 2018). Groups working in partnership with agencies such as regional councils are more likely to monitor biodiversity outcomes (Peters et al., 2015).

3.3 Social outcomes

The management or eradication of mammalian predators from urban areas can potentially have social, economic and public health/wellbeing benefits alongside any benefits to biodiversity (Russell et al., 2015; Wilson et al. 2017). Furthermore, these social outcomes are a key reason for cities, including Wellington City, and countries to invest in biodiversity restoration (Shanahan et al., 2018; Wellington City Council, 2015). However, there is little research on the economic or public health benefits of removing introduced mammalian predators, even though the potential benefits are likely to be significant, particularly for eradicating rats (Russell & Stanley, 2018). Such benefits could include a reduced risk of zoonotic diseases, reduced damage to food (e.g., vegetable gardens), improved quality of rainwater collected from roofs, reduced damage to building insulation and roofing and reduced fires associated with rodent damage of wiring (Wilson, 2018).

Wellbeing outcomes

Exposure to nature can offer considerable benefits to human health and wellbeing (Bowler et al., 2010; Hartig et al., 2014). These benefits include higher levels of perceived general health (Maas et al., 2006; Van Dillen et al., 2013), better mental health (Dallimer et al., 2012; Fuller et al., 2007; Mitchell, 2013; Sugiyama et al., 2008), less respiratory illness and allergies (Donavan et al., 2018; Hanski et al., 2012; Lovasi et al., 2008), lower stress levels (Nielsen & Hansen, 2007; Van Den Berg & Custers, 2011), better cognitive functioning (Bratman et al., 2012; Kuo, 2001), reduced mortality from cardio-vascular disease (Donovan et al., 2013; Mitchell and Popham, 2008), lower likelihood of obesity (Nielsen and Hansen, 2007; Ellaway et al., 2005), quicker recovery from surgery (Ulrich, 1984), increased social contacts and social cohesion (Kuo, 2015) and increased physical activity (Lee et al. 2013; Sugiyama et al., 2010; Timperio et al., 2008).

The mechanisms for these health outcomes are varied and depend on the amount of nature exposure an individual experiences (Shanahan et al., 2016; Cox et al., 2017), whether individuals have an existing connection to nature and socio-demographic variables (Shanahan et al., 2019). For example, the mental health benefits attributed to spending time in nature can be because nature provides opportunities for psychological restoration which can replenish fatigued cognitive functions (Byrka et al., 2010; Collado & Corraliza, 2015; Kaplan & Kaplan, 1989) and being in nature can de-escalate the physiological stress response (Ulrich, 1991; Ward Thompson et al., 2012). Increased social cohesion is another pathway through which the natural environment supports health (Hartig et al., 2014). Social cohesion is positively influenced by the presence and quality of urban green spaces (e.g., de Vries et al., 2013). Being in urban nature may increase the opportunities for social contact, increased social contacts can in turn develop into increased social support and a sense of belonging in the local community which ultimately can contribute to feelings of social cohesion (Francis et al., 2012).

Participating in a community conservation initiative, such as predator eradication, can provide passive experiences of nature and opportunities for social connection that create the potential to access these benefits. Collaborating on a project and working towards a common goal can also build social cohesion and strengthen connections in the community (Shanahan, 2020; Virapongse et al., 2019). Wellbeing and social benefits are rarely measured by community groups or collective. However, participants in community gardens report similar physical, mental and social benefits as those reported from exposure to nature (Cleghorn et al., 2010; Cowie, 2010; Earle, 2011; Miles et al., 1998; Pillemer et al., 2010; Kingsley et al. 2009).

Attitudes & behaviours to predator eradication

Public support for managing predators can be variable and depends on the social and cultural context, the type of methods employed and the species of predator involved (Glen et al., 2013; Perring et al., 2018). The success of Predator Free 2050, and indeed PFW’s project, depends on the public's attitudes towards the initiatives and their willingness to change their behaviours to actively participate or at least align behaviours that can undermine the operation (such as removing rubbish from around property or rat proofing compost bins). In New Zealand, people generally consider small mammalian predators, such as mustelids and rats, pests (Russell, 2014) and the large number of community trapping groups indicates a level of support for their eradication. However, the concept of a pest and aspects of management can be contested issues (Allen & Horn, 2009). For example, some Māori regard the kiore, an introduced Pacific rat, as culturally important (Linklater & Steer, 2018). A particular area of contention in predator management is the non-selective nature and aerial application of poisons such as 1080 (Russell, 2014) and the humaneness of other poisons such as the anticoagulant Brodifacoum (Goldson et al., 2015; Russell, 2014).

Social science theory and research indicate that a person's attitude towards a particular action is a reliable, but not infallible, predictor of them carrying out that action (Ajzen, 1991; Gifford & Chen, 2017). Therefore, we might expect people who support predator eradication in Wellington City to actively participate in PFW's project.

Equity and social justice

Equity can be defined simply as the fair or just treatment of individuals or groups (Law et al, 2017). Although simply defined, equity can have many facets such as social, environmental and intergenerational and the consideration non-human life (Wells et al., 2021). Pascual et al. (2014) suggest four dimensions of equity that pertain to ecological projects: distributional, procedural, recognitional and contextual:

> "*Procedural equity refers to equitable involvement of stakeholders in making rules and decisions. Recognitional equity refers to the respect for knowledge systems, values, social norms, and rights of stakeholders. Contextual equity refers to the broad social, economic, political, and cultural contexts, both past and present, that influence the ability of an actor to participate in decision making, ensure fair distribution, and gain recognition: for example, power dynamics, ethnicity, gender, age, and education*." (p. 2, Wells et al., 2021).

The United Nations Decade on Ecosystem Restoration (2021–2030) stresses the importance of the recognition and procedural aspects of equity: the participation of relevant stakeholders, including women, young people, persons with disabilities, Indigenous peoples and local communities (United Nations, 2019). Equity is also an underlying principle of the Collective Impact Framework; without considering equity, the conditions outlined in the model would not create lasting change (Brady & Splansky Juster, 2016).

In practice, equity is rarely considered in restoration projects (Wells et al., 2021). The challenge is how do we meaningfully involve sectors of the community who have historically been excluded from decision-making processes and obtain equity in ecological outcomes and participation? We can find a way in to those communities and acknowledge the structural barriers presented by social, political, and economic issues and attempt to address them when working with those communities (Wolff et al., 2016).

3.4 Evidence of ecological and social outcomes

In the following sections we examine the evidence for ecological and social outcomes of PFW's work on Miramar Peninsula and in Wellington City for which data or other evidence is readily available. Ecological outcomes examined here include the progress in the eradication of the targeted predators and outcomes for terrestrial bird populations, kororā (little penguin) breeding and wētā and invertebrate populations. Social outcomes explored here include the potential to improve human wellbeing, promoting environmental justice and residents' changes in attitudes and behaviours around predator eradication.

3.4.1 Progress in the eradication of targeted mammalian predators

We analysed the raw data for the Miramar eradication obtained from Trap.NZ from January 2017 to June 2022. The data included here is from the Trap.NZ projects labelled 'Miramar Eradication', 'Miramar Volunteers' and 'Predator Free Miramar'. Predator Free Wellington commenced trapping mammalian predators in July 2019. Community groups such as Predator Free Miramar are responsible for the earlier data. Data is reported here as corrected trap catch rate and expressed as the catches per 100 trap nights. Trap nights is the number of nights the trap is set for over the selected period. However, when a trap is sprung, Trap.NZ assumes the trap is available for only half the nights from the previous trap record date.

Rats

Rats were the most common targeted predator on Miramar Peninsula (Table 3.1). In total, there were over 70 times more rats killed than mustelids. The number of rats killed per calendar year peaked in 2019 at 3145 and has declined to 37 for the year to 30 June 2022 (Table 3.1, Figure 3.2). Community-led trapping groups, householders and businesses killed over 5000 rats before PFW began their trapping on the Peninsula in July 2019 (Henry, 2019). The catch data does not represent the entire number of rats caught; many would have taken poison from the bait stations.

Table 3.1 The number of mammalian predators killed each year on Miramar Peninsula from 1 January 2017 to 30 June 2022.

	Rats	Weasels	Stoats	Mice	Hedgehogs
2017	1009	7	15	922	71
2018	2316	13	10	1936	192
2019	3145	44	6	2511	234
2020	970	9	0	1443	387
2021	275	2	0	2197	312
2022	37	1	0	947	100
Total	7752	76	31	9956	1296

Miramar was declared free of Norway rats (*Rattus norvegicus)* in January 2021 (PFW, 2021). The abundance of ship rats (*R. rattus*) has been dramatically reduced since the peak in 2019. The first six months of 2022 have recorded the lowest numbers of ship rats killed, per 100 trap nights, compared to each of these months in previous years (Figure 3.2).

The number of rats caught fluctuates throughout the year, peaking in autumn/winter (March to June in New Zealand) after the breeding season in spring/summer (November to February) (Efford et al., 2006). The number of rats caught during the autumn/winter season peaked in 2019 and has been decreasing over the subsequent winters (Figure 3.2).

Fewer rats were caught in the heavily residential, central part of the Peninsula (Figure 3.3). Most rats were caught on the border of the urban areas where there was some vegetation cover or in the bush such as at the northern end of the Peninsula. A notable exception to this is the residential areas in Strathmore and Miramar north (Figure 3.3) where high numbers of rats were caught up until 2019.

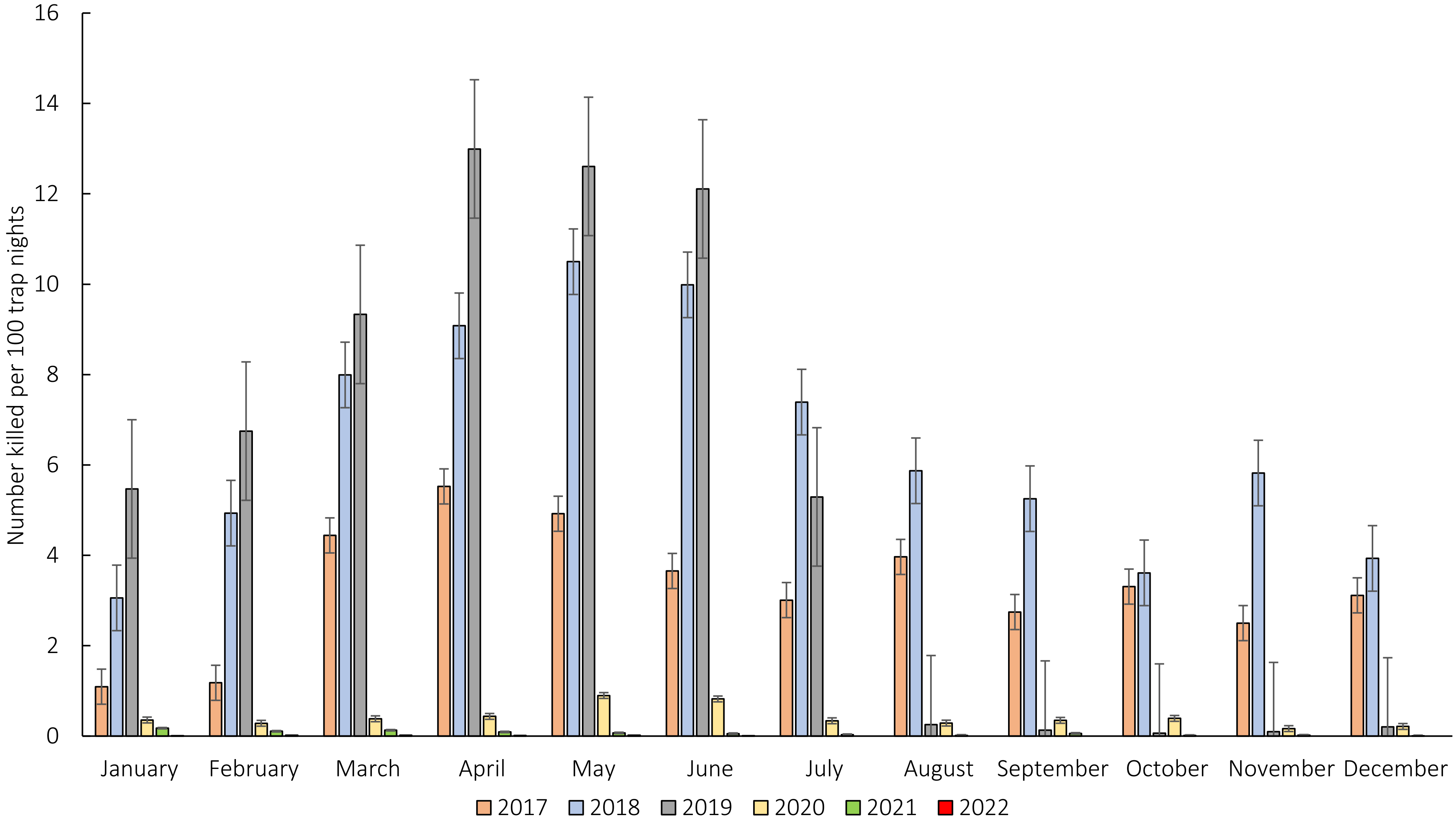

Figure 3.2 Corrected catch trap rate for rats (the number of rats killed per 100 trap nights) (± SE) on Miramar Peninsula from 1 January 2017 to 30 June 2022. Predator Free Wellington's eradication began in July 2019. In April 2020 a one-month nationwide Covid-19 lockdown stopped field work.

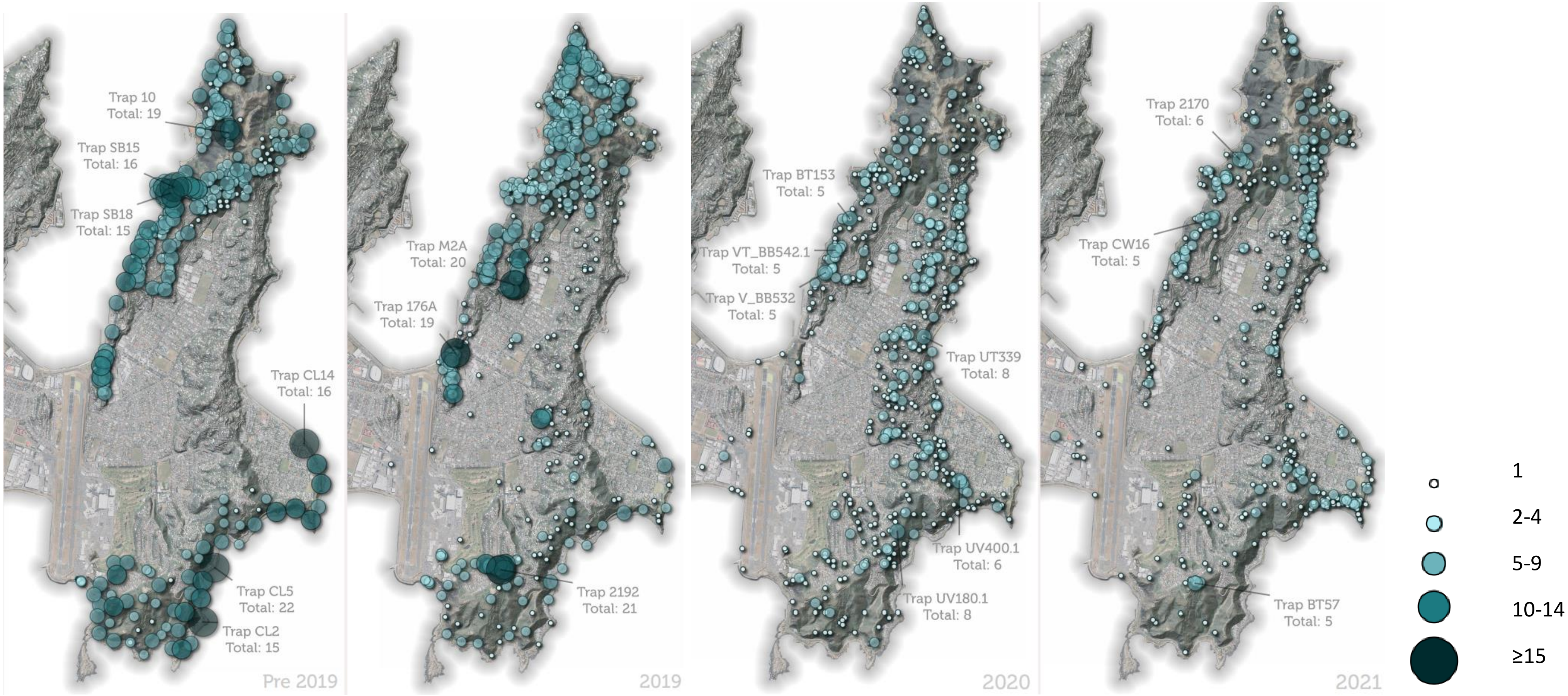

Figure 3.3 Time series of rat catch totals and distribution on Miramar Peninsula from 2019 to September 2021. Courtesy of Predator Free Wellington, LINZ CC by Creative Commons 4.0.

Mustelids

Mustelids occur in low numbers on the peninsula compared to rats. Twice as many weasels (*Mustela nivalis*) have been caught compared to stoats (*Mustela erminea*) (Table 3.1, Figure 3.4). The number of weasels caught peaked in 2018. Miramar Peninsula was declared free of mustelids in January 2021 (PFW, 2021).

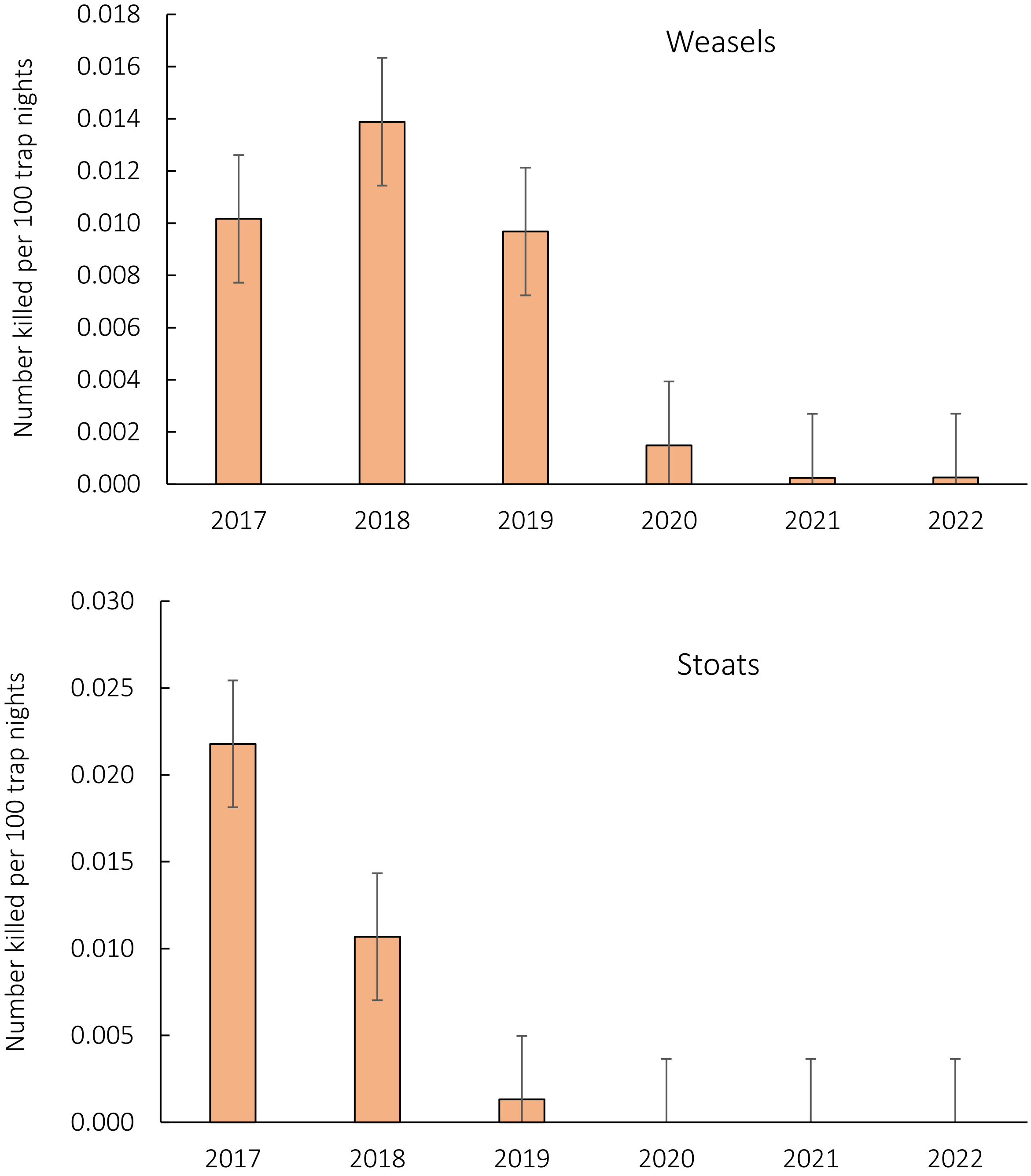

Figure 3.4 Corrected catch trap rate for weasels and stoats (the number killed per 100 trap nights) (± SE) on Miramar Peninsula from 1 January 2017 to 30 June 2022.

Incursions

Although Miramar was declared free of mustelids and Norway rats in January 2021, two weasels were killed on the Peninsula in 2022, one stoat has been sighted several times, and there were two verified incursions of Norway rats. No mustelids have been detected by chew card or wax block monitoring during 2022. Several Norway rats and a weasel were killed in buffer zone in 2022.

Hedgehogs and mice

Although not target species for the PFW eradication, any kills of hedgehogs (*Erinaceus europaeus)* and mice *(Mus musculus)* were recorded in Trap.NZ. One thousand, two hundred and ninety-six hedgehogs were caught from 2017 to 30 June 2022, their number peaking in 2018 (Table 3.1).

Around 10,000 mice have been killed in traps on the Peninsula from 2017 to 2022. More are likely to have been killed by poison from the bait stations. The annual number of mice killed per 100 trap nights has remained ≥ 0.20 since 2020, when the rat and mustelid numbers were dramatically reduced the on the Peninsula (Figure 3.5).

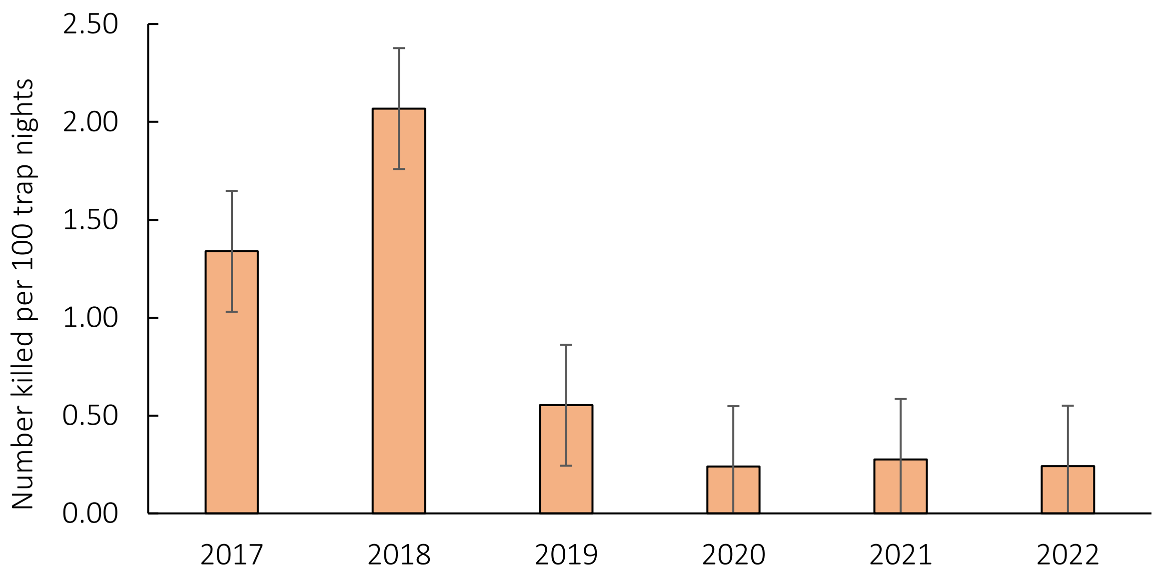

Figure 3.5 The corrected trap catch rate for mice (number of mice killed each year per 100 trap nights) (± SE) on Miramar Peninsula between 1 January 2017 and 30 June 2022.

Summary

Catch and monitoring data demonstrate a decline in rat and mustelid numbers on Miramar Peninsula during the PFW operation. As at 30 June 2022, PFW are still catching ship rats on Miramar Peninsula. The last ship rats are proving elusive and require an innovative approach (see, Appendix 3). Incursions of Norway rats, weasels and stoats appear to have occurred since they were declared eradicated in January 2021, as these species have been found in traps or sighted on the Peninsula. At this level of incursions, the multiple layers of biosecurity protection in place appear to be working.

The removal of large mammalian predators can lead to a population explosion of mice and to heavier mice through the lack of predation and greater access to food, at least in fenced eco-sanctuaries (Goldwater et al., 2012; Watts et al., 2022). A dramatic increase in mouse numbers can have a negative impact on invertebrates such as wētā, spiders and beetles (Watts et al., 2022) and likely on seedling recruitment. Mice numbers have not decreased in recent years on the Peninsula, in contrast to the reduction in rat numbers. Research into the impact of rat and mustelid removal on the mice population on Miramar Peninsula is needed to understand the potential impact on native invertebrates. Likewise, hedgehogs have been trapped in large numbers. Hedgehogs can be underestimated as mammalian predators (Russell & Stanley, 2018) and their impact on the native biodiversity on the Peninsula is unknown. However, Nottingham et al. (2019) provide evidence that the diet of urban hedgehogs includes earthworms, slugs, wētā, centipedes and lizards.

3.4.2 Terrestrial birds on Miramar Peninsula

Introduction and Methods

Evidence for changes in the terrestrial bird community was drawn primarily from a five-minute bird count data set created by Greater Wellington Regional Council (GWRC, unpublished raw data). This data was collected from a network of 84 five-minute bird count (5MBC) stations across Miramar Peninsula which was established to monitor the response of local bird populations to the eradication of mammalian predators on the peninsula. This bird survey method is well tested throughout New Zealand and has been used in a systematic way to monitor birds in the Wellington region for over 10 years (full methodology is described in (McArthur, Flux, & Harvey, 2021). The limitations inherent in the 5MBC method (Hartley,

2012) have been minimised on Miramar Peninsula by carrying out the survey at the same time each year, in similar weather conditions, using the same highly experienced observers each year (McArthur & Ray, 2021).

Seventy-seven of the 84 stations were laid out on a 320 m x 320 m grid across Miramar Peninsula. A further seven stations already situated in native forest habitat on the Peninsula were incorporated into the network (Figure 3.6). A single bird count has been carried out at each station on fine, calm days each year between late October and late November since 2017. Two of these surveys were carried out before PFW began the eradication and three were carried out afterwards. In 2018 there were 83 stations (station 77 was not included due to logging at the station). Raw data on terrestrial bird species used in this section are supplied by and used with permission from GWRC (GWRC, unpublished raw data), in conjunction with the associated reports (Ray, & McArthur, 2018, 2019; Ray, 2020; McArthur & Ray, 2021; McArthur et al., 2021).

We analysed the raw bird count data to determine several indicative statistics including:

- The total number of terrestrial birds detected across all 5MBC stations on the peninsula
- The overall encounter rates for native verses introduced species
- The mean number of birds of each species encountered at each station
- The number of stations where each species was encountered for the years 2017 to 2021.

To meet the assumptions of normality required for parametric tests, the data were transformed as per McArthur & Ray (2021) by adding a value of 1.0 to all count data to remove zero scores. A square root transformation was then applied to all count data. Paired, two-tailed t-tests were used to test for statistical significance in the mean number of terrestrial birds that were observed in 2021 compared to the mean number observed in 2017 (the earliest data available), for species that occurred in over 15% of the stations over these years. These include native birds (tūī, riroriro, tauhou and pīwakawaka) and introduced birds (sparrow, blackbird, starling, chaffinch, greenfinch and dunnock).

Figure 3.6 Locations of the five-minute bird count stations surveyed on Miramar Peninsula from November 2017 – November 2021. Yellow triangles represent the seven bird count stations established in 2011 as part of the Wellington City bird monitoring programme; blue circles represent the 77 bird count stations established in 2017 for the Miramar Peninsula bird monitoring programme (Figure from, McArthur & Ray, 2021).

Evidence for change in the terrestrial bird community

A total of 5927 terrestrial birds were encountered during the five, 5MBCs on Miramar Peninsula from 2017 to 2021. In 2017, the terrestrial bird community on Miramar peninsula was dominated by introduced and naturalised species (hence forth called introduced species) (Figure 3.7), with over five times more introduced birds per station than native birds. By 2021, the proportion of introduced to native birds had decreased to around 2.7 times, driven largely by the increase in native bird detections (Figure 3.7).

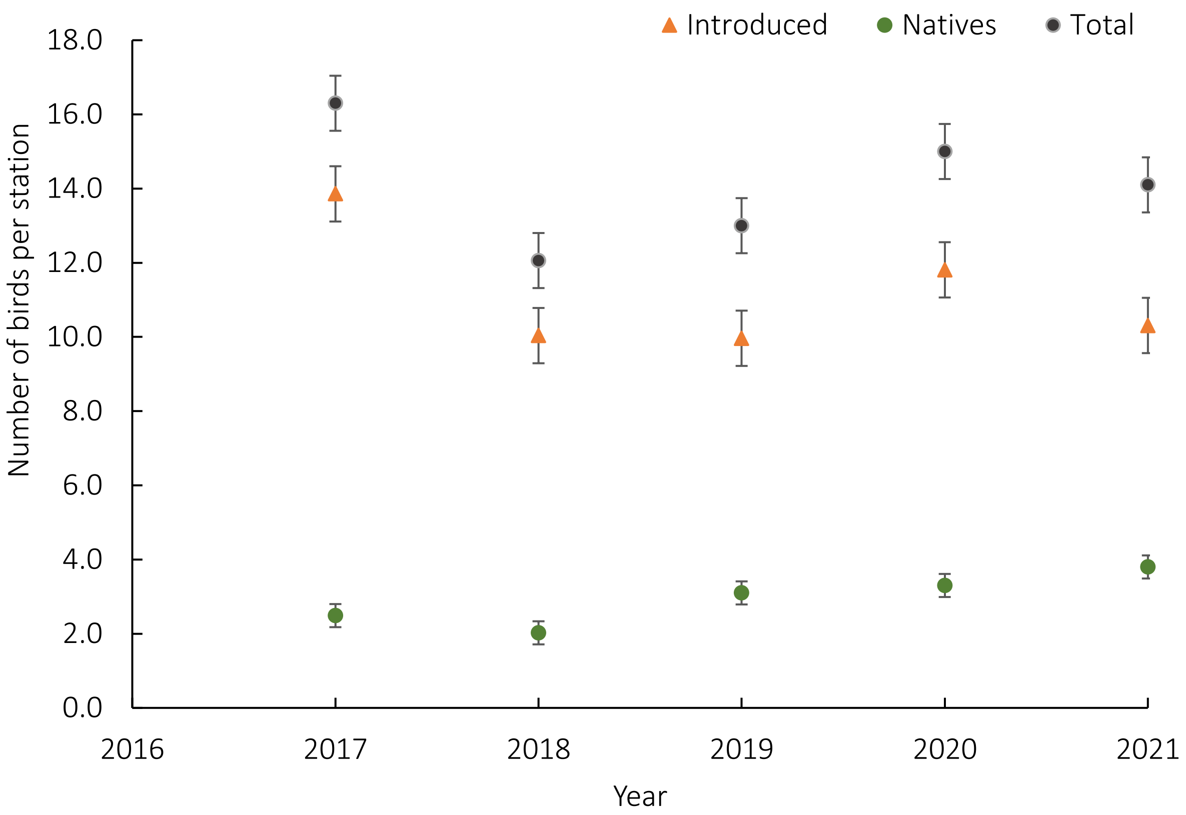

Figure 3.7 The mean number (± SE) of encounters per bird count station for all birds and introduced and native bird species on Miramar Peninsula from 2017 - 2021.

Twenty-two terrestrial bird species were observed between 2017 and 2021. Of these, 9 species were native (Table 3.2, Figure 3.8) and 13 were introduced species (Table 3.2, Figure 3.10). Most of the native species were classified as Not Threatened according to the New Zealand Threat Classification System (Robertson et al., 2017), except for kererū which are regionally At Risk and Recovering and kārearea which are At Risk and Recovering nationally but are Regionally Critical (for detailed data on the occurrence and distribution of native birds on Miramar Peninsula, see Appendix 4).

Table 3.2 List of terrestrial birds encountered on Miramar Peninsula and mentioned in this report with the threat classification for native species.

Species Māori Name[1]	Common Name	Scientific name	Threat ranking[2]	Trend
NATIVE BIRDS				
tūī	tūī	*Prosthemadera novaeseelandiae*	NT	Increasing
tauhou	silvereye	*Zosterops lateralis*	NT	
riroriro	grey warbler	*Gerygone igata*	NT	Increasing
pīwakawaka	fantail	*Rhipidura fuliginosa*	NT	Increasing
kōtare	NZ kingfisher	*Todiramphus sanctus*	NT	
warou	welcome swallow	*Hirundo neoxena*	NT	
pīpīwharauroa	shining cuckoo	*Chrysococcyx lucidus*	NT	
kererū	kererū	*Hemiphaga novaeseelandiae*	AR, R	
kārearea	NZ falcon	*Falco novaeseelandiae*	RC	
INTRODUCED BIRDS				
manu pango	Eurasian blackbird	*Turdus merula*		Decreasing
tiu	house sparrow	*Passer domesticus*		Decreasing
tāringi	common starling	*Sturnus vulgaris*		Increasing
pahirini	chaffinch	*Fringilla coelebs*		
	greenfinch	*Carduelis chloris*		
	rock pigeon	*Columba livia*		
	dunnock	*Prunella modularis*		Increasing
	goldfinch	*Carduelis carduelis*		
	song thrush	*Turdus philomelos*		
makipai	Australian magpie	*Gymnorhina tibicen*		
	yellowhammer	*Emberiza citrinella*		
	redpoll	*Carduelis flammea*		
	eastern rosella	*Platycercus eximius*		
NATIVE SPECIES identified by citizen science reports and PFW field staff				
kākāriki	red-crowned parakeet	*Cyanoramphus novaezelandiae*	AR, R	
korimako	bellbird	*Anthornis melanura*	NT	
kākāriki	kākā	*Nestor meridionalis*	AR, R	
ruru	morepork	*Ninox novaeseelandiae*	NT	

[1] Māori bird names have been sourced from the Māori Dictionary Project (https://maoridictionary.co.nz/) and from Gill et al. (2010). Scientific names and common names have been sourced from Gill et al. (2010).

[2] New Zealand Threat Classification System rankings listed in Robertson et al. (2017) and the regional threat rankings in Crisp (2020). Abbreviations: NT, Not threatened; AR, R, At risk, recovering; RC, Regionally critical.

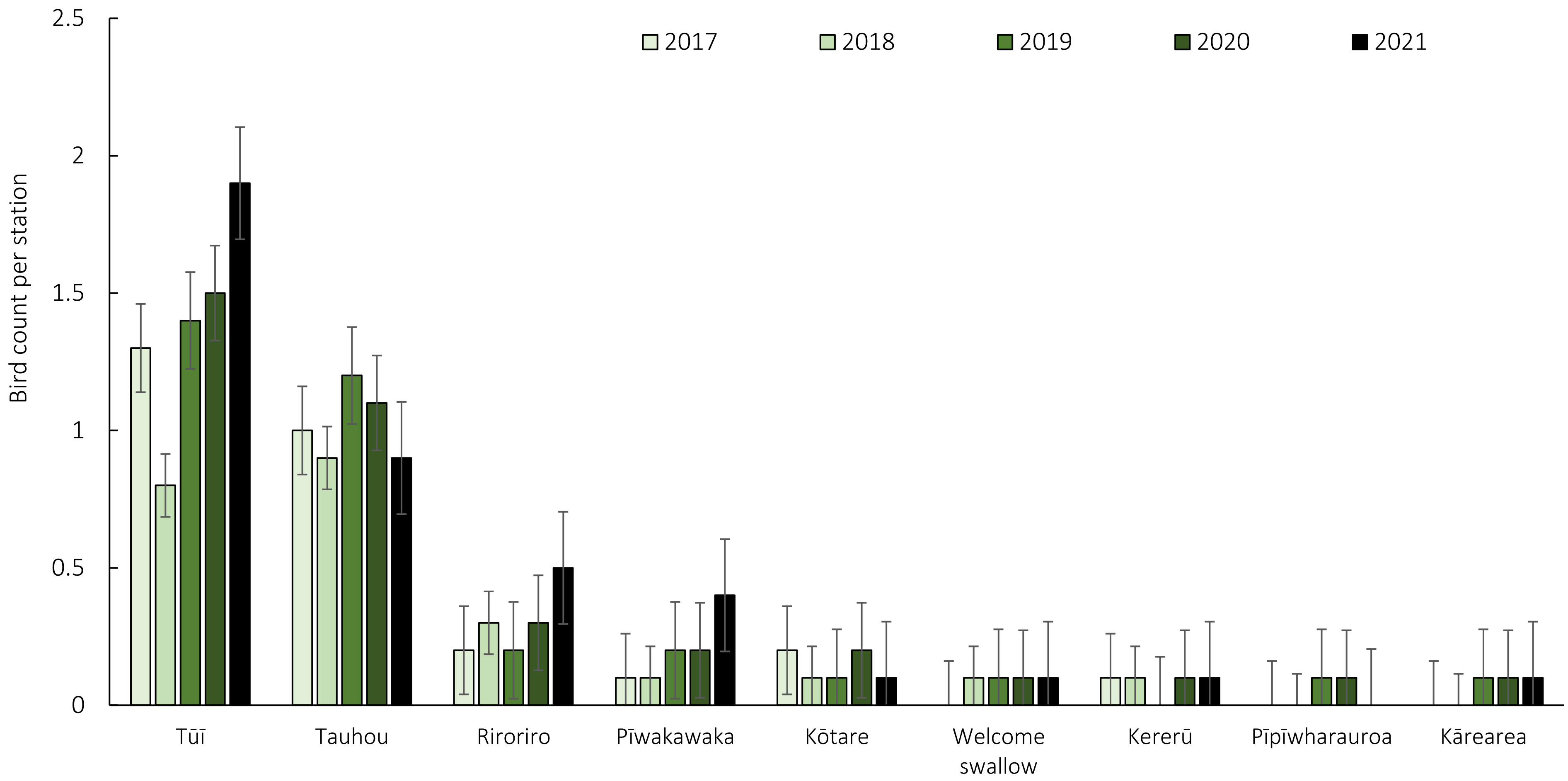

Figure 3.8 Bird counts per station (± SE) for native species observed at 5MBC stations on Miramar Peninsula from 2017 to 2021.

Four native bird species (tūī, tauhou, riroriro and pīwakakwaka) were observed at >15% of stations between 2017 and 2021. Figure 3.9 suggests that the number of tūī, riroriro and pīwakawaka encountered on Miramar Peninsula began to increase after 2019, when the PFW eradication began. The number of tauhou, however, appears to be declining.

The mean number of tūī, riroriro and pīwakakwaka encountered per station increased significantly from 2017 to 2021 (Table 3.3): tūī increased by 49%, riroriro increased by 275%, and pīwakawaka increased by 550%. However, the number of encounters of tauhou remained unchanged. The remaining native species were encountered at <15% of stations (Figure 3.8, Appendix 4).

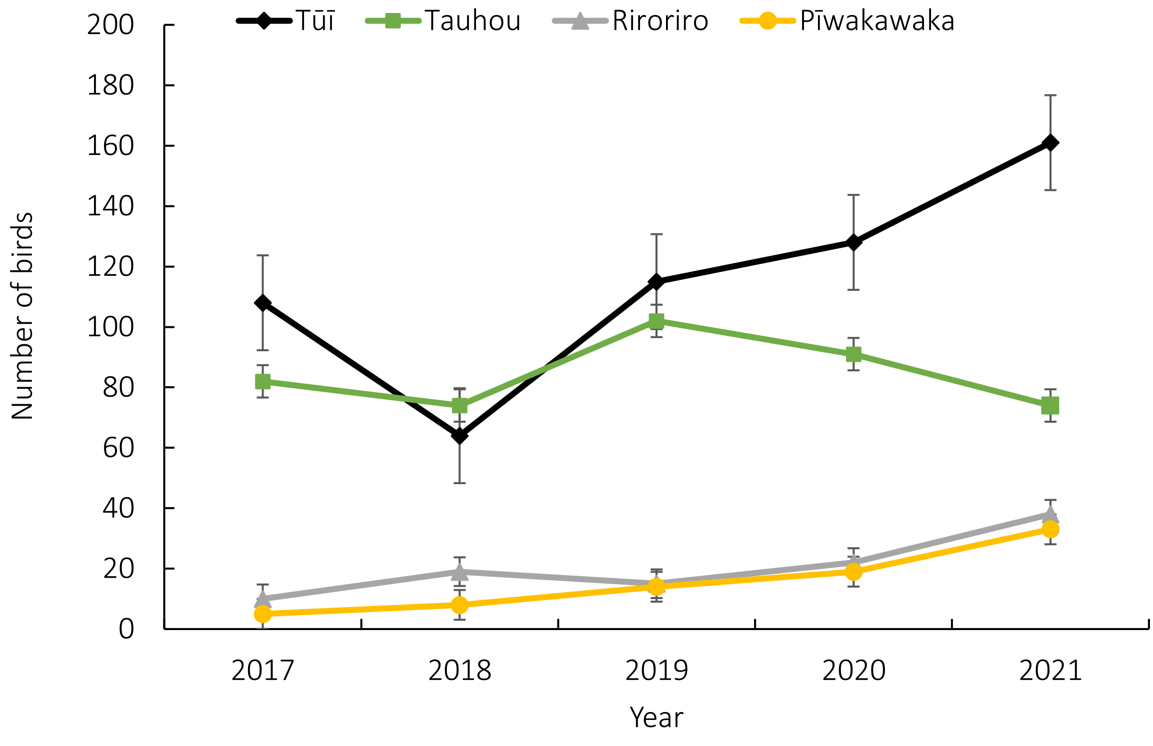

Figure 3.9 Total number of birds (± SE) for four native forest bird species, encountered at >15% of stations, on Miramar Peninsula from 2017 to 2021, demonstrating change over time and their relative abundance.

Table 3.3 The mean number of native terrestrial bird encounters per station in 2017 compared to 2021, for species that occurred at >15% of stations.

Native bird	Mean count per station		Paired, two-tailed t-tests
Tūī	2017	1.29	$t_{(83)}$ = -3.18, p = 0.002
	2021	1.92	
Tauhou	2017	0.98	$t_{(83)}$ = -0.59, p = 0.6
	2021	0.88	
Riroriro	2017	0.12	$t_{(83)}$ = -4.83, p < 0.001
	2021	0.45	
Pīwakawaka	2017	0.06	$t_{(83)}$ = -4.62, p = 0.001
	2021	0.39	

In addition to increasing numerically, tūī were more widely distributed across the Peninsula in 2021 compared to 2017. In 2017, tūī were encountered at 57% of the stations. This increased to 80% of the stations by November 2020 and 75 % in 2021 (Appendix 4). Tūī were observed in all the major habitat types but most commonly found in native forest habitat (McArthur & Ray, 2021). Tauhou were found 60% of the stations in 2021, twice as many stations compared to 2017 (Appendix 4). Riroriro and pīwakawaka were observed at over five times more stations in 2021 compared to 2017 (Appendix 4). Riroriro and pīwakawaka were relatively uncommon in suburban areas which had relatively little mature tree cover, and were mostly observed in the northern bush area in 2017. But their range increased to include the southern end of Peninsula by 2021.

The most common introduced species, sparrows and blackbirds, decreased significantly between 2017 and 2021 (Figure 3.10, Table 3.4). In contrast, dunnocks and starlings significantly increased from 2017 to 2021. There was no significant change to the number of rock pigeon, chaffinch or greenfinch per station from 2017 to 2021. The remaining introduced species were encountered at <15% of stations (i.e., goldfinch, song thrush, Australasian magpie, yellow hammer, redpoll and eastern rosella).

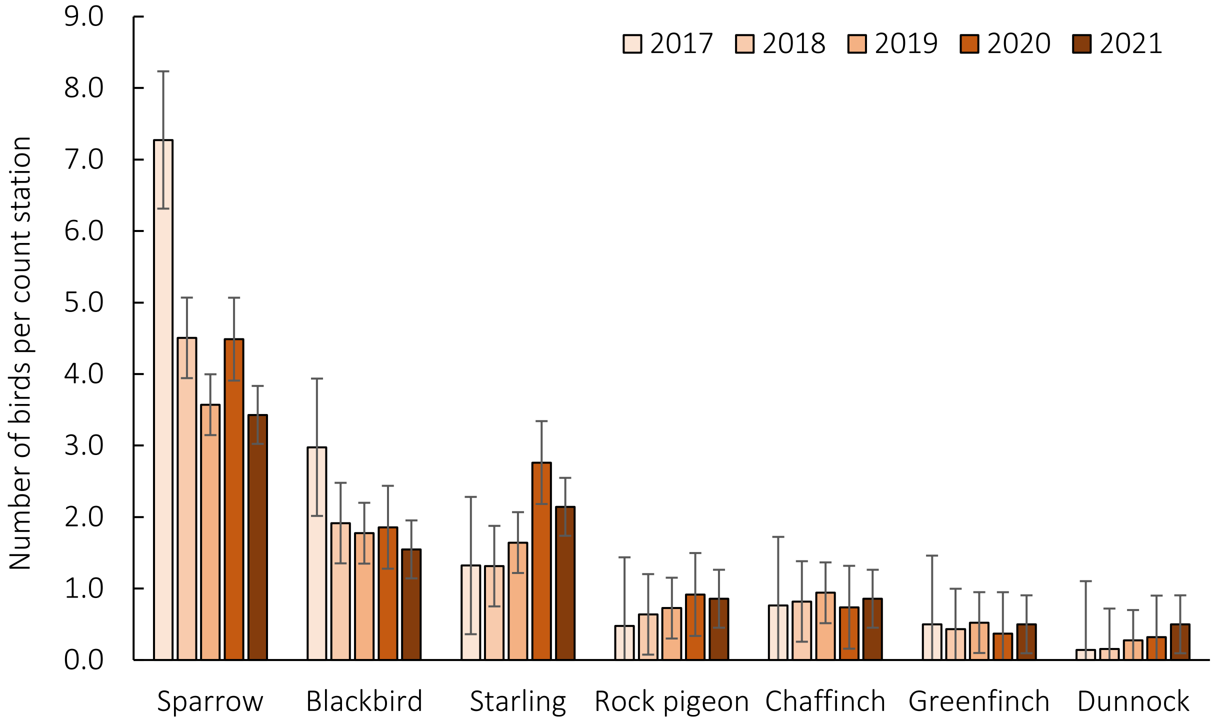

Figure 3.10 Bird counts per station (±SE) for the most common introduced species observed at 5MBC stations from 2017 to 2021.

Table 3.4 The mean number of introduced terrestrial bird encounters per station in 2017 compared to 2021, for species that occurred at >15% of stations.

Introduced bird	Mean count per station		Paired, two-tailed t-test
Sparrows	2017	7.27	$t_{(83)} = 8.95$, $p < 0.001$
	2021	3.43	
Blackbirds	2017	2.98	$t_{(83)} = 5.64$, $p < 0.001$
	2021	1.55	
Dunnocks	2017	0.14	$t_{(83)} = -4.395$, $p < 0.001$
	2021	0.50	
Starlings	2017	1.32	$t_{(83)} = -3.57$, $p < 0.001$
	2021	2.14	
Rock pigeon	2017	0.48	$t_{(83)} = -1.17$, $p = 0.24$
	2021	0.86	
Chaffinch	2017	0.76	$t_{(83)} = -0.95$, $p = 0.34$
	2021	0.86	
Greenfinch	2017	0.50	$t_{(83)} = -0.20$, $p = 0.84$
	2021	0.50	

Trends on Miramar Peninsula compared to the rest of Wellington

In addition to the annual bird counts on Miramar Peninsula, GWRC undertakes annual 5MBCs in the forest habitat across the whole of Wellington City. The total number of both native and introduced forest birds counted across the whole of Wellington City (which includes Miramar) have increased since these surveys began in 2011, with native species increasing at a faster rate than introduced species (McArthur et al., 2021). When examined in isolation, the trends on the Peninsula are different as described earlier - the average number of birds detected appears to be increasing for native species and decreasing for introduced species. The increase of tūī and pīwakawaka seen on Miramar Peninsula reflects trends seen in the rest of the city (McArthur, Flux & Harvey, 2021), although tui increased by 121% across the whole of Wellington and increased by only 49% on the Peninsula. Encounters with tauhou, although frequently encountered in the 5MBCs, have not changed in Wellington City or on the Peninsula. The number of riroriro observed on the Peninsula is increasing, but has not changed in Wellington City over time. In contrast, kererū and kākā are increasing in the forest habitats across Wellington City but show no change on the Peninsula.

There are limitations on the interpretation of data sets such as that developed by GWRC (Bibby et al., 2000; McArthur & Ray, 2021), however, they do provide a broad indication of large-scale trends over time (Hartley, 2012).

A recent meta-analysis of the response of New Zealand native forest birds to mammalian predator control demonstrated that riroriro and piwakawaka did not generally respond to predator management (Fea et al., 2020). These smaller species can tolerate the presence of mammalian predators and may actually decline in presence of an abundant population of larger endemic birds (Fea et al., 2020; Miskelly, 2018). This contrasts with the current situation on Miramar Peninsula.

Birds such as kereru, which can suffer high levels of nest predation by mammals (Carpenter, Walker, Monks, Innes, Binny, & Schlesselmann, 2021) might be expected to recover or establish from other sites in Wellington after intensive predator management (Fea et al., 2020). Kererū are, as yet, found in low number in the 5MBCs on Miramar Peninsula. Kererū have been at low numbers on the Peninsula for many years and have a low reproductive rate (Casey, 2001), so may take longer to re-establish. The recovery of native bird populations is also limited by habitat quality, especially in urban areas such as Miramar Peninsula which has little native forest.

Other lines of evidence

Community perceptions

Four native forest birds, that were not observed in the 5MBCs, have been reported by residents and visitors to Wellington using the citizen scientist tool e-bird (Sullivan et al., 2009). These species include kākāriki (red-crowned parakeet), kākā, and ruru (morepork) which were observed as early as 2018 and korimako (bellbird) which was first recorded in 2019 (Ray & McArthur, 2018, 2019). Citizen science records also corroborate the distribution pattern for tūī, ririro and tauhou but suggest pīwakawaka may be more widespread than shown by the 5MBC data (McArthur & Ray, 2021). PFW field operatives have confirmed the presence of kākāriki and kākā and ruru capturing images of them in photos, videos or audio recordings (PFW, 2020a, 2020b).

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Higher levels of biodiversity in areas where people live, work and play can result in increased encounters with wildlife and, therefore, the possibility of obtaining greater wellbeing benefits from spending time in nature. Wellingtonians appear to be noticing the measurable increase in native birds. For example, 90% of respondents in Shanahan (2020) reported seeing tūī occasionally or more often, and 35% reported seeing the previously locally extinct kākā occasionally or more often.

PFW carried out an online survey in association with a community Chew Card Tuesday event in April 2021. The survey asked "Are you noticing more wildlife in your neighbourhood as a result of reserve and backyard trapping?" and ".... what differences have you noticed?"

Of the survey participants who lived on Miramar Peninsula, 76% (n = 74) reported noticing more wildlife and, in comparison, 49% (n = 572) of residents from the rest of Wellington City reported noticing more wildlife in their neighbourhood (Table 3.5).

Residents commented on seeing more birds and greater variety of birds in general, and some reported seeing more lizards. Around 20% of the comments from Miramar residents mention noticing more tūī and pīwakawaka, which is in line with statistical increase demonstrated by the 5MBC data. The survey has some limitations such as survey participants were not randomly selected and they were most likely people who were already interested and/or participating in the eradication in some capacity. However, the survey complements the more systematic evidence provided by the 5MBC and suggests an avenue for future research.

Table 3.5 Proportion (%) of Wellington City residents who report noticing more wildlife in their neighbourhood as a result of trapping in the city.

	Miramar (*n* = 74)	Rest of Wellington (*n* = 572)
Yes	76	49
Not sure	19	37
No	5	14

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Anecdotal reports

Predator Free Wellington regularly receives anecdotal reports of bird sightings from Wellington residents and PFW field operatives. Of particular interest is the delight residents express seeing species not commonly seen on the Peninsula or not seen there for many years (Text box 3).

Text box 3. Quotes from residents reporting wildlife sightings (PFW, 2020a)

"5.38am, woke to the call of a ruru for the first time in my 10 years on Pretoria Road above Karaka Bay – wonderful!"

PAUL

"I can hear a Morepork in my backyard right now, which is Carter Reserve. First time I have ever heard one in the suburbs in my life!!! A real celebration."

FIONA

"We've lived on Rotherham Terrace for 20 years and never seen a NZ Falcon in our street before!"

KERRIN

"A big Keruru again today Cnr Totara and Camperdown"

JOHN

"I saw a Kotare with a skink in its beak on the Maupuia track this afternoon, then it's vibrant colours when it flew."

ANN

∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞∞

In August 2021 members of Te Motu Kairangi-Miramar Ecological Restoration came across a burrow containing a male common diving petrel (*Pelecanoides urinatrix*). The common diving petrel is very vulnerable to introduced predators and this sighting may be the first nesting attempt on the Wellington mainland for over 100 years (Miskelly, 2013).

3.4.3 Kororā, little penguins, breeding success

Introduction and Methods

Kororā, little penguins (*Eudyptula minor*), breed around Wellington's coast close to urban areas from July to February each year (Flemming, 2013). Introduced predators are a major threat to kororā, in particular dogs, mustelids, cats and rats. Places for Penguins is a conservation project under the auspices of Forest and Bird, Te Reo O Te Taio. The project provides nest boxes (Figure 3.11), plants native vegetation and undertakes predator control around Wellington's south coast and inner harbour to create safer places for kororā to breed. Places for Penguins have monitored kororā nest boxes during the seven breeding seasons from 2014/15 to 2020/21.

Figure 3.11 Kororā in nest box. (http://www.penguin.net.nz/species/blue/bluenest.html).

Kororā nest boxes were deployed at 13 sites around the coast of Wellington during the 2014/15 to 2020/21 breeding seasons. There were 7 sites on Miramar Peninsula and 6 sites around the south coast and inner harbour (located in Evans Bay, Island Bay and on Taputeranga Island, in Island Bay).

Volunteers monitor the nest-boxes fortnightly during the breeding season and monthly in the non-breeding season. The volunteers record the number of eggs, chicks, fledglings and losses. Chicks were counted as fledged if they had disappeared from the nest-box no earlier than seven weeks after hatching. In the 2020/21 the boxes on Taputeranga Island were not monitored regularly through the critical breeding period. Therefore, the data for this site in 2020/21 is not complete.

The raw data for this report are supplied by and used with permission from Places for Penguins, Wellington (Places for Penguins, unpublished data). Raw data were analysed to determine the total number of breeding pairs and breeding success of birds from Miramar Peninsula and from Evans and Island Bays as a control population. Breeding success was assessed using the following metrics:

- Chicks fledged per breeding pair
- Hatching success (number of chicks hatched /number of eggs),
- Fledgling success (total number of chicks fledged/number of chicks hatched)
- Reproductive success (number of chicks fledged/number of eggs).

Figure 3.12 Sites (red lines) where penguin nest boxes are deployed on Miramar Peninsula. Other sites in Wellington with nest boxes include Evans Bay, Greta Point and Balaena Bay and Island Bay, including Taputeranga Island. Figure prepared by Sam Whitburn 2022.

Evidence for change in kororā breeding

Two hundred and thirty-five breeding pairs of kororā were monitored in nest boxes around the coast of Wellington over the breeding seasons from 2014/15 to 2020/21. These 235 nesting pairs laid 410 eggs, from which 360 chicks hatched and 324 chicks successfully fledged. The total number of breeding pairs increased from 25 in the 2014/15 breeding season to 41 in the 2020/21 breeding season, likely reflecting the increase in the number of nest boxes available from 2014/15 (89) compared to 2020/21 (128). See Appendix 5 for detailed data of kororā breeding in Wellington.

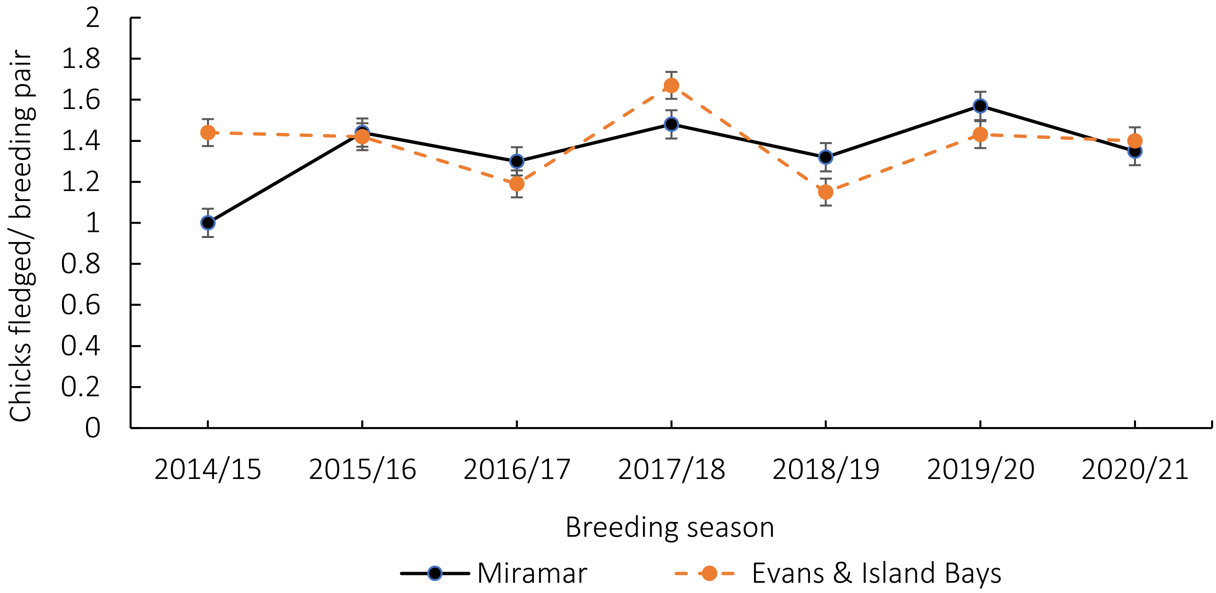

Figure 3.13 The number of kororā chicks fledged per breeding pair/nest box (± SE) from sites around Miramar Peninsula and Evans & Island Bays from 2014/15 to 2020/21.

The average number of chicks fledged per pair remained at around 1.4 ± 0.05 SE, for all years of monitoring, fluctuating between 1.2 and 1.6 (Figure 3.13, Appendix 5). Further, hatching, fledging and reproductive success all remained relatively constant with no statistical evidence of differences between the years before and after PFW began their eradication (Figure 3.14 A - C, Table 3.6). There is also no significant difference between the Miramar sites and the sites in Evans and Island Bays after PFW began their eradication (Table 3.6). Together, these results provide no indication of an effect of the predator eradication on kororā breeding success. The predator control done by Places for Penguins around the kororā breeding sites may already have reached adequate levels to ensure kororā are protected from predators while breeding. Places for Penguins only monitored kororā breeding at nest boxes but kororā also make natural burrows often hundreds of meters from the coastline. We do not know how the eradication affected breeding in natural burrows.

Table 3.6 Breeding success of kororā, measured as the mean number of chicks fledged per breeding pair, mean hatching, fledging and reproductive success [95% CI], in nest boxes on Miramar Peninsula before (2014 - 2018) and after (2019 - 2020) Predator Free Wellington began their eradication of mammalian predators.

	Miramar Peninsula		Evans & Island Bays	
Breeding seasons	2014/15 – 2018 /19	2019/20 – 2020/21	2014/15 – 2018/19	2019/20 - 202021
Mean number of chicks fledged per pair	1.31 [1.1, 1.5]	1.46 [.1 2.9]	1.37 [1.11, 1.63]	1.46 [1.01, 1.91]
Mean hatching success	0.88 [.81, .93]	0.93 [.30, 1.5]	0.87 [.71, 1.03]	0.87 [.85, .89]
Mean fledging success	0.94 [.86, 1.0]	0.88 [.69, 1.1]	0.89 [.80, .98]	0.77 [.60, .94]
Mean reproductive success	0.82 [.72, .93]	0.81 [.48, 1.14]	0.87 [-.13, 1.87]	0.81 [.48, 1.14]

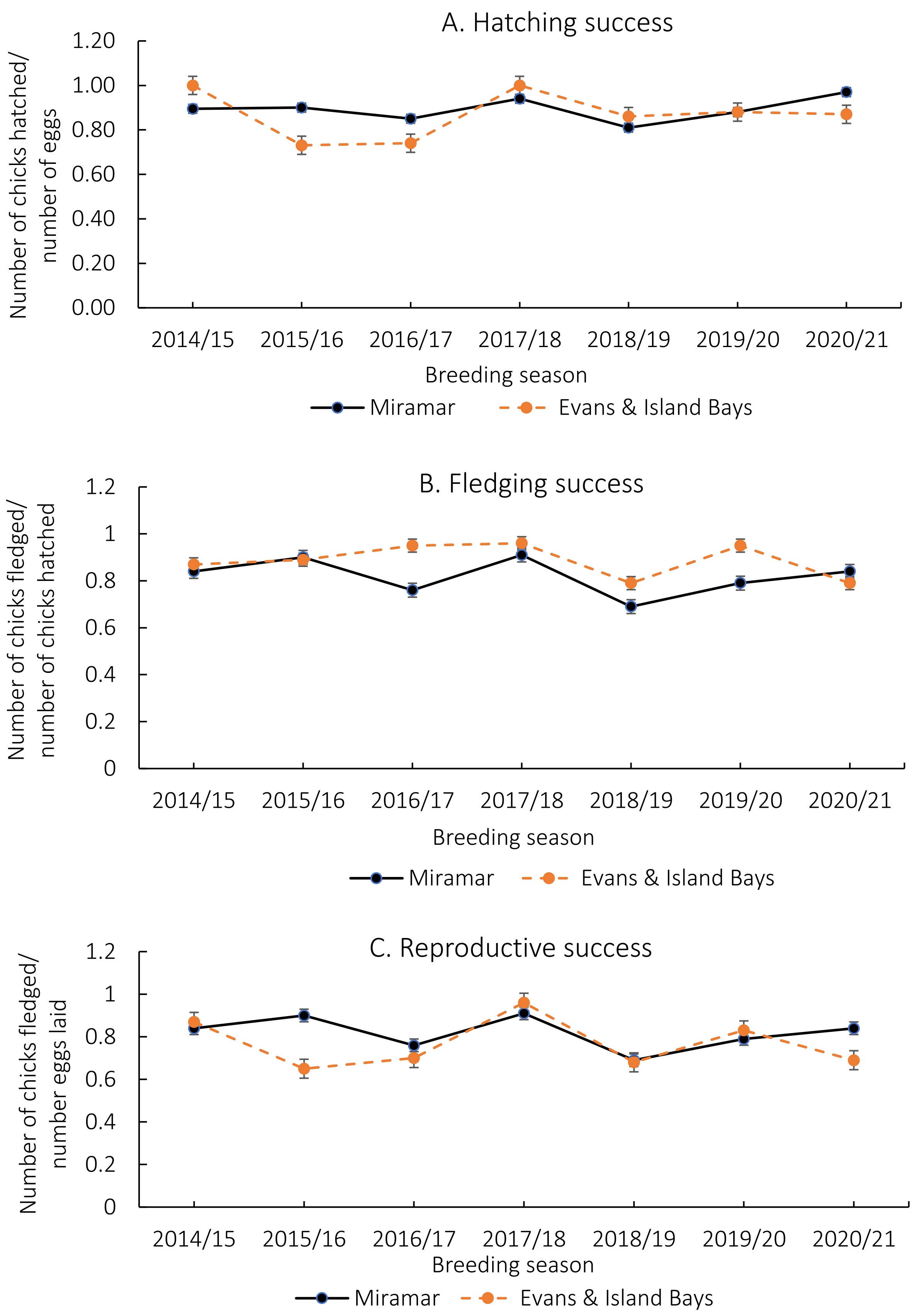

Figure 3.14 A - C Hatching, fledging and reproductive success (± SE) for kororā from sites around Miramar Peninsula and Evans & Island Bays, Wellington, from 2014/15 to 2020/21.

3.4.4 Tree wētā and other invertebrates

Introduction and Methods

Researchers from Te Herenga Waka, Victoria University of Wellington, investigated the effect of the predator eradication undertaken by PFW on Miramar Peninsula on the populations of endemic wētā (Wellington tree wētā, *Hemideina crassidens* and cave wētā, *Gymnoplectron s*pp) and other invertebrates - spiders, beetles and cockroaches (Hartley, Balls & Nelson, 2021). A summary of Hartley et al.'s (2021) findings are reported in this section.

Surveys of invertebrate and predator abundance were undertaken before and after the predator eradication on Miramar Peninsula began. Twenty-four sites were selected across three geographical zones in Wellington. The zones roughly correspond to Phase 1, (Miramar Peninsula), Phases 2 - 3 (Wellington's central suburbs) and Phase 4 (Wellington's western suburbs) of PFW's eradication zones (Figure 1.1). This provided the treatment sites in Miramar and control sites in urban Wellington where PFW had not yet begun their predator eradication. Each zone contained three habitat types - amenity, forest and residential gardens (Figure 3.15). At each site a line of 10 tracking tunnels, 10 chew cards and four wētā motels (Figure 3.16) was installed at a distance of 50 m apart to monitor for predators and invertebrates. The tracking tunnels and chew cards were retrieved after six nights and the wētā motels left *in situ*. The surveys were conducted twice a year in November and May, from November 2017 to May 2021. The tracking tunnel and chew card deployment was independent of those deployed by PFW.

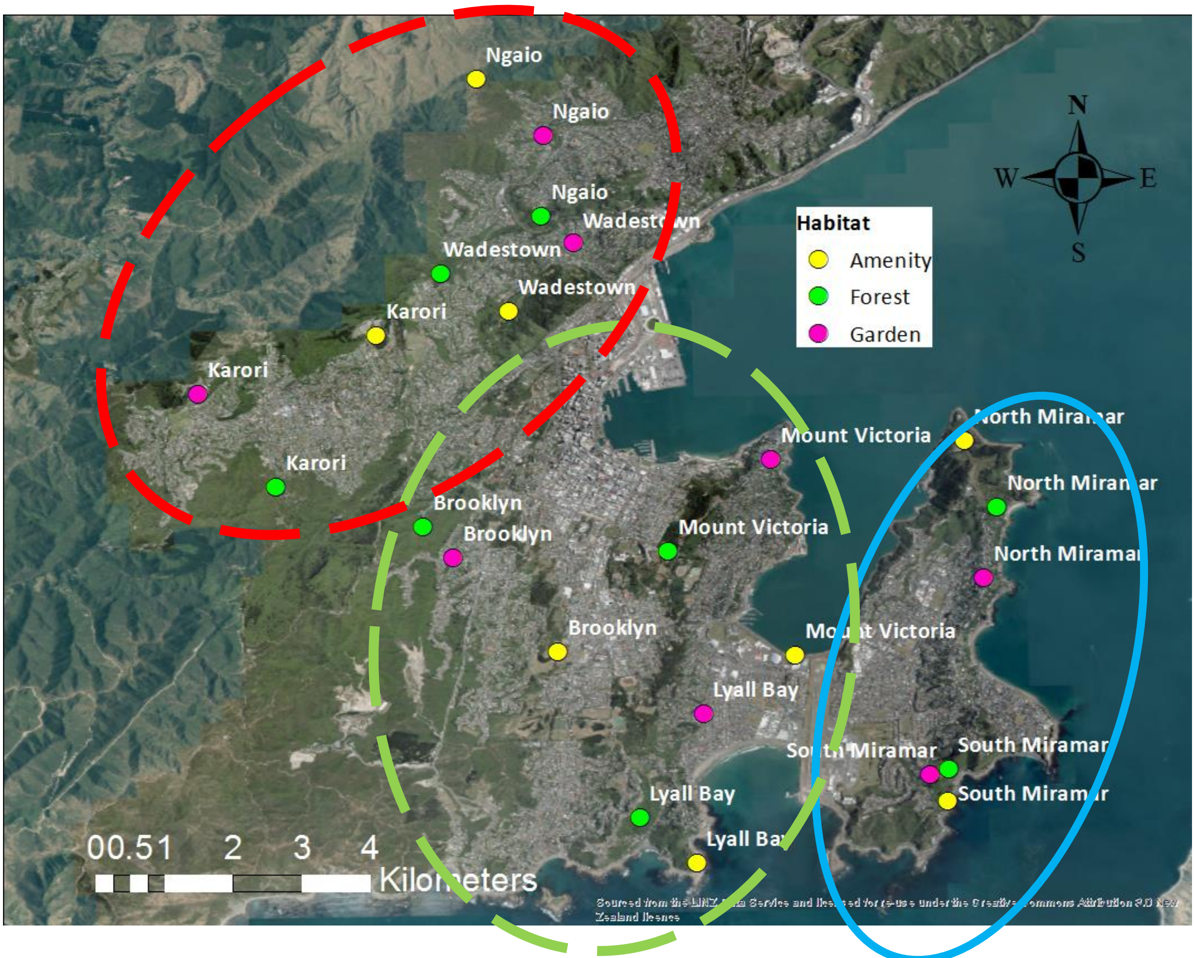

Figure 3.15 Sites for predator and invertebrate monitoring in zones across Wellington City showing the three geographic zones, monitoring sites and types of habitats. Image courtesy of Hartley et al. (2021).

Figure 3.16 Wētā motel packed with tree wētā. The motels mimic wētā's natural habitat in trees or logs. The motels have entrance holes through which wētā can come and go and a gallery where wētā can crawl into and be safe from predators. Image courtesy of Hartley et al. (2021).

Evidence for changes in invertebrate populations

Rats were not detected at Hartley et al.'s (2021) sites on Miramar Peninsula from November 2019. However, rats continued to be detected in the central and western suburbs (Figure 3.17).

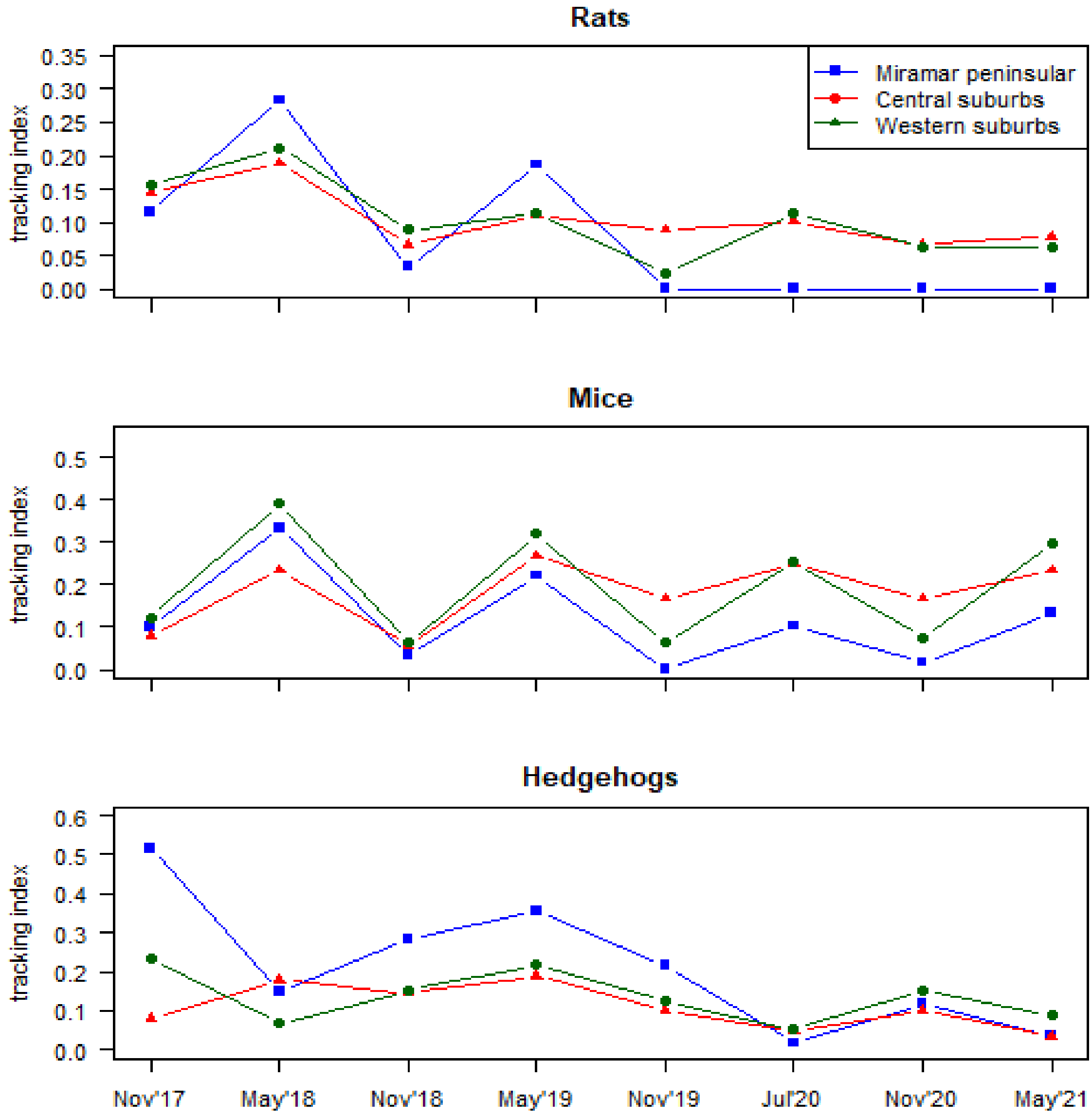

Figure 3.17 Predator tracking index (mean catch per line) for rats, mice and hedgehogs in three zones across Wellington City, before and after Predator Free Wellington's eradication began on Miramar Peninsula in July 2019. Image courtesy of Hartley et al. (2021).

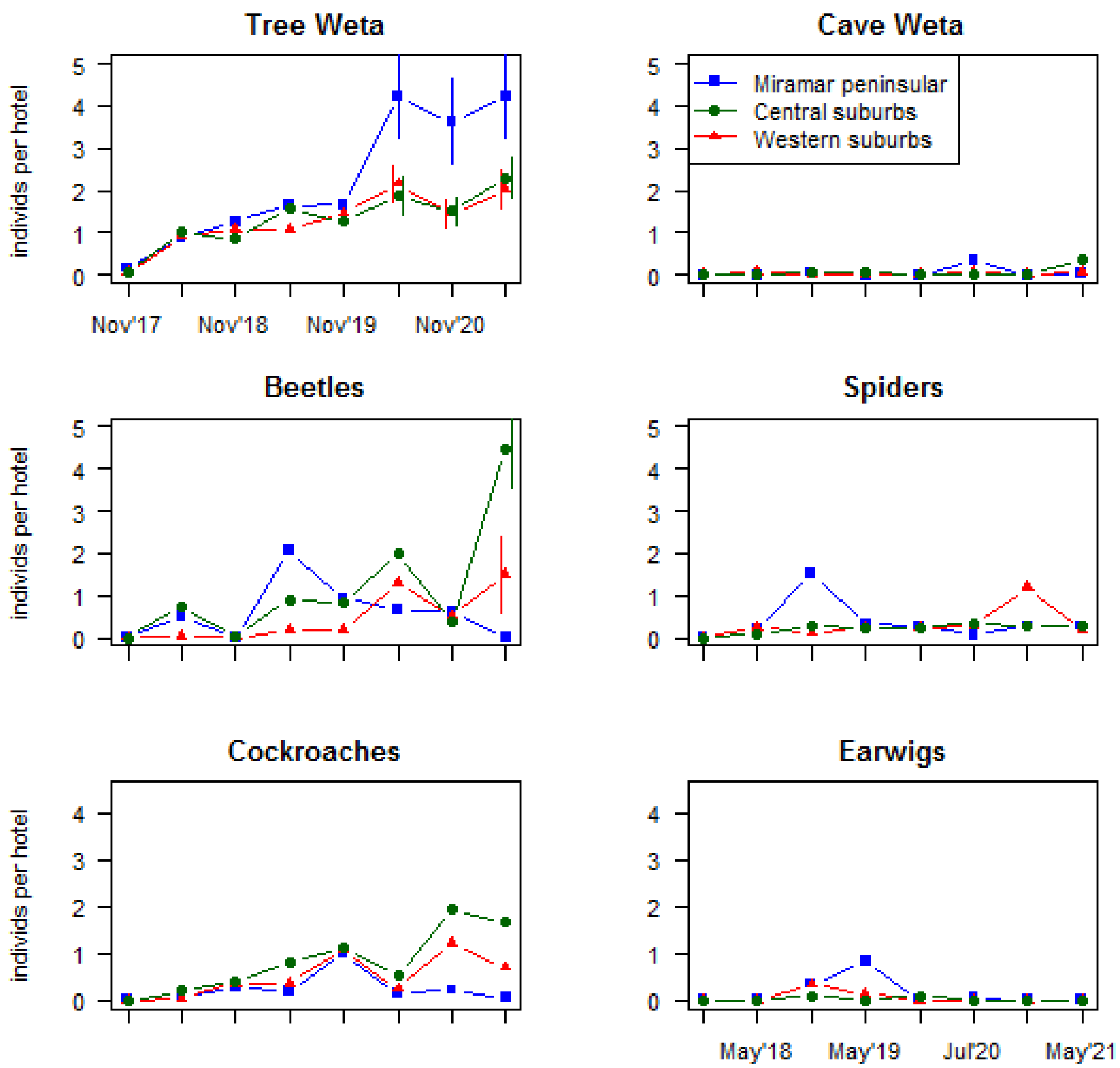

Figure 3.18 Tracking index (mean catch per line) for wētā and other invertebrates found in wētā motels at sites in three zones across Wellington City, before and after Predator Free Wellington's eradication began on Miramar Peninsula in July 2019. Image courtesy of Hartley et al. (2021).

The absence of rats at sites at Hartley et al.'s sites on Miramar Peninsula from November 2019 corresponded with an increase in the number of tree wētā found in wētā motels on the Peninsula (Figure 3.18). Twice as many tree wētā were detected on Miramar Peninsula once rats were considered absent compared to when rats were present (Figure 3.18). This increase in tree wētā on Miramar Peninsula was not replicated at other sites across Wellington. Cockroaches and beetles appear less prevalent in Miramar motels compared to motels in the rest of Wellington after November 2019. In contrast, cave wētā, spider and earwig numbers were unchanged and were detected at comparable levels across all the sites (Figure 3.18). Together, this suggests the eradication has had a varied effect on the invertebrate community in the Miramar area.

3.4.5 PFW's impact on biodiversity on Miramar Peninsula

The biodiversity on Miramar Peninsula has shown some signs of recovery since PFW began its eradication of predators in June 2019, but given ecological recovery can take decades or even hundreds of years, it is too early to see the full impact of the project. In summary, we have found evidence for the following improvements:

- Mustelids and Norway rats have been eradicated from the Peninsula as at January 2021
- Ship rats have been dramatically reduced
- The abundance of native forest birds has increased or a change in distribution was noted (including tūī, riroriro and pīwakawaka)
- Tree wētā increased at sites where rats were considered absent
- Species previously absent from the Peninsula such as kārearea, which are at regionally critical levels, and kakariki, kākā and ruru have been observed in the area in recent years.

In contrast, we found no evidence for improvements in:

- The number of tauhou, kōtare, or kererū or other native bird species
- Improvements in kororā breeding
- The number of cave wētā

There is also evidence that:

- The number of beetles and cockroaches decreased where rats were considered absent
- The number of mice has not decreased since rats were dramatically reduced.

3.4.6 Wellbeing outcomes from participation in ecological restoration

Introduction

Many studies have now been published to explore various dimensions of the health and wellbeing outcomes from time spent in nature, but generally there is a significant amount of complexity and numerous factors that affect human populations. This is the same in the communities in Miramar and beyond; factors beyond the presence of rats, stoats and possums will undoubtably be impacting the community. There are, however two useful threads of evidence that support the existence of health and wellbeing outcomes for the communities involved at this stage; the first is an online survey of Wellington residents (aged 18 years or older) that was undertaken between March and June 2019 to determine the relationship between residents' exposure to nature and various health outcomes (Shanahan, 2020). The intention is to replicate this survey at two-yearly time points as the city progresses through predator eradication and to examine how perceptions, wellbeing and nature connectedness changed for people over time. The survey was repeated in 2021, but the data have not yet been published. Despite this, the 2020 report is helpful in elucidating some of the health and wellbeing outcomes that arise from individuals participating in trapping as a pro-environmental activity.

The second thread of evidence analysed for this report is from an online survey run by PFW in association with a community 'Chew Card Tuesday' event held in April 2021. Participants were recruited through their social media and PFW's partners. There were 646 responses. The survey asked "Do you feel more connected to your community as a result of being involved in predator free?"

Evidence for health and wellbeing outcomes

The Shanahan (2020) survey had 1200 useable responses with the survey respondents demonstrating a bias towards older and female participants and those with higher incomes when compared to the regional population. Over half of the survey respondents reported participation in some form of environmental volunteering: 30% in planting, 14% in citizen science projects and 10% in other types of environmental volunteering such as beach clean ups. Of particular interest for this report is that 31% participated in trapping either in their own backyard or in local greenspace.

Mental and physical wellbeing

Shanahan (2020) found that the amount of time individuals spent in public natural spaces was positively associated with lower levels of depression, but had no significant association with their anxiety, stress or treatment for blood pressure. However, individuals who participated in trapping had significantly lower levels of depression, stress and anxiety than survey participants who did not trap (Figure 3.19). Participating in trapping was not associated with any differences in treatment for high blood pressure (Figure 3.19).
Several socio-demographic factors were associated with health outcomes; age, income, number of children in the home, and frequency of physical activity were related negatively to depression, anxiety and stress scale and positively to social cohesion. There is significant complexity in the interpretation of such data (specifically, the cause and effect cannot be disentangled), but this does provide support for the ongoing research in this area.

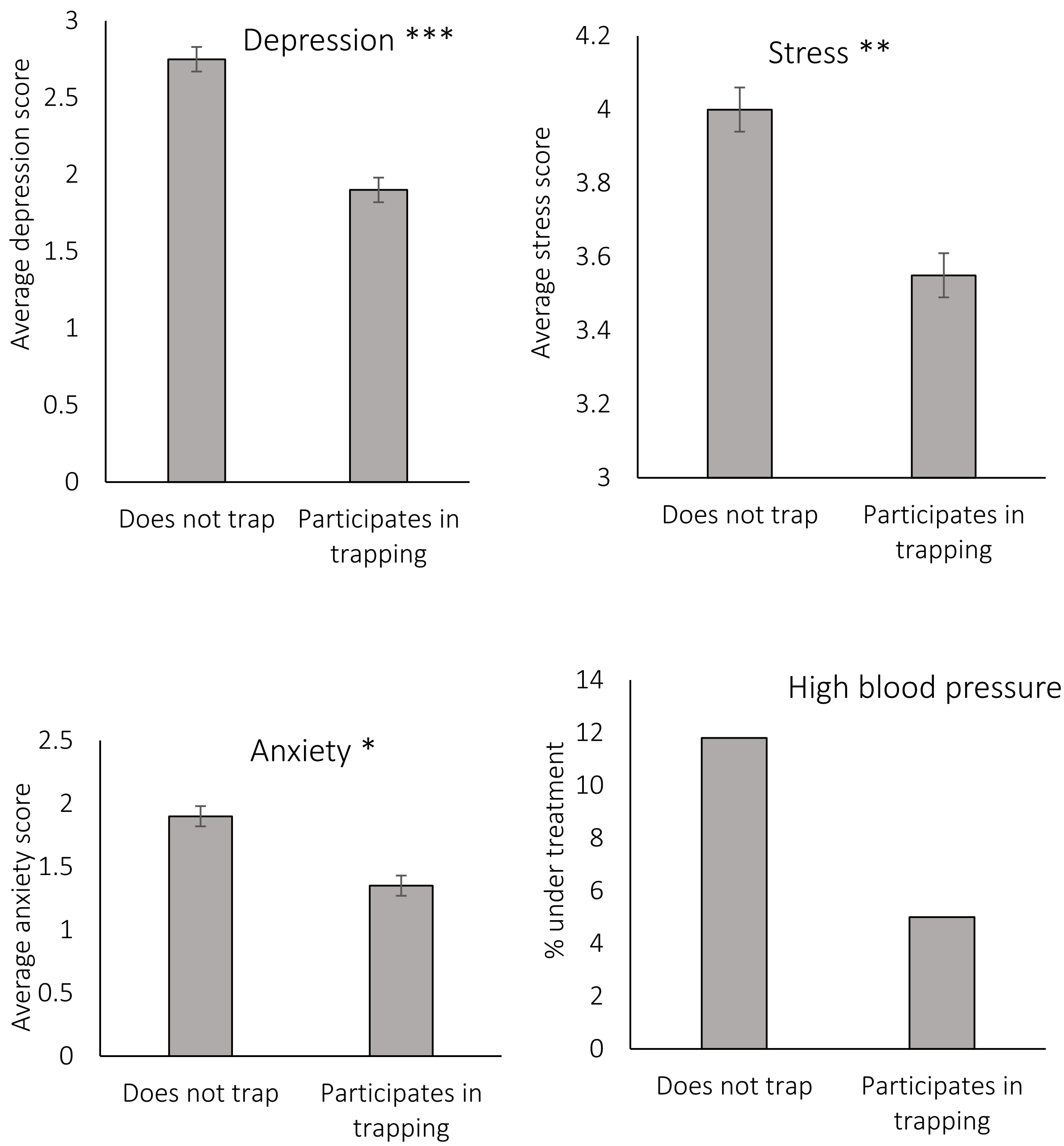

Figure 3.19 The bivariate relationships (± SE) between mental and physical health measures and participation in trapping. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$ (Shanahan, 2020).

Social wellbeing

Social cohesion was a key outcome of focus in the Shanahan (2020) report, which found that individuals who participated in trapping had significantly higher levels of social cohesion than those who did not participate in trapping (Figure 3.20).

Figure 3.20 Bivariate relationships (± SE) between social cohesion and participation in trapping. *** = $p < 0.001$ (Shanahan, 2020).

This result is supported by the PFW survey associated with "Chew Card Tuesday". Sixty-five percent of survey respondents (N = 646) reported feeling more connected to their community as a result of participating in PFW (Table 3.7). The proportion of residents who felt more connected to their community as a result of being involved in PFW from Miramar (67%, n = 74) was similar to that for residents from the rest of Wellington City (65%, n = 572).

Table 3.7 Proportion (%) of Wellington City residents who reported feeling more connected to their community as a result of participating in Predator Free Wellington.

	Miramar (*n* = 74)	Rest of Wellington (*n* =572)
Yes	67	65
Not sure	23	28
No	10	7

PFW's survey has limitations. For example, there is no control group, or data from before PFW began the eradication. Therefore, we cannot know whether the levels of social connectedness reported can be attributed to respondents' participation in PFW's eradication. A high level of social connectedness may have already existed in the Wellington community and may have contributed to the success of the landscape-wide project (Bradshaw, 1996).

Mechanisms for positive health and wellbeing benefits

Participating in trapping is associated with benefits to mental health beyond those associated with spending time outdoors, including lower levels of depression, anxiety and stress and stronger feelings of social cohesion. Shanahan's (2020) Wellington study took place at one point in time and, therefore, does not prove a causal relationship between participating in trapping and the wellbeing outcomes. It is likely that people with better health are more likely to participate in volunteering such as trapping. However, the results of their repeat survey, undertaken in April 2021, may provide deeper insight into the impact of participating in trapping on participants' wellbeing.

The mechanism(s) for these additional benefits remain unclear because participation was recorded as a binary, yes/no by Shanahan (2020) and details about contextual factors, such as how long people had been involved in trapping, how often they participate or the extent to which people participate are unknown. However, trapping as part of a community group may increase the opportunities for social contact, which can in turn develop into increased social support and a sense belonging in the local community which ultimately can contribute to feelings of social cohesion (Francis et al., 2012). Participation in environmentally responsible behaviour has also been associated with greater levels of personal happiness (Bechtel & Corral Verdugo, 2010; Brown and Kasser, 2005) and caring for the environment can provide a sense of meaning which can support mental wellbeing (Ryan & Deci, 2001).

3.4.7 Equity and social justice in predator eradication

Community participation in ecological projects, such as predator eradication, tends to be uneven across different sectors of society (Hart et al., 2022). In Europe and North America for example, participants in citizen science projects are predominantly from white ethnic groups, are highly educated, affluent and middle aged or older (Hart et al., 2022). Similar demographic characterisations can be found in volunteer ecological projects in New Zealand (e.g., Peters et al., 2015), although McFarlane et al. (2021) found tangata whenua entities (iwi/hapū/whānau/rūnanga) lead and are key contributors to some ecosystem regeneration collectives. Uneven participation in ecological projects can mean that the potential benefits of participating are limited to particular sectors of society (Brouwer & Hessels, 2019).

Evidence for social justice outcomes of PFW

Shanahan's (2020) research already summarized in Section 3.4.6 also demonstrated that participation in, and the subsequent benefits from, ecological projects can be associated with economic advantage in Wellington. That study found that 31% of respondents participated in trapping (*n* = 367), yet trappers were more likely to come from more advantaged neighbourhoods. These trappers reported benefits such as lower levels of depression, anxiety and stress and higher levels of social cohesion than non-trappers. At this stage it is unknown whether a breadth of people across the socio-economic status spectrum are involved in PFW, but this would be worth understanding to help explore whether PFW is contributing to social justice or not.

In addition, economic advantage has been associated with tree cover in cities (Shanahan et al., 2014; Watkins & Gerrish, 2018). This association could be because residents of more affluent neighbourhoods have more resources to plant and care for trees or people with more money may move to greener neighbourhoods. There is considerable evidence that urban trees provide wellbeing benefits to residents (Hartig et al., 2014) and improve local environmental conditions (for example, providing shade and reducing air and surface temperatures; Armson & Ennos, 2012). An inequitable distribution of amenities such as urban trees implies an unequal access to the health and wellbeing benefits that they provide.

PFW is an eradication effort. Therefore, no neighbourhood on the Peninsula could be overlooked to achieve success. This may have driven a more equitable approach to community participation in the project and greater equity in ecological or social outcomes. We were able to explore whether equality existed in this dimension of the project on Miramar peninsula by examining the relationship between neighbourhood advantage, tree canopy cover (demonstrating existing ecological inequity) and landholders' participation in the project.

Methods

Tree canopy cover is a widely used way of describing urban forests (Morgenroth, 2021). We used the tree canopy coverage data from Morgenroth (2021). A tree is defined as exceeding 3.5 m height with a minimum diameter of 1.5 m. Therefore, smaller trees were not included as part of the canopy cover (Morgenroth, 2021). See Morgenroth (2021) for methodology and accuracy of the data.

The New Zealand Deprivation Index 2018 (Environmental Health Intelligence New Zealand, 2018) is a measure of deprivation derived from New Zealand census data for an area (not for individual people). The measure is based on economic variables such as household income, employment, level of education and homeownership. A mesh-block, with a population of 60 - 110 people, is the smallest geographical area for census data. The New Zealand Deprivation Index provides a deprivation score for each mesh block in New Zealand. Each suburb of the seven suburbs is made up of a number of mesh blocks. We calculated the median score for all mesh blocks that make up each suburb to determine a measure of deprivation for that suburb. Simple linear regression was used to test if the percentage tree canopy cover was associated with neighbourhood scores on the New Zealand Deprivation Index .

PFW had to obtain permission from landholders across the peninsula before they could deploy traps and bait stations on private land. Therefore, the density of traps and bait stations in each suburb was used as a proxy for participation in the project.

Results

The tree canopy cover on the Peninsula varies from around 3% to over 39% in each suburb (Figure 3.21) and is at the lower end of the range of canopy cover found across Wellington City (Morgenroth, 2021). The level of the New Zealand Deprivation Index varies from 1 to 10 in mesh blocks across the Peninsula. There was a statistically significant, negative association between tree canopy cover and New Zealand Deprivation Index scores ($r = 0.67$; $F(1, 5) = 4.02$, $p = 0.01$) that accounts for 45% of the variance in tree canopy cover (Figure 3.22). That is, suburbs with greater levels of economic disadvantage have less tree canopy cover.

Predator Free Wellington obtained permissions from 3000 households, businesses and schools to deploy and service trapping tunnels and bait stations on private property to complete the planned network of trapping stations on the Peninsula. The one-to-one approach of Engagement Field Officers had a 99% success rate of recruiting land-holders (PFW, 2020b). (See Section 2.3.2 for details).

The density of traps and bait stations was the same across the peninsula, irrespective of the New Zealand deprivation score or tree canopy cover of the neighbourhood – 20 trapping tunnels and 40 bait stations per square kilometre (Figure 3.23). This represents a level of equity in participation of landholders from all suburbs on the Peninsula.

Figure 3.21 Canopy cover on Miramar Peninsula Map sourced through https://data-wcc.opendata.arcgis.com/maps. Figure prepared by Sam Whitburn, 2022.

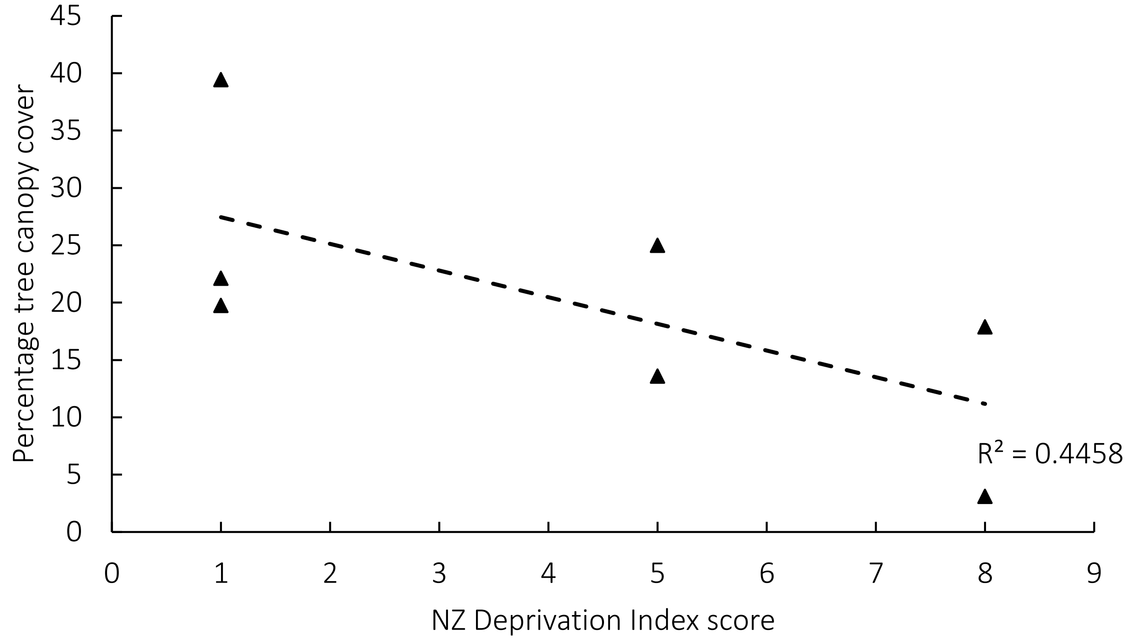

Figure 3.22 The relationship between New Zealand Deprivation Index score and percentage of tree canopy cover for suburbs on Miramar Peninsula.

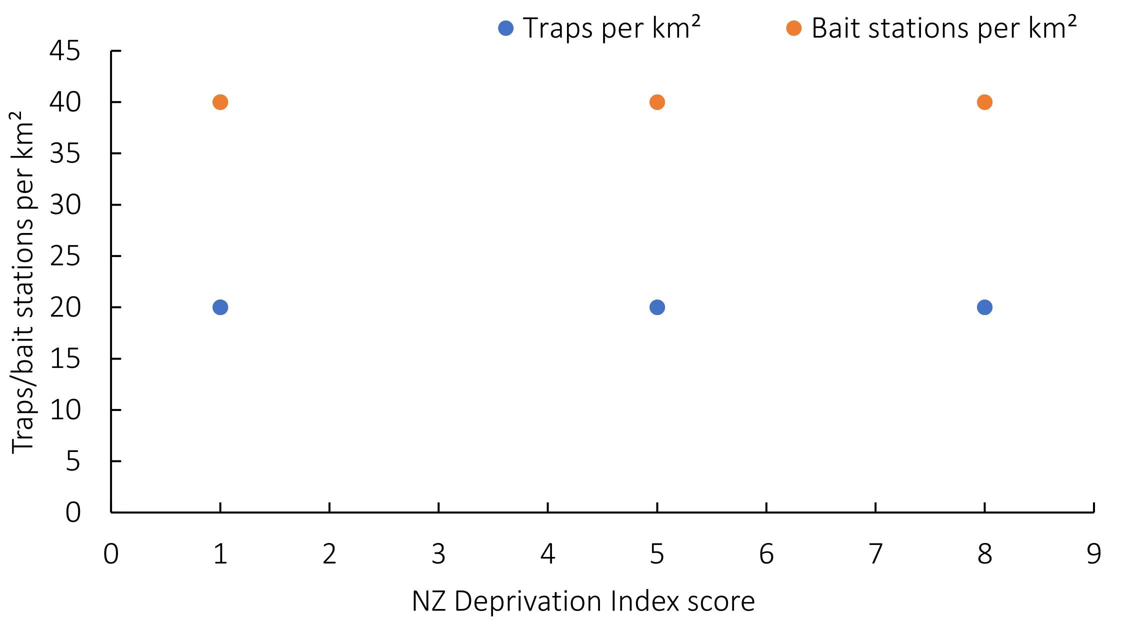

Figure 3.23 The relationship between the New Zealand Deprivation Index score and the density of traps and bait stations for suburbs on Miramar Peninsula.

How does PFW contribute to environmental equity and social justice?

All mustelids and Norway rats were declared eradicated from Miramar Peninsula (as at January 2021) and almost all of the ship rats. Proof of freedom from ship rats has been established in urban areas with the remaining ship rats mostly confined to dense bush. This eradication, across all sectors of the Peninsula, is an example of an equitable ecological outcome. However, because tree canopy cover varies with the level of the New Zealand Deprivation Index across the Peninsula, the recovery of forest birds is less likely in suburbs with low levels of canopy cover.

It is important to not only consider equity in terms of environmental outcomes but to consider equity in how to engage with a community and how to encourage an inclusive culture (Hanleybrown et al., 2012). As PFW entered each new suburb, they built relationships with community leaders and used the existing community networks to engage community members in an effort to understand the unique context and particular needs of that community. Then PFW tailored their approach for the particular local context. This enabled PFW to achieve the high levels of participation, even in marginalised communities.

The Engagement Field Officers (EFOs) one-to-one approach of recruiting landholders further empowered participation. EFOs had conversations with individuals and could explain details of the project and what was required of the landholder. For example, providing information that the project was free and that landholders did not have to service traps helped remove barriers for participation for some residents.

Although participation may be at the most fundamental level for many, that is allowing the deployment and servicing of traps and bait stations on their property, it is part of an ongoing relationship with PFW and the work of conservation. A positive relationship between the public and PFW can build trust in the organisation, its people, methods and potential to succeed. According to the Stages of Change Framework (Prochaska & DiClemente, 1992), behaviour change begins with people being unaware of or unable to acknowledge a problem (such as the impact of introduced predators on native species). This precontemplation phase progresses to a person beginning to think about the problem and preparing to change their behaviour to help address that problem and eventually culminates in them changing and maintaining that behaviour. Participation and engagement at even the most fundamental level may pave the way for greater participation in the future and begin a journey towards environmental stewardship. In addition, it may encourage a shift in mindsets to promote new social norms that embrace conservation as an activity that is for anyone - not just for experts or conservationists - and understand that conservation can happen in urban areas (Lam et al., 2020a). Community approaches, such as seen in this project, can be a powerful method for widening participation, and can help make projects relevant to community members.

3.4.8 Wellingtonians' attitudes and behaviours toward predator eradication

Introduction

Wellington City Council (WCC), together with PFW, has undertaken biennial surveys of Wellington City residents, 18 years and older, from 2017 to understand their attitudes and behaviours towards mammalian predator control. Each online survey was distributed using the WCC Capital Views research panel and was available to the general public and advertised through social media. The survey asked questions about residents' attitudes towards predator eradication in Wellington, their participation in predator control and other conservation activities and also collected demographic information. In the following section we report the results of the 2021 survey (Wellington City Council, 2021).

Results

The April 2021 survey had 1260 responses - 815 through the research panel and 445 from the general public. The survey respondents demonstrated a bias towards older and female participants compared to the Wellington City population.

Support for predator eradication

The majority of respondents supported predator eradication in Wellington City:

- 95% of respondents agreed that mammalian predators were a problem in New Zealand
- 91% of respondents agreed that native species should have greater rights than predator species

- 96% of respondents thought that investment in predator control would benefit future generations
- 93% of respondents indicated their support for the eradication of predator species (rats, stoats and possums) in Wellington City.

A further 5% supported the eradication depending on details of the project such as methods and locations, cost benefits and the feasibility of achieving eradication. The level of support for predator eradication in 2021 survey is over 10% higher than in the 2017 survey (84%), undertaken well before PFW began their eradication on Miramar Peninsula.

Almost one fifth of the survey respondents had concerns or lacked understanding about the predator control operation. The main concern for these respondents was around the potential risks or the impact predator control can have on other animals, people or plants, especially the use of poisons. Other concerns were for animal welfare and unintended consequences. These concerns were similar to those recorded in the Engagement Field Officers' reflection logs.

Participation in predator control/eradication

Participation in predator control/eradication varied across Wellington City in 2021:

- 44% of the respondents said they currently participated in predator control, down 10% from 2019.
- Respondents from the Eastern Ward, which includes Miramar Peninsula, were more likely to report current involvement in predator control (52%) than those from other wards.
- About a third of those who participated in predator control were involved with a Predator Free group.
- A high proportion (63%) of respondents from Miramar reported participating in PFW's eradication project.
- The type of activities people participated associated with the Predator Free community groups included trapping, reading newsletters, following on social media or talking to neighbours about trapping.

- Around two-thirds (68%) of respondents indicated they would be interested in being directly involved in future predator control in their local area. For a further 20%, involvement depended on the details of the project.
- Most respondents (63%) had no preference for which control method (traps or baits) was used in their area
- But 20% preferred traps over poison and were reluctant to use poison if traps were not available.

The main reasons given by respondents for undertaking predator control were:

- Predators are a threat to native species (80% of respondents)
- People did not like predators on their property (64% of respondents)
- People thought predators carried disease (33%) and caused property damage (26%).

The main reasons survey respondents said they did not participate in in predator control included:

- Predators weren't a problem on their property.
- They had not considered participating (33%)
- They did not want to handle dead animals
- They expressed a lack of knowledge around the methods
- They thought participation was too difficult or too expensive.

Interestingly, respondents from the Northern Ward, (Figure 1.1), were more likely than respondents from the rest of Wellington to say they had not participated in predator control because they did not know how.

Going forward

The support for mammalian predator eradication in Wellington City has increased by over 10% since 2017. However, a proportion of residents (around 20%) still hold concerns about the operation, particularly around animal welfare, and the risks of predator control methods, especially poisons. This is despite PFW's efforts to engage the community, build trust in the project and convey the safety and humanness of their methods. The public acceptability of methods may become an increasing concern as new technology, such as gene drive approaches, is developed (MacDonald et al., 2020).

The respondents' mixed motivations for participation are a noticeable feature of the Wellington City Council surveys. Although biodiversity gains motivate many people, social benefits such as rat free homes can be an important reason to participate (Russell & Stanley, 2018). One of the strengths of PFW's approach is that social motivations and outcomes were considered as important as ecological motivations or outcomes and incorporated into the project design.

People's professed attitudes are often inconsistent with their actual behaviour (Gifford & Chen, 2017; Kollmuss & Agyeman, 2002). Although 93% of survey respondents supported the eradication, only 44% were currently involved at some level, a 10% decrease since 2019. A similar attitude-action gap was observed in a recent survey of New Zealanders attitudes and behaviours around PF2050 (Macaskill et al., 2022). Interestingly, a higher proportion of Miramar residents report current involvement in predator control than residents from other suburbs in Wellington. This may be because people from Miramar have witnessed the PFW operation first hand and have connected with the PFW team which may have allayed residents' concerns and overcome some of their barriers to participation. There is an opportunity to capitalise on the high numbers of respondents who indicated their interest in trapping in their local area as PFW moves into the next Phases of their work.

3.4.9 Summary: evidence of social outcomes

We have presented reliable evidence that residents of Wellington who are involved in trapping are more likely to experience lower levels of depression, anxiety and stress and greater social cohesion than residents who do not participate in trapping. But as mentioned previously, this research does not prove a causal relationship between participating in trapping and the wellbeing outcomes. In addition, the details of the kind of participation that led to benefits is not understood.

It is likely that the eradication of predators on Miramar Peninsula and through Wellington City will have a number of wellbeing outcomes not discussed in this report. For example, eradicating rats potentially decreases the risk of humans contracting zoonotic diseases such as leptospirosis, giardia and salmonella. We might expect less damage to food supplies in gardens and less food contamination in homes and reduced anxiety from having rats and mice in homes. Rats can damage building insulation and gnaw electrical wiring that contributes to fires (Wilson et al., 2018). Unfortunately, there is little research to support these outcomes not just in Wellington but in general (Russell & Stanley, 2018).

PFW has achieved a measure of equity in ecological outcomes and participation across the Peninsula where residents have varied socio-economic circumstances. There are a variety of ways in which equity plays a role in PFW's eradication work:

- Their community approach to recruitment and engagement considered the social and economic contexts and knowledge and values systems that influence the ability of a person to participate (Wells et al., 2021)
- Assuming the cost of the project with respect to providing finance and labour which establishes a fair sharing of costs and benefits (Wells et al., 2021).

However, issues of equity go beyond what has been investigated here. In particular, PFW seeks an opportunity to partner with Māori, and uphold Indigenous rights and integrate Indigenous knowledge into the project (Lyver et al., 2019; Wehi & Lord, 2017).

The evidence of wellbeing benefits and other social outcomes associated with predator eradication is in its early stages. As PFW moves into the next phases of their operation, there is an opportunity to undertake research into some of these social outcomes. Enhancing human wellbeing is a key motivator of biodiversity conservation (Shanahan, 2018) and can motivate a wider range of participants, who may not be driven by conservation goals (Russell & Stanley, 2018). In addition, family wellbeing and the broader wellbeing of society are important factors underpinning attitudes towards predator management for Māori (Black et al., 2021).

SECTION 4. DISCUSSION

Transformative societal change requires systematic change across social-ecological systems and collaborations between organisations and communities working together for a common purpose (Berkes, Colding & Folke, 2003; Kania & Kramer, 2011; Lam 2020b). A shift towards collaborative, community-based conservation is recognised as an alternative to the dominant paradigm of top-down, expert driven environmental management (Berkes, 2004). Such collaborations require learning new ways to work together, focused on building relationships between organisations with the skills and resources to coordinate the operation and the wider community (Kania & Kramer, 2011). PFW provides an exemplar of a long-term collaboration between the community (groups, businesses and house-holders) and across-sector organisations (local government, NGOs) that aims to eradicate mammalian predators from Wellington City and in doing so promote both social and ecological outcomes.

The PFW collective, facilitated by the core PFW team serving as a backbone entity, contributes to the full range of amplification processes and enabling factors described by Lam et al. (2020a) and McFarlane et al. (2021) to upscale the impact of community-led initiatives:

- *Amplifying within* seeks to increase impact by *stabilising* and *speeding up* a project to make it more efficient and prolong its impact. *Stabilising* also ensures the project is deeply embedded in their particular context and equipped to face challenges.
- *Amplifying out* involves *growing, replicating* or *spreading* an initiative to impact more people and places. This can be geographically (in a similar or different context), by involving more people and/or by increasing the number of initiatives.
- *Amplification beyond* changes society's rules and values. A project that *scales deep* changes people's values, norms and beliefs. This can include a reconsideration of how stakeholders relate to one another and the wider public, and how we determine impact. *Scaling up* impacts on higher institutional levels.

Amplifying within

PFW works to *stabilise and speed-up* the existing community-based efforts in Wellington City by increasing their capacity and capability through training, resourcing, knowledge and connectivity, which can otherwise constrain their efforts (Peters, 2019; Doole, 2020). As such, the collective is supporting the community environmental groups' abilities to achieve their goals and sustain their efforts over the long periods of time necessary to eradicate predators and to maintain this state. In addition, an independent entity coordinating the operation increases its efficiency and helps maintain the momentum of the work (Holmgren, 2018).

Amplifying out

PFW *amplifies out* the existing community-led eradication project on Miramar peninsula by:

- *Growing* the geographical area and connectivity of the existing predator control activities in Miramar to attempt a landscape level eradication. They have increased the number of people contributing to the work by involving the wider community alongside community environmental groups and invested in field staff (supported by Jobs for Nature funding) along with the contributions from others in the collective who provide funding, resources, staff and technical knowledge which adds considerably to the efforts of volunteers working in their leisure time.
- *Expanding* the original goal which was to control mammalian predators on the Peninsula to work to eradicate them.
- *Replicating* their Phase 1 project on Miramar Peninsula incrementally across Wellington City. Phase 2 is now underway.
- *Spreading* their core principles and approaches to other places, by providing support and advice to other groups from around New Zealand.

Amplifying beyond

Few restoration projects explicitly try to influence wider societal understanding or attitudes towards sustainability issues (Lam et al., 2020a). However, part of PFW's strategy is to *scale deep* and transform the way the conservation projects are done and the way the Wellington community values nature. The aspects of the project that contribute to *scaling deep* include:

- Growing support for mammalian predator eradication in Wellington by fostering an appreciation of native biodiversity through environmental education, both formally and informally, and encouraging community feedback and participation.

- Encouraging input from diverse stakeholders and promoting shared learning which can build trust and foster a shift in the way the effort to protect native biodiversity is understood and valued over time (Waterton et al. 2015).
- Encouraging a shift in people's mindsets through education and participation in the project to challenge social norms around who can participate in conservation (Norton et al., 2018), that is, championing the idea that everyone can participate at some level.
- Integration of social and ecological outcomes, that can form feedback loops to reinforce one another. Achieved by regarding conservation as a social as well as ecological endeavour, a strategy which can be more successful in cities rather than using an ecological approach alone (Gobster, 2012).
- Network building and relationship-building between groups and with the wider public, which is thought to contribute to a sense of a group identity (Mumaw & Raymond 2021).
- Changing the way projects are funded, moving from funding projects individually to a collective funding model. This can be a system intervention that influences how conservation is traditionally financed and can open up opportunities for a wider participation (Abson et al., 2016).

Collaborative initiatives are often criticised for being too top-down and offering solutions that are not informed by community needs (Raderstrong & Boyea-Robinson, 2016). PFW Ltd. was established as a top-down initiative by local government organisations and a philanthropic foundation and their activities are governed by the Biodiversity Act (Russell & Stanley, 2018). However, PFW Ltd. also builds on community-led initiatives and works alongside community groups that have recruited hundreds of household trappers. PFW has demonstrated a meaningful level of community engagement that goes beyond informing and consulting the wider community about the project to include them as stakeholders and actively involve them in the project which can help ensure their concerns and needs are understood and considered (Raderstrong & Boyea-Robinson, 2016). PFW Ltd. is now moving towards a collaborative leadership where members of the community are involved as co-leaders and can drive decisions and the direction of the work. This has been achieved by:

- A community-by-community strategy and a one-to-one recruitment of landholders. Although time consuming, these strategies have effectively engaged the wider public and have resulted in broad grass-roots support.
- Investing in community environmental groups, including them at an early stage of each phase of the operation and building collaborative relationships.
- Identifying key actors from the community to take part in decision-making.

It can take 5-10 years for an initiative such as PFW to become established in a community (Baral, Stern & Heinan, 2007) and PFW has only been working on the Peninsula since 2019; despite this it has achieved a high level of community support.

A strength of the collaboration on Miramar Peninsula is that some ecological outcomes are being empirically measured, which is not always the case in community-led initiatives (Jones & Kirk, 2018). Local communities are invested in both conservation and social outcomes and their ongoing support can be critical to success (Brooks et al., 2020). Information on social outcomes is, therefore, also necessary to evaluate the success of restoration projects in peopled landscapes (Wortley et al., 2013; Russell & Stanley, 2018). In this instance, the evidence of social outcomes associated with predator eradication is in its early stages. As PFW moves into the next phases of their operation, there is an opportunity to measure and report social change through planned research. For example, predator eradication in Wellington has economic costs and benefits that are challenging to assess, and planned research by economists could assist in this area. Further research into how the cost of eradication and the cost to maintain biosecurity compares to the cost of ongoing control (Parkes et al., 2017) would be useful, alongside consideration of economic benefits to human health, food supplies and buildings, tourism, exports and employment (Russel 2015; Wilson et al., 2018). Future research might also examine social and ecological outcomes and how they feedback to influence conservation behaviour over time.

Going forward, it is important to consider whether the level of support PFW has enjoyed will be sustained when the responsibility of maintaining biosecurity is handed back to the local community. A network of monitoring stations has been designed to protect the Peninsula from reinvasion, however this requires the good will and action on the part of community environmental groups, backyard trappers and the wider public to report and deal with incursions. The Wellington City Council survey discussed in this report revealed a gap between Wellingtonians' supportive attitude towards predator eradication and their participation in backyard trapping. On the Peninsula, the high level of community participation has largely involved giving permission for PFW to deploy and service trapping tunnels and bait stations and has not required hands-on action. However, there is reason to be hopeful because the community-led initiatives on Miramar Peninsula achieved remarkable results before PFW began its eradication.

Providing evidence of social and ecological outcomes can provide much needed public acceptance/support for a project. However, practical and ethical concerns remain, even among those who support the eradication. The concerns centre especially on animal welfare issues and the use of poisons in peopled landscapes (Wellington City Council, 2021). Failure to address these concerns could impair community ownership of the initiative (Wolff et al., 2016), especially as new technologies such as gene-editing are developed (MacDonald et al., 2020) or the management of other mammalian predators, such as hedgehogs or cats, is considered (Russell & Stanley, 2018).

This research was led by western science researchers, and as such does not address Māori perspectives. Mātauranga Māori has an important contribution to the restoration of urban environments, including in invasive species control (Black et al., 2021). Kaitiakitanga is a way in which Māori manage the natural environment based on Māori worldviews and their long-term connection to place (Walker et al., 2019). The practice of kaitiakitanga by tangata whenua-led collectives can have holistic and long-term regeneration purposes that can lead to enduring outcomes (McFarlane et al., 2021). We hoped to involve Māori researchers who could more deeply explore the nature of the relationship between PFW and mana whenua, examine potential challenges to the implementation of a partnership approach and explore potential pathways forward. Unfortunately, we were unable to fulfil this need. It is a critical area for development and a major opportunity for community collectives more broadly.

This is the first time this scale of mammalian predator eradication has been attempted in a densely peopled environment globally. This research report can inform the next phases of

PFW's eradication plan for Wellington City and has particular relevance for PF2050 goals. The learnings can be applied to wider conservation objectives, in particular has long-term implications for improving large-scale community engagement in ecological restoration projects locally, nationally and internationally. The strategies used by the PFW collective to interweave technical expertise and community engagement could be applied to other 'wicked' problems that require a systems approach, such as developing a regional response to address aspects of climate change which could culminate in community-wide behaviour change.

"Our project is about system change, demonstrating that in the face of widespread global environmental degradation a dedicated collective of people can change the tide." (PFW, 2019)

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Appendix 1 Key informant interview questions

All participants will have been provided with an information sheet and confirmed their consent before the interview starts.

Interviews will occur in a location the participant feels comfortable with.

Question	Areas for potential further enquiry and discussion
Can you please tell me about your position with Predator Free Wellington (PFW)?	Your areas of responsibility What your role involves Whether the role is field based The number of people you supervise Do you work with volunteers
What has worked well in the predator eradication from your perspective?	Technical aspects of eradication Managing relationships within organization Engagement of volunteers Engagement with wider community Gaining consent from householders and businesses to access property Approach for different communities
What key innovations or adaptions have you implemented?	Identification, testing and evaluation of these innovations Adaptations to technical and public engagement plans Career development pathway for employees Managing relationships with volunteers
What challenges have you had and how did you overcome them?	In technical, organisational and public engagement areas
How will you manage biosecurity maintenance as PFW winds down its involvement in Miramar?	Bio-security maintenance plan Public involvement What do you still need to know?
What future research would be useful to inform your practice?	What would be good to know for Phase 2? Post-graduate student opportunities

Appendix 2 The Predator Free Wellington Collective

Predator Free Wellington Limited (PFW Ltd.) is a charitable company, listed in 2018, that is guided by a Board of Trustees and supported by three founding partners: the NEXT Foundation (a philanthropic foundation), Wellington City Council and Greater Wellington Regional Council (GWRC). The board is made up of two representatives from each of three founding partners, one independent person and one representative of mana whenua (appointed by the Taranaki Whanui ki Te Upoko o Te Ika Trust, Port Nicholson Block Settlement Trust).

The core PFW Project Team, employed by PFW Ltd., has expertise in leadership, management, stakeholder engagement and communication and includes the Project Director, Project Coordinator, Communication and Digital Manager and Stakeholder Engagement Manager. The PFW Project team extends to include:

- the GWRC Biosecurity Team who were contracted to lead and implement the technical operation and have ecological and technical expertise in predator control and wildlife monitoring,
- Wildlife Management International Ltd., and Zero Invasive Predators Ltd. offered ecological monitoring, and technical support and innovation respectively,
- The Engagement Field Officers and the Field Operators who are contracted through GWRC,
- the Research Lead from Zealandia Te Māra a Tāne,
- community environmental groups and
- the wider public (community groups, large landowners, householders, schools and industry/businesses).

The constituent groups remain independent of one another and are not under the authority of PFW Ltd., but agree to work with one another, combining their resources and skills over an extend time period to achieve their common goals (Peters, 2019; Doole, 2020).

Previous eradication work on Miramar Peninsula

Wellington City Council, in partnership with GRWC, had previously undertaken management of introduced mammalian predators across Wellington City, including the eradication of possums on Miramar Peninsula in 2006 (GWRC, 2016). In addition, much work was done voluntarily by community groups established in local communities around Wellington. Te Motu Kairangi, Miramar Peninsula, was home to several not-for-profit volunteer environmental groups working on the Peninsula before PFW Ltd. formed:

Te Motu Kairangi-Miramar Ecological Restoration. Te Motu Kairangi-Miramar Ecological Restoration aimed to restore the ecological health of the peninsula through weeding, planting native plants and undertaking mammalian predator control. Around 20 key volunteers, and others when they are able, planted over 15,000 eco-sourced trees, shrubs and enrichment species across the peninsula (as at May 2019), some which were locally extinct. In addition, Te Motu Kairangi-Miramar Ecological Restoration provide bird nest-boxes, wētā hotels and traps for invasive wasps (Te Motu Kairangi-Miramar Ecological Restoration, 2022).

Forest & Bird, Te Reo O Te Taio, Places for Penguins group was established in 2007 to create a safer place for kororā, little penguins (*Eudyptula minor*), to breed around Wellington's coast. This includes 7 locations on Miramar Peninsula and 6 other locations in Evans Bay, Island Bay and on Taputeranga Island (in Island Bay). Volunteers, from Victoria University of Wellington's chapter of the Society for Conservation, provide and monitor nest-boxes, plant native vegetation (supplied by Forest and Bird's Wellington nursery) and undertake predator control (with over 200 traps) around the breeding sites (Places for Penguins, 2021).

Predator Free trapping groups. Initially, there were three Predator Free community groups on Miramar Peninsula involved in mammalian predator control: Predator Free Miramar, Predator Free Seatoun and Predator Free Breaker Bay. By 2019, these three groups had combined under Predator Free Miramar which now covers the entire Miramar Peninsula. Predator Free Miramar is a community-led effort which aims to rid the Peninsula of rats, mice and mustelids to bring back the birds and the bush to Wellington's eastern suburbs (Henry, 2019). Established in 2017, Predator Free Miramar provides residents free traps for their backyards. Residents' commit to keeping the traps baited, checking them regularly and reporting any catches. By Christmas 2019, Predator Free Miramar had 1448 traps in residents' backyards and in reserves and residents had reported catching more than 5000 rats along with other predators (Henry, 2019).

In addition to ecological work, all these community groups promote their work when opportunities arise such as at community gatherings and school fairs. Some groups give talks to school children and take groups on nature walks. The community groups on the Peninsula communicate with their members and other interested people through social media and newsletters and maintain websites. Growth of these groups has been predominantly by word of mouth. The environmental groups working on the Peninsula were reliant on external funding from grants and donations.

These environmental groups largely work independently of one another and but have established relationships. They come together through their shared desire to see native biodiversity flourish and their connection to the Peninsula. There are times they help each other with their work. For example, Predator Free Miramar's founder maintained a few trapping lines for Te Motu Kairangi-Miramar Ecological Restoration. The groups have been supported by local businesses who have donated wood for trapping tunnels and peanut butter to bait them. Some of the foundation partners of PFW Ltd. have previously supported the community efforts on the Peninsula. For example, Wellington City Council provided native plants for Te Motu Kairangi-Miramar Ecological Restoration and supported Places for Penguin's pest control efforts.

Appendix 3 The technical operation

A 'remove and protect' model was the basis for the eradication (Bell, Nathan & Mulgan, 2009). This model requires the complete removal of predators from an area and then protecting that area against reinvasion.

Remove

The distribution of mammalian predators on the Peninsula was surveyed by GWRC Biodiversity Team in March 2017 and March 2019, before PFW began their eradication. Community volunteers placed chew cards, made of corflute and containing a peanut butter and aniseed lure (Figure 1), on a 200 m x 200 m grid that covered the peninsula.[1] This provided 281 monitoring points on public land (GWRC, 2017; 2019). The cards were retrieved after 3 nights of clear weather. This data helped identify key problem areas and was the baseline used to monitor progress each year.

Figure 1. Chew card attached to a tree trunk showing rat chews.

Other risk factors were also investigated by the GWRC Biodiversity Team. For example, was food waste from restaurants and supermarkets going to be a problem? Would businesses, especially freight companies, be willing to change their behaviour? How would rats in stormwater drains be dealt with? Any identified risks were built into the plan.

A precise GPS grid was constructed over the entire peninsula for the placement of traps (in wooden tunnels), bait stations and monitoring devices (chew cards or wax tags) so that there was a trap within the home-range of every rat. This means there would be a 100% chance of every rat coming across one of these devices. Bait stations and traps, 6000 devices in all, were placed on private property, in bush reserves, parks, coastal and commercial areas.

An initial pre-feeding the rats and mustelids, without setting the traps, allowed the neophobic predators to get used to entering the tunnels, established the traps as a source of food and created scent trails for other rats to follow. Then the bait stations were baited with toxic blocks and the traps baited and set and checked every two weeks (Figure 2).

PFW Ltd. invested in Trap.NZ. to record their trap and bait station data. Trap.NZ is used nationally as a predator trapping and monitoring data management system. TrapNZ is convenient for field operators because data can be entered using a phone application while on location. Trap.NZ can then generate reports, graphs and maps which can help PFW understand which traps are most effective or which areas need more attention.

Catching the last rats. By January 2021 Miramar Peninsula was declared free of mustelids and Norway rats and the ship rat population was dramatically reduced (PFW, 2021). However, the last ship rats on the Peninsula are proving to be elusive. Intensive monitoring, bait-take analysis, use of cameras and certified rat detection dogs, helped the team identify areas where rats persisted. Areas of known rat activity areas were then blanketed with devices.

In addition, the architecture of bait stations was adapted to try lure the remaining rats into the bait stations and tracking cameras were strategically deployed to monitor the rats' behaviour during these attempts to catch them. For example, individual rats were hesitant to enter the trapping tunnels or bait stations. Therefore, the bottom of the tracking tunnels was removed so there was no change in substrate when the rats entered the tunnel. In addition, the entrances of the bait stations were camouflaged using ribbed drainage pipes, linked chain or by weaving vegetation through wire mesh to encourage rats to access them. Other rats were observed to be 100% arboreal. Corflute trapping tunnels[3] were deployed on tree branches to try and catch them.

Figure 2. Trapping tunnels and bait stations used in PFW's eradication. From the top left: Double set BT200 trap, trapping tunnel and bait station deployed at Karaka Bay, bait stations - closed and showing the toxic blocks (Images PFW; Whitburn, 2022).

[3] You can obtain information on how to build a corflute tunnel from: pfw.org.nz/resources

Proof of freedom from ship rats. Over time areas of the Peninsula have been declared ship-rat free. This began in the urban zone in June 2020. Freedom from rats was ascertained by analysing bait take, monitoring with chew cards and wax tags, installing 80 monitoring cameras across the urban zone and having the certified rat detection dogs scour the coastline. Alongside the extensive monitoring on the Peninsula, Manaaki Whenua Landcare Research is using the data gathered throughout the operation to develop a mathematical model that can be used to predict the probability PFW have hit zero predators.

The public have been included to help provide proof of freedom. For example, PFW is undertaking chew card surveys to targeted areas on the peninsula. In March 2022, PFW targeted 200 households in Seatoun, a suburb thought to be free of ship rats. Residents were asked to reset and monitor their existing traps, to place the chew cards provided in a rat friendly area and report back their findings via an online form. Those who reported their results were entered into the draw for prizes donated by local businesses. Ten percent of households reported back and indicated there was no evidence of rats or other target predators in traps or on their chew cards. Although, there were low numbers of returns, they were geographically well spread across the suburb. These results may give a layer of assurance that can support the ongoing work of protecting the Peninsula from incursions.

And Protect

The GWRC Biodiversity Team determined (through predator surveys in the Kilbirnie area, GWRC, 2018) that the isthmus, separating Miramar Peninsula from the rest of Wellington City, and the coast were particularly vulnerable to reinvasion. Areas where rubbish dumping was an issue also needed to be addressed. Together the core PFW Project Team, the GWRC Biodiversity Team and ZIP planned an expansion of the coastal defences (traps and bait stations) and designed a virtual barrier across the isthmus.

A virtual barrier is a system that aims to exclude predators that attempt to enter the peninsula (Bell et al., 2019). It took a lot of work to align many different stakeholders affected by this plan, to understand their needs and incorporate those needs into the barrier design. The final barrier consisted of a combination of traps and bait stations every 50 m across

Rongotai, the ‘neck’ of the peninsula and 4 lines of traps along the coastlines. The Phase 2 eradication will add another layer of protection for the Peninsula.

Alongside the virtual barrier and tracking network, engaging the general public to protect the peninsula from reinvasion is crucial. They are the eyes and ears on the ground. PFW set up a “Live intelligence centre' where the public can report a sighting or evidence of predator. Via a phone line (0800 NORATS) or email (hello@pfw.org.nz). PFW responds within 24 hours to these notifications. They do so to build trust in organisation and keep the community engaged in reporting and in the project. A recent stoat incursion (April 2022) tested the biosecurity plan. The stoat was sighted twice by field operators, picked up on a monitoring camera and a member of the public who reported the sighting. The multiple sightings provide encouraging evidence that the multiple layers of protection can work. PFW Ltd. have a fixed term contract for their project and are planning for the biosecurity maintenance to become completely community-led in future.

Appendix 4 The occurrence and distribution of native bird species on Miramar Peninsula from 2017 to 2021.

	Occurrence and distribution of native birds				
	2017	2018	2019	2020	2021
			Tūī		
Number of stations	84	83	84	84	84
Total number of encounters	108	64	115	128	161
Mean number birds per station	1.29	0.77	1.37	1.52	1.92
Number of stations detected	48	36	62	67	63
Percentage of stations detected	57%	43%	74%	80%	75%
			Tauhou/silvereye		
Number of stations	84	83	84	84	84
Total number of encounters	82	74	102	91	74
Mean number birds per station	0.98	0.89	1.21	1.08	0.88
Number of stations detected	23	37	47	51	50
Percentage of stations detected	27%	45%	56%	61%	60%
			Riroriro/Grey warblers		
Number of stations	84	83	84	84	84
Total number of encounters	10	19	15	22	38
Mean number birds per station	0.12	0.23	0.18	0.26	0.45
Number of stations detected	6	13	13	18	32
Percentage of stations detected	7%	16%	15%	21%	38%
			Pīwakawaka/fantail		
Number of stations	84	83	84	84	84
Total number of encounters	5	8	14	19	33
Mean number birds per station	0.06	0.10	0.17	0.23	0.39
Number of stations detected	5	6	11	16	28
Percentage of stations detected	6%	7%	13%	19%	33%
			Kererū		
Number of stations	84	83	84	84	84
Total number of encounters	1	1	0	2	2
Mean number birds per station	0.01	0.01	0	0.02	0.02
Number of stations detected	1	1	0	2	2
Percentage of stations detected	1%	1%	0%	2%	2%

			Kōtare/kingfisher		
Number of stations	84	83	84	84	84
Total number of encounters	3	2	6	11	7
Mean number birds per station	0.04	0.02	0.07	0.13	0.08
Number of stations detected	2	2	6	9	7
Percentage of stations detected	2%	2%	7%	11%	8%
			Kārearea/NZ falcon		
Number of stations	84	83	84	84	84
Total number of encounters	0	0	1	1	2
Mean number birds per station	0	0	0.01	0.01	0.02
Number of stations detected	0	0	1	1	2
Percentage of stations detected	0%	0%	1%	1%	2%
			Pīpīwharauroa/Shining cuckoo		
Number of stations	84	83	84	84	84
Total number of encounters	0	0	1	1	0
Mean number birds per station	0	0	0.01	0.01	0
Number of stations detected	0	0	1	1	0
Percentage of stations detected	0%	0%	1%	1%	0%
			Welcome swallow		
Number of stations	84	83	84	84	84
Total number of encounters	0	2	4	2	1
Mean number birds per station	0	0.02	0.05	0.02	0.01
Number of stations detected	0	2	2	2	1
Percentage of stations detected	0%	2%	2%	2%	1%

Appendix 5 Breeding data for kororā in Wellington for the breeding seasons 2014/15 to 2020/21.

	Breeding season							
Site	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	TOTAL
Miramar								
Number nest boxes available	65	65	66	65	70	71	71	473
Number nest boxes occupied/No. pairs	16	18	20	21	19	21	23	138
Number eggs	19	29	34	34	36	42	37	231
Number chicks	17	26	29	32	29	37	36	206
Number fledged	16	26	26	31	25	33	31	188
Chicks fledged per breeding pair	1	1.44	1.30	1.48	1.32	1.57	1.35	1.36
Hatching success (Number hatched/eggs)	0.89	0.90	0.85	0.94	0.81	0.88	0.97	0.89
Fledgling success (Number chicks fledged/chicks hatched	0.94	1.00	0.90	0.97	0.86	0.89	0.86	0.91
Reproductive success (Number fledged/ eggs)	0.84	0.90	0.76	0.91	0.69	0.79	0.84	0.81
Rest of coast								
Number nest boxes available	24	40	41	41	43	57	57	303
Boxes occupied/No. pairs	9	12	16	15	13	14	18	97
Number eggs	15	26	27	26	22	24	39	179
Number chicks	15	19	20	26	19	21	34	154
Number fledged	13	17	19	25	15	20	27	136
Chicks fledged per breeding pair	1.44	1.42	1.19	1.67	1.15	1.43	1.50	1.40
Hatching success (Number hatched/eggs)	1.00	0.73	0.74	1.00	0.86	0.88	0.87	0.86
Fledgling success (Number chicks fledged/chicks hatched	0.87	0.89	0.95	0.96	0.79	0.95	0.79	0.88
Reproductive success (Number fledged/ eggs)	0.87	0.65	0.70	0.96	0.68	0.83	0.69	0.76
Total								

Number nest boxes available	89	105	107	106	113	128	128	776
Number nest boxes occupied/No. pairs	25	30	36	36	32	35	41	235
Number eggs	34	55	61	60	58	66	76	410
Number chicks	32	45	49	58	48	58	70	360
Number fledged	29	43	45	56	40	53	58	324
Chicks fledged per breeding pair	1.2	1.4	1.3	1.6	1.3	1.5	1.4	1.4
Hatching success (Number hatched/eggs)	0.94	0.82	0.80	0.97	0.83	0.88	0.92	0.88
Fledgling success (Number chicks fledged/chicks hatched	0.91	0.96	0.92	0.97	0.83	0.91	0.83	0.90
Reproductive success (Number fledged/ eggs)	0.85	0.78	0.74	0.93	0.69	0.80	0.76	0.79