Editorial

Kia ora koutou

Welcome to the latest edition of *Kararehe Kino*, which is a little different from its predecessors. Firstly, we have made a subtle change to its sub-title: from 'Vertebrate Pest Research' to 'Animal Pest Research'. This is to reflect the wider scope and context of our contemporary research, which includes work on wasps and other invasive invertebrates and their impacts. Secondly, for the first time in a while, this is an issue without a theme. We felt there were a number of interesting research stories that might not fit into a themed issue but that were really worth sharing with our stakeholders and end-users.

Finally, and on a more personal note, this is my first editorial as leader of the Managing Invasives portfolio within Manaaki Whenua – Landcare Research after stepping into the role following Dan Tompkins's shift to manage the science strategy for Predator Free 2050. I'd like to acknowledge the great job that Dan did in managing the portfolio and in providing oversight to *Karerehe Kino* over the past few years. We also managed to squeeze one more article out of Dan before he left. In it Dan describes how PF2050 came about, what it's trying to achieve, and how this will be rolled out. It is a timely and valuable overview that provides a perspective on much of our work.

Dan's overview of PF2050 ends with a reference to our national need to control pests in order to protect our imperilled native biodiversity. This is a point that Rachelle Binny and her colleagues expand on in their article describing their attempts to use outcome monitoring data from multiple conservation sites across New Zealand to identify and quantify the benefits of pest control. One of the most challenging aspects of the work for the team was the fact that the sites collect data on different things in many different ways. The researchers highlight the need for some consistency in how biodiversity outcomes are monitored, particularly in the light of the renewed national efforts to control mammalian predators, so that the massive expenditure on programmes can be justified and realistic expectations set.

Rachelle and her colleagues rightly point out that, despite its importance, predation is not the only thing that affects threatened populations or the habitats in which they exist. Ecology is incredibly complex, and unlike in some of the 'harder' physical sciences, subtle interactions between species and their environments mean that we must always be on the lookout for unexpected relationships and management effects. Some of these subtleties are explored in two of our other articles.

In one, Deb Wilson and colleagues discuss possible reasons why rat-tracking rates did not increase following possum control on the Otago Peninsula, as might have been expected from similar responses at other sites. In the other, Pablo Garcia-Diaz discusses the impacts of introduced mammals on breeding colonies of two South American seabird populations. It may surprise some people, but Pablo found that rabbits had the most significant impact on the breeding productivity of a burrow-nesting shearwater population. There are interesting parallels in this finding to our own fight against introduced mammalian pests. In the 1970s, production of grey-faced petrel chicks on Moutohorā in the Bay of Plenty was negligible due to the impacts of Norway rats. Rat numbers were sustained on the island outside of the petrel breeding season because of their predation on rabbits.

One of the reasons for enlarging the scope of *Karerehe Kino* from its original focus on vertebrate pests is to acknowledge the work our researchers do on other invasive animals. In his article, Dean Anderson describes how mathematical modelling helped him to identify the most cost-effective strategy for eradicating electric ants from areas of Queensland where they have become established, probably as 'hitch-hikers' on potted plants. Dean notes that the electric ant is considered to be one of the world's worst invasive species due to its rapid spread from its native South American range.

The rise of new or 'emerging' invasive species is addressed by Darren Ward. Darren and his colleagues studied a massive global database to try to understand if patterns in the distributions of emerging invasive species can help to predict future risks. Their analyses showed that many new invaders are being detected, possibly as a result of ever-expanding global trade networks and climate change. This, warns Darren, means there are still large numbers of potential invaders that nations have yet to encounter.

Much of our core research still deals with detecting and controlling vertebrate pests. There is currently a great deal of interest in the use of trail cameras as monitoring devices that don't require the animal being monitored to interact with them beyond moving within the camera's

field of view. Grant Morriss and Graham Nugent discuss the use of cameras to monitor the effects of deer-repellent-coated 1080 baits on sika deer numbers. They also describe using the collected images to infer changes in possum numbers following control, and also how they might provide insight into interactions between the two species. The use of trail cameras is also discussed by Al Glen and colleagues, who use them on Hawke's Bay farmland in a study comparing their ability to detect feral cats with that of specially trained detector dogs. They describe the pros and cons of using dogs to detect pests and look at how dogs' abilities could be used in optimal search strategies.

As well as developing new technologies, it is important to modify and improve existing techniques. In their article, Bruce Warburton and Grant Morriss test a series of modifications to leg-hold trap sets to see if possum capture rates can be increased. They describe how changes to the distribution of the standard lure and the addition of more visual cues had the desired effect. Most of the pest control that we use requires individual animals to interact with a device or a bait. Graham Nugent and his colleagues raise some fascinating questions about how learned aversion and species-specific behaviours can influence the effectiveness of control when comparing variants of the dual-1080 bait drop. Their work highlights the fact that only by understanding these details can we really understand why some baiting regimes are more effective than others and modify management based on reliable information.

Understanding and modifying predator behaviour may also be the key to reducing impacts on threatened prey species when lethal control cannot be used (e.g. where social factors limit the available methods, or overseas, where pests are native species), or has not resulted in complete eradication of the pest. Grant Norbury explains how super-saturating the environment with prey scent cues can lead to reduced predation on the prey themselves as predators learn that the scent more often than not leads to no food reward. As the last two articles show, there is still much to be learned about how pests behave, and about how that knowledge can be used to manipulate those behaviours to our advantage.

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Conservation dogs for controlling and monitoring invasive species

Since prehistoric times hunters have used dogs to help find and capture their quarry. Today specially trained dogs are also used in conservation, including monitoring rare or endangered species and detecting invasive plants and animals. Manaaki Whenua researchers have been studying the use of conservation dogs to manage invasive species.

In collaboration with the Department of Conservation (DOC), universities, and the New Zealand Conservation Dogs Programme, Al Glen and colleagues have tested the ability of trained dogs to detect invasive animals, compared the cost-effectiveness of trained dogs with that of motion-triggered cameras, and investigated how the use of trained dogs could be enhanced by search methods originally developed for military applications.

The Conservation Dogs Programme (www.doc.govt.nz/conservationdogs) is underpinned by dog teams trained to detect various native and introduced species. The teams assist in monitoring rare avifauna such as kiwi and whio (blue duck), and in tracking down invasive animals such as rodents, stoats and feral cats. When an incursion is reported into a pest-free area, such as an island or fenced sanctuary, conservation dog teams are often called in to help find and remove the invader. The teams also conduct routine surveillance of pest-free islands such as Rangitoto and Motutapu, and check vessels and cargo bound for these and other pest-free islands to prevent pests from invading them.

The Conservation Dogs Programme includes regular surveillance of pest-free islands, such as Rangitoto, to check for possible incursions by invasive species [Photo: Al Glen]

Scientists from Manaaki Whenua, DOC and Auckland University recently took advantage of a routine surveillance operation in the Hauraki Gulf to estimate the probability that trained dog teams could detect rats at distances of up to 100 m. The trial used dead laboratory rats, and the island's rodent-free status ensured there was no scent of wild rats to interfere with the results. The dogs detected 100% of rats placed directly along their search path, but the probability of detection declined sharply with increasing distance from it. For rats placed 10 m from such search paths, there was a 33% probability they would be detected. However, in practice dogs probably detect rats from greater distances by following scent trails left behind by them as they move.

In a separate trial, Al and his colleagues used motion-triggered cameras to monitor feral cats on farmland in Hawke's Bay. After the cameras had been left in place for 3 weeks, the monitored area was also searched by a specialist cat detection dog team. The two methods had a very similar probability of detecting a cat, if present, and the cost of each method was also similar. However, the choice of using cameras or dogs depends on several factors. For example, cameras are only useful for detection, whereas dogs can assist their handlers to locate and capture or kill animals. On the other hand, cameras can operate in most weather conditions, whereas dogs require fine weather. That said, both methods will have an ongoing role in managing invasive species in New Zealand.

Al and his colleagues' research so far shows that conservation dogs are undoubtedly a valuable tool in wildlife management. However, the search methods used by dog teams are generally *ad hoc* and based on the personal judgement and experience of the handler. For example, one dog team may choose to search along parallel transects, whereas another may focus on areas of habitat likely to be preferred by the target species. If nothing is detected, what does that mean? Is the target species absent from the search area, or do teams

just need to keep searching?

Al Glen (right) visited Amami Oshima in Japan, where conservation dogs bred in New Zealand are helping track down invasive mongooses [Photo: K. Hoshino]

Search theory − a branch of mathematics originally developed for naval applications – can help answer these questions. Armed with estimates of detection probability and the range of distances at which a target animal is likely to be detected, optimal search patterns can be designed for different areas. Search methods can also be standardised so that results can be directly compared between different times and places. A review paper soon to be published in the journal *Wildlife Biology* describes how and why these approaches could further enhance the usefulness of conservation dogs.

The review paper also outlines priorities for further research. First among these is to estimate the detection probability for a range of non-rodent target species at various distances, as estimated for rats. Detection probability may vary depending on conditions such as temperature, wind, habitat, and the dog team's level of skill and experience. As more is learnt about these variables, it will be possible to use software to design optimal strategies for specific search scenarios, including different areas, habitats, target species, and available resources. Such software already exists for applications such as search and rescue. Similar tools could help pest managers more effectively harness the formidable abilities of conservation dogs.

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Managing invasive mammals to conserve threatened seabirds in South America

Seabirds and invasive mammals do not get along well when sharing islands. This is true both in New Zealand and around the globe. As a result, the suppression of invasive mammal populations (i.e. reducing their numbers) and, whenever possible, eradication are priority actions to conserve seabirds.

However, not all seabirds respond equally to different species of invasive mammals, and conservation responses need to take this into account. Understanding the impacts of invasive mammals is essential to designing and implementing targeted conservation actions to reduce or eliminate the damage on seabirds they can cause. Evaluating the impacts of invasive mammals on two threatened seabird species inhabiting South American islands to inform the conservation management of these two species has been the focus of some of Pablo García-Díaz's recent research.

Invasive rats are a major threat to seabirds

In close collaboration with Oikonos Ecosystem Knowledge (http://oikonos.org/), a non-government organisation, Pablo studied the effects of invasive mammals on breeding colonies of the pink-footed shearwater. This bird is ranked as 'Vulnerable' in the International Union for Conservation of Nature (IUCN) Red List (www.iucnredlist.org/), and its breeding strongholds are the islands of the Juán Fernández Archipelago and other offshore islands in the Gulf of Arauco, Chile. Thanks to long-term monitoring of the breeding colonies of the species by Oikonos, combined with advanced modelling techniques, it was possible to quantify the relationship between the reproductive success of the shearwaters and the presence of invasive mammals in the breeding colonies.

The team found that rabbits were the invasive mammals most negatively affecting the reproduction of pink-footed shearwaters, whereas other invasive mammals, including rats, had smaller (but not negligible) negative effects. Detailed modelling of the long-term monitoring data further revealed that invasive rabbits reduced the rates of nesting burrow occupancy by adult shearwaters early in the breeding season and to fewer burrows occupied by breeding pairs of shearwaters. This indicates that managing the populations of invasive rabbits in breeding colonies of the shearwaters will contribute to improving their reproductive output.

Invasive ship rats and Norway rats are well-known predators of seabird eggs and chicks. The removal of invasive rats from islands worldwide has yielded substantial conservation benefits for nesting seabirds. In a second research case study, Pablo summarised the existing research and knowledge on the effects of invasive rats on breeding populations of *Spheniscus* penguins in South America. Three species of penguins of this genus occur in South America: the Humboldt penguin, listed as 'Vulnerable' in the IUCN Red List; the Magellanic penguin, listed as 'Near Threatened'; and the Galapagos penguin, considered 'Endangered'. Invasive rats are often assumed to be a threat to these three species, yet robust evidence was lacking.

Using standardised methods for evidence synthesis in environmental sciences (http://www.environmentalevidence.org/), Pablo carried out a literature review seeking research and other information sources investigating the relationship between invasive rats and South American *Spheniscus* penguins. For the evidence synthesis, a total of 31 studies were reviewed. However, a closer analysis of these studies revealed that only seven (23%) provided evidence relevant to the research topic, and only one of the seven studies attempted to quantify the rates of rat predation on penguin eggs and chicks.

The evidence extracted from these seven studies clearly showed that invasive rats are an important threat to breeding *Spheniscus* penguins in South America, and therefore abating the pressure exerted by invasive rats on nesting penguins will help the struggling penguin populations. The evidence synthesis also revealed substantial knowledge gaps when it comes to the interactions between *Spheniscus* penguins and invasive mammals. Remaining knowledge shortfalls are the scarcity of quantitative studies (only one) and the poor understanding of the ecology of nesting penguins in the presence of multiple invasive mammals, such as both cats and rats (with cats and rats interacting with each other).

The cases of the pink-footed shearwater and the *Spheniscus* penguins add to the overwhelming amount of evidence demonstrating the negative effects of invasive mammals on breeding seabirds. Nonetheless, these two cases also showcase the role of a nuanced understanding of the interactions between invasive mammals and nesting seabirds in designing and implementing conservation actions tailored to the specific problems being addressed.

Unfortunately, sufficient long-term monitoring data are not often available, as in the case of the *Spheniscus* penguins, and sometimes there is a pressing need to act to avert further population declines. In these circumstances, adopting an adaptive management approach would be an excellent way of both ensuring the protection of the target species and filling knowledge gaps. Adaptive management can be described as learning by doing, and its application involves rolling out conservation actions to mitigate the effects of priority threats while

collecting data that will serve to refine and update planned conservation actions.

Tackling the impacts of invasive mammals is a top priority for successfully conserving seabirds, a globally imperilled group of vertebrates, and it is a task that can be supported by sound research exploring the impacts of invasive mammals.

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Predator Free 2050

The mission to make New Zealand predator free by 2050, eradicating introduced predatory mammals critically threatening native biodiversity, is building momentum. A survey conducted last year by Wellington City Council reported that 84% of Wellingtonians support ridding the city of such predators and 69% are willing to be actively involved.

The predator free goal to eradicate possums, rats and stoats was announced in 2016. The idea emerged from conservation discussions articulated by Sir Paul Callaghan in his last public speech at Zealandia Sanctuary in 2012, and was explored in a Pest Summit convened by the Department of Conservation (DOC) that year. Much of the strategy now in place came to the fore at that workshop, which identified seven priority strategic and research areas:

- mass mobilisation, to get the whole country behind the mission
- extension to very large scale, through strategic and ecologically based pest management
- continuing improvement to current toxin- and device-based (e.g. trap) approaches
- improved surveillance, detection and monitoring
- better lures to increase predator interaction with control and surveillance devices
- exploring the potential of new genetics-based pest control approaches
- national coordination.

Since 2012 huge progress in large-scale projects has been made through initiatives such as Project Janszoon in Abel Tasman National Park, Cape to City in Hawke's Bay, and more recently the Taranaki Mounga Project. The investment in public conservation land administered by DOC is underpinned by the Tomorrow Accord between the NEXT Foundation and the New Zealand Government, which requires agreed biodiversity outcomes to be maintained by government in perpetuity. DOC also increased its predator control work through the Battle for Our Birds initiative, designed to target predator populations following beech mast seeding events to prevent predators from irrupting to very high levels. This initiative has since been broadened to cover all DOC's landscape-scale small-mammal pest suppression and eradication activities. Outside of public conservation land administered by DOC, commitments to landscape-scale predator management are also being reflected in regional council pest management plans and long-term plans, notably in Taranaki and Hawke's Bay.

The Predator Free New Zealand Trust (PFNZ), founded in 2012, has made a significant contribution to building community interest and capacity in the predator free by 2050 movement. Many new community-driven initiatives focusing on predator management have sprung up in recent years, such as Predator Free Wellington and Predator Free Dunedin. Supporting these initiatives are new computer-based management tools to help the planning, monitoring and reporting of community-based trapping, such as TrapNZ and CatchIT. Most recently, Squawk Squad, funded by the Kickstarter Campaign, has helped lead the way into social media and education, teaming up with Goodnature Limited and Encounter Solutions to provide crowd-sourced remotely monitored trapping solutions for sanctuaries, and with DOC and other partners in engaging 40 000 children across 800 schools during Conservation Week in 2017.

Research planning, funding and progress have likewise come a long way since 2012. During establishment of the New Zealand's Biological Heritage National Science Challenge (BHNSC) research project on small mammal management, confidence in the predator free by 2050 goal was built through a stakeholder survey and a joint stakeholder−researcher workshop. Survey respondents highlighted possums, rats and stoats as the top three invasive mammal pests of concern (Figure 1), with priority given to landscape-scale management, eradication, and surveillance/reinvasion. This gives strong confidence that the majority of conservation stakeholders in New Zealand support the predator free by 2050 initiative. In the subsequent BHNSC joint stakeholder/researcher workshop, the research and strategy priorities from the 2012 Pest Summit were independently reflected and fleshed out (Figure 2).
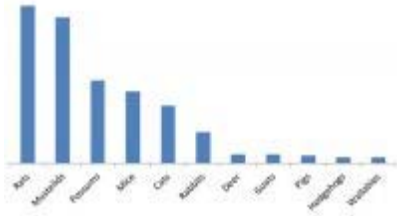
Figure 1. Stakeholder responses to the question 'Which invasive mammal pests would you like to be better able to control, in order of priority?' (n = 19). Note over 90% of 'mustelid' references were to stoats.

Figure 2. The Predator Free 2050 research/strategy landscape, as constructed by a BHSNC stakeholder/researcher workshop in 2016.

With the remit to invest in potentially game-changing research, the BHNSC initiated work on an improved lure for stoats, biosensors for vertebrate pest surveillance, sequencing the full genome of the brushtail possum, foundational exploration into the feasibility of new genetics-based pest control approaches, the development of a possum-specific toxin, and societal perspectives and the bioethics of mammal pest control. This complemented ongoing work on lures and specific toxin development for other pests, and ongoing development and improvement of a range of traps, conventional toxins, and surveillance approaches across the pest research and management community. Recognising the importance of close-to-market investment to get improved tools into the hands of conservation practitioners, the BHNSC also reviewed priorities in this area. Some of these have already been picked up by DOC's Tools to Market research fund, with recent support for predator-selective and rat-specific toxins, and long-life rat lures.

Complementing the traditional approaches in research on pest management is Zero Invasive Predators Ltd (ZIP), a not-for-profit research and development organisation formed in 2015. ZIP is employing an agile adaptive management model to develop approaches to eradicate invasive mammals and then defend predator-free areas from reinvasion without relying on predator-proof fences. After initially focusing on peninsulas, ZIP are now using remove-and-protect methodologies in mainland areas. So far they have successfully cleared 2500 hectares, and aim to push this up by an order of magnitude over the next 2 to 3 years.

Completing the picture is Predator Free 2050 Limited (PF2050 Ltd), formed in November 2016 to coordinate partnership approaches to large landscape projects and breakthrough science. It aims to supercharge local and regional efforts to scale up predator suppression and eradication, working closely with community groups and regional and city councils, and to focus research efforts to achieve a breakthrough science solution capable of eradicating at least one small mammal predator by 2025. This momentum is not just national: the international conservation community once again sees New Zealand as leading the way, with our Predator Free 2050 programme serving as a founding initiative for the International Union for Conservation of Nature's Honolulu Challenge on Invasive Species, also launched in 2016.

The science strategy for PF2050 Ltd was constructed by a team of 10 experts convened by the BHNSC and independently peer reviewed, with the goal of complementing existing efforts to give the whole research portfolio the best chance of achieving the 2025 goal. In line with this strategy, PF2050 Ltd is now investing across four research programmes:

- 'Environment and Society' is building on work underway in the BHSNC to explore social and cultural views on predator eradication, and to confirm and expand our understanding of the environmental and ecological consequences of this programme
- 'Best Use of Existing Approaches' is testing whether advances made with currently employed tools and approaches can make eradication at the landscape scale possible, initially for possums and building on developments in the eradication of bovine TB
- 'Exploring New Approaches' is building on foundational work in the BHNSC to address knowledge gaps with regard to risk, benefit and the technical feasibility of new genetic approaches, enabling an informed consideration of their potential
- 'Computer Modelling' underpins the strategy and is developing shared tools that all communities and agencies contributing to Predator Free 2050 can use to design, monitor and improve the right approach for their goals and environment.

The need to concentrate effort in the Predator Free 2050 programme was driven home by the Parliamentary Commissioner for the Environment's *Taonga of an Island Nation: Saving New Zealand's Birds*. This report, released in 2017, highlighted the fact that over 80% of native bird populations are in decline, primarily due to the impacts of introduced predators.

The huge progress made since 2012, summarised above, shows that New Zealand is well on the way to meeting this need. There is now real confidence in a national partnership between iwi, communities, business, researchers and government following a common agenda to eradicate the introduced predatory mammals critically threatening native biodiversity.

Rapid-repeat 'dual' 1080: Can 1080 survivors be killed with a second sowing of 1080?

Achieving 100% kill of possums and rats in a single low-cost operation spanning just a few months is an aspirational goal for Manaaki Whenua − Landcare Research (MWLR) scientists Graham Nugent, Bruce Warburton and Grant Morriss. Doing so at very large scales in remote forest and mountain land would simultaneously result in such areas being immediately free of bovine tuberculosis (TB) in possums, and achieve local possum and rat freedom. This could greatly speed up progress towards the twin national goals of predator freedom by 2050 and eradication of TB by 2055.

The only currently available low-cost tool that can deliver close to 100% kills of both pest species over very large areas is two aerial pre-feeds of non-toxic bait followed by aerial 1080 baiting. However, post-baiting recovery of possum and rat populations suggests there will nearly always be a few survivors. Affordable ground-based options for locating and killing 1080 survivors are limited, so there is emerging interest in determining whether they could instead be killed using a further application of 1080 bait (i.e. 'dual' or rapid-repeat 1080).

In 2015 OSPRI commissioned MWLR to begin development of the dual 1080 concept. To kick things off the team met with experts from OSPRI, the Department of Conservation (DOC), and Zero Invasive Pests (ZIP) to design a possible approach. That workshop proposed a protocol comprising sequential application, about 2 months apart, of 1080 delivered in two different bait types, with each 1080 baiting round preceded by two non-toxic pre-feeds. A simple but crucial question was whether all or most of the (few) possums and rats that survived the first application of 1080 would be killed by the second. If not, the second application would be pointless.

In a first test of the method, a field team led by Grant used radio-tracking, chewcards, trail cameras, and bait acceptance trials to monitor the outcomes of three different 1080-baiting regimes in duplicate 100 ha blocks near New Creek, Westland. Both the first and second regimes involved a single broadcast application of 1080 in RS5 cereal bait sown at 2 kg/ha, and pre-fed either once (the usual operational protocol) or twice (the team's recommendation for optimal kill efficacy). Both were highly effective, with all 75 radio-collared possums present in those four blocks killed during the first baiting in September 2016 (Table). Chewcards, baited and lured with peanut butter and cinnamon, were deployed to measure changes in pest activity. Over the next 9 months no possums were detected on the continuously deployed chewcards in two of the blocks, but a few survivors were detected in the other two. The pattern was the same for rats.

Table: Outcomes of three 1080 baiting regimes used in New Creek, showing the percentage kill of radio-collared possums and the percentage reduction in 7-night chew-card indices (CCIs) of possum and rat abundance achieved by the first cereal-1080 baiting (in September 2016), and the CCIs for possums and rats after a second baiting with EDR-coated cereal bait (in February 2017). Note: na = not applicable.
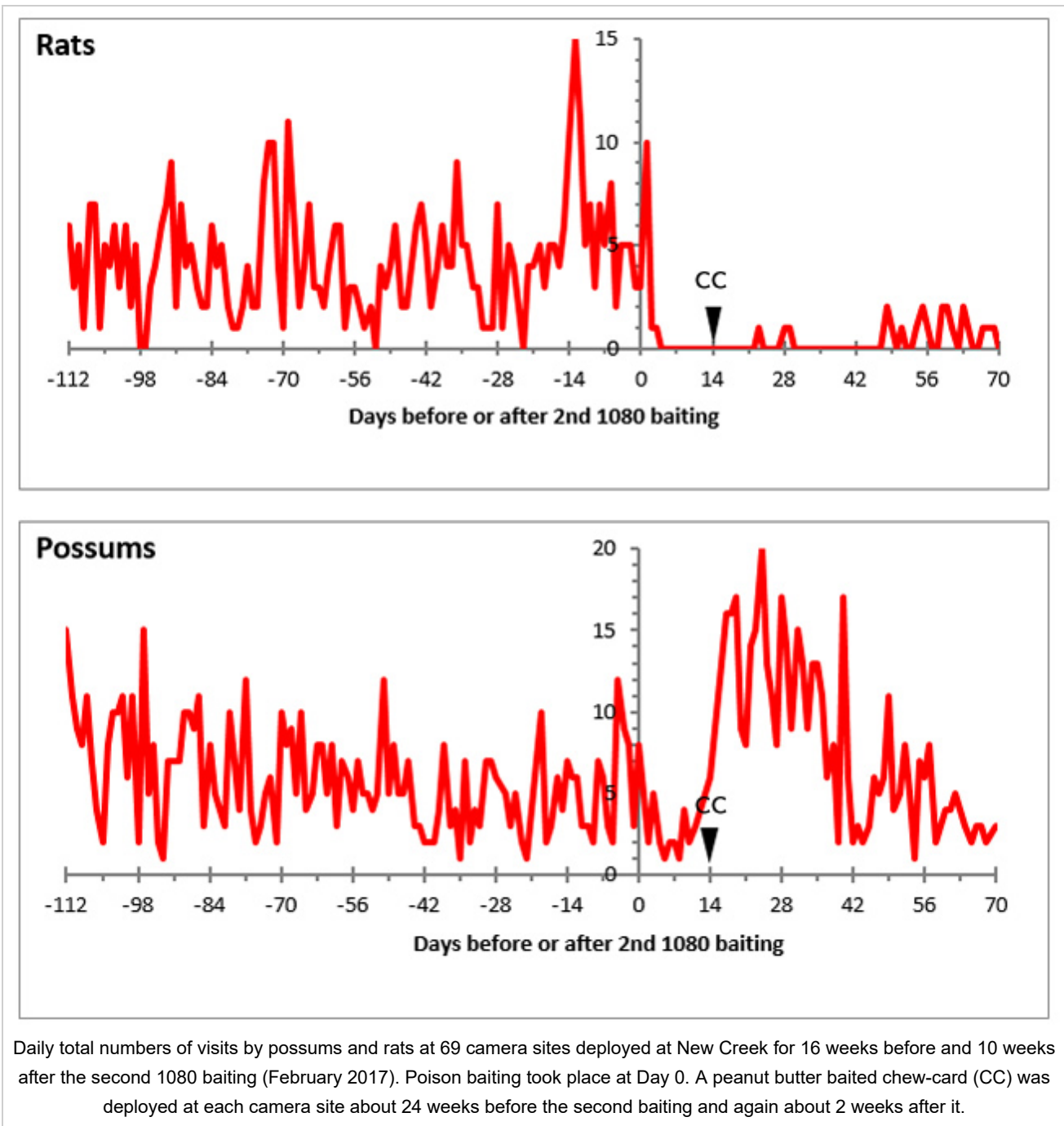
Treatment	% kill (no. possums) 1st baiting	% reduction in possum CCI 1st baiting	% reduction in rat CCI 1st baiting	% reduction in possum CCI 2nd baiting	% reduction in rat CCI 2nd baiting
No pre-feed	98% (84)	90%	45%	No reduction	100%
1 ´ pre-feed	100% (34)	100%	100%	na	na
2 ´ pre-feed	100% (41)	100%	100%	na	na

The third regime ('dual 1080' baiting) was applied to four blocks and involved two applications of 1080 cereal bait. The first 1080 baiting was not preceded by non-toxic pre-feeding, so, as expected, there was some survival of both possums and rats. Bait acceptance trials showed that most if not all survivors would not eat any of the cereal bait type actually used in the first baiting, nor any of three other cereal bait types or carrot bait.

The subsequent second application of 1080 (in February 2017) involved a slightly different bait preparation (RS5 coated with Epro deer

repellent [EDR], which changed the appearance and smell of the cereal bait). This was hand laid as either single baits randomly dispersed (in two blocks) or clusters of four baits (in two blocks) at 0.75 kg/ha, with the second baiting preceded by two aerial applications of the same EDR-coated RS5 bait in non-toxic form. Trail camera monitoring showed that rat activity immediately declined to zero following this second toxic baiting, with no rats detected until 3 weeks later (Figure). The second baiting with EDR-coated bait was clearly highly effective at killing rats, suggesting that pre-feeding twice with this second bait type had overcome their learned aversion to cereal bait from the first 1080 baiting.

Daily total numbers of visits by possums and rats at 69 camera sites deployed at New Creek for 16 weeks before and 10 weeks after the second 1080 baiting (February 2017). Poison baiting took place at Day 0. A peanut butter baited chew-card (CC) was deployed at each camera site about 24 weeks before the second baiting and again about 2 weeks after it.

For possums the picture was different. Trail camera activity dropped by about half for a few days but then sky-rocketed to twice the levels observed prior to the second round of 1080-baiting (Figure). The explanation for this apparent doubling of possum activity lies in the fact that freshly baited and lured chewcards were placed at each camera site about a week after the second 1080 baiting. This observation indicated that the second 1080 baiting had only killed, at best, half the possums, probably mostly just the juveniles that had not been independent at the time of the first baiting. Importantly, however, it also showed that despite their learned aversion to cereal bait types and carrot, survivors still ate the peanut butter-based paste in the chew-cards and returned frequently to check for more.

Multiple camera site visits (67) by adult female (F) and juvenile possum (J) pairs were recorded before the second 1080 baiting at New Creek, as in the image on the left. Afterwards there were only two such visits, both by the same juvenile (second image)

Overall, the trial suggests that the dual 1080 baiting concept merits further development. For rats, it appears that most learned aversion can be overcome by a twice-prefed second baiting, so the next step could be to test efficacy at large scales to answer the question: is the percentage kill actually 100% or 'just' 99.99% (one survivor per 10,000 rats)? Recent and current operations by ZIP will test this possibility (see http://zip.org.nz/findings/2017/11/1080-to-zero-trial-in-south-westland). For possums, a second baiting round using only a moderately different formulation of the same cereal bait appeared to have low efficacy, so is unwarranted. Somewhat serendipitously, however, we found that possums averse to cereal bait would readily eat a bait type that differed hugely in appearance, form, texture and taste, which suggests that a more drastic change of bait types could make a second baiting much more effective. Fortuitously, peanut butter-based prefeed and 1080 baits are already registered for possum control, albeit not yet for aerial delivery, so trials are underway to progress the dual 1080 baiting concept with such baits.

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Monitoring a sika deer population with trail cameras to assess survival following 1080 baiting

During aerial 1080-baiting operations against possums wild deer are also often poisoned. In areas where wild deer are valued by hunters and landowners, a deer repellent can be added to the bait to reduce this by-kill. Epro deer repellent (EDR) has been used for this purpose for more than a decade, and studies have demonstrated greatly reduced incidental by-kill of red deer and fallow deer when EDR is added to 1080 baits. However, the effectiveness of EDR in reducing the by-kill of sika deer has not been assessed.

A recent 1080 possum control operation over 10 000 ha in the Paemahi area of the Kaimanawa Forest Park gave Grant Morriss and Graham Nugent an opportunity to measure whether aerial baiting using EDR-coated 1080 bait has a significant impact on sika deer populations. Grant and Graham established two grids of trail cameras, each covering 600 ha, and compared the number of deer photographed a month before the 1080 operation (June 2017) with that a month later (July) (Figure 1). The team estimated the sika population in the Paemahi area to be 15–20 deer per square kilometre.
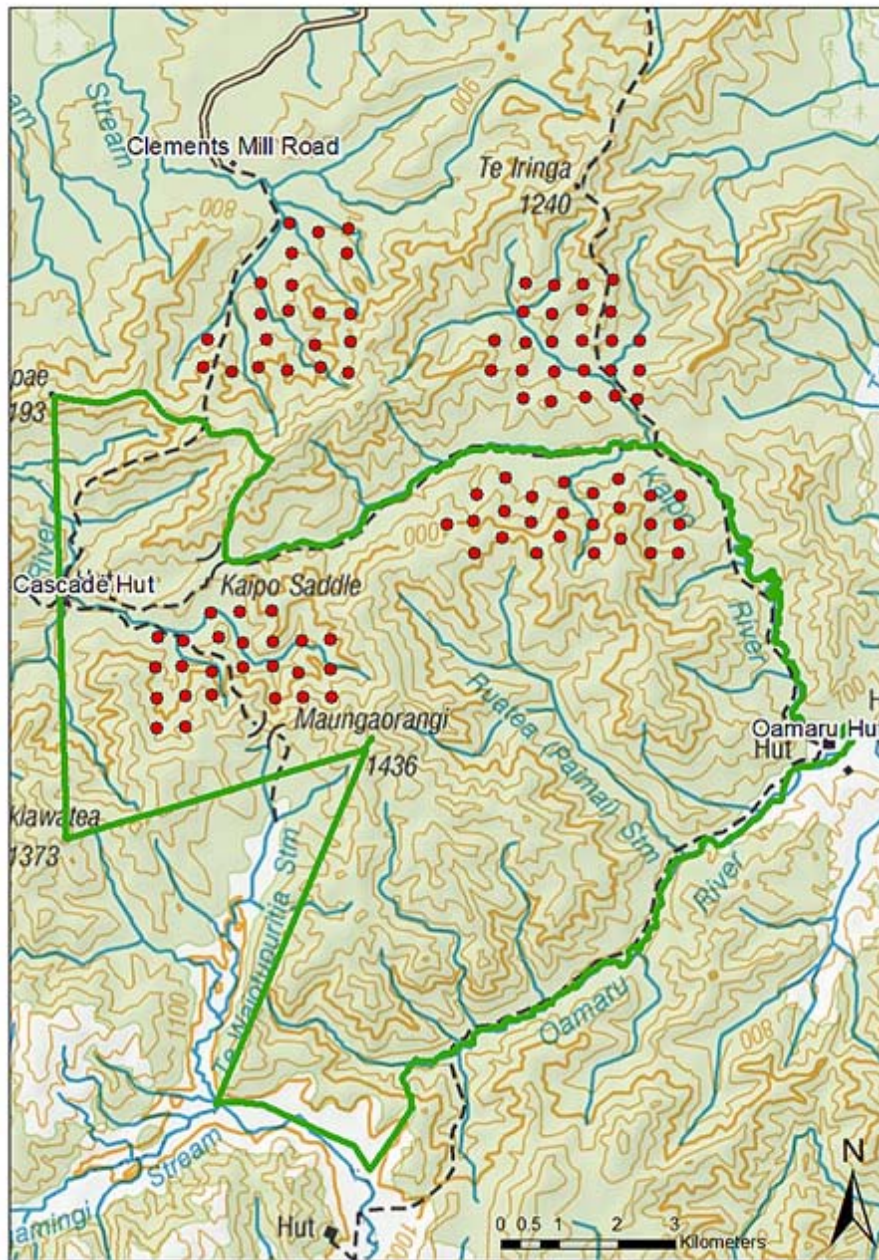
Figure 1. Location of trail cameras (red dots) deployed in the Kaimanawa Forest Park, winter 2017. The green line shows the boundary of the Paemahi possum control operation that was poisoned with EDR cereal bait.

Two other trail camera grids were established in a nearby unbaited area of similar habitat and the sika deer populations there were similarly monitored to determine any natural changes in their sighting rate. Interestingly, rather than the usual method of deploying chewcards or traps to assess possum numbers, this approach provided an opportunity for the team to test the utility of trail cameras for monitoring changes in the activity and number of the target species (possums), and any behavioural interactions between deer and possums.

Grant and Graham examined over 10 000 images produced by the trail cameras, of which approximately 7000 were of sika deer. Numbers of photographs of sika were high throughout June (Figure 2), peaking at averages of five visits a day in the area where 'EDR-1080' bait was due to be dropped at the end of that month, and 10 visits a day in the 'no-1080' area. For both areas, deer sighting rates naturally declined by approximately 40% towards the end of June, due primarily to sika stags moving out of the area after mating (confirmed by video analysis). Importantly, there was no discernible change in sika deer sighting rates in either the poisoned or non-poisoned areas after the poison drop: deer sighting rates remained fairly constant for the next 4 weeks (Figure 2), regardless of area.
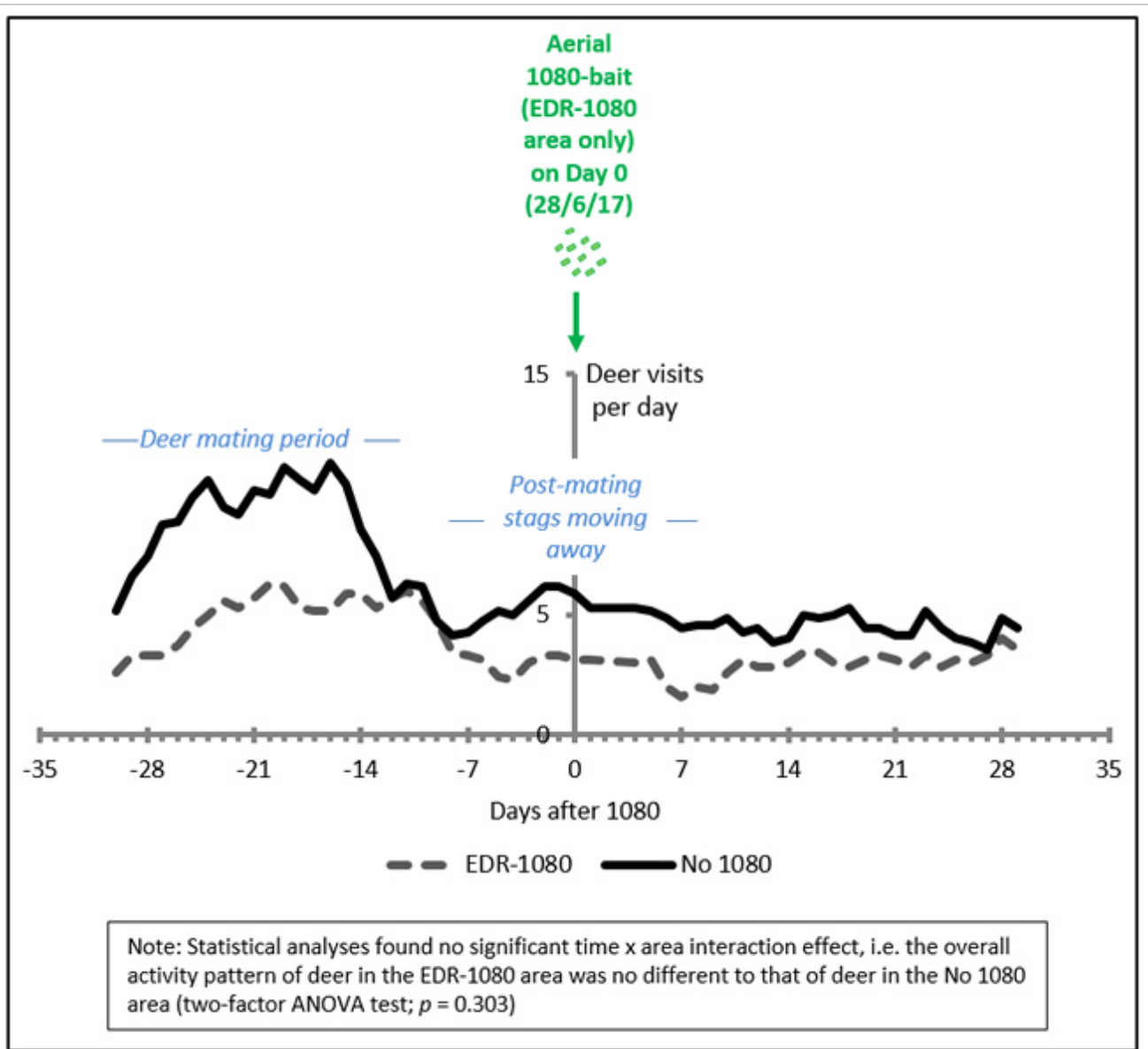
Figure 2. The number of camera-triggering deer visits per day for two areas in the Paemahi area in 2017: a treatment area that received aerial EDR-coated cereal bait (EDR-1080) and a non-treatment area (No 1080). Trail cameras monitored daily deer visits to the camera sites for a month before and after the poison drop (Day 0). Note, for both areas, the incidental decline in deer numbers over 1–2 weeks before Day 0, was due to stags leaving the area after mating.

The picture was very different for possums (Table). The total number of visits to camera sites by possums over 30 days before and after the poison drop revealed a reduction in the number of possums following baiting from an average of three sightings per day pre-drop to zero post-drop. While not corroborated by one of the more usual means of monitoring possum numbers, the trail cameras suggested a near 100% kill of possums.

Table: Changes in the number of sika deer and possum visits recorded at 81 camera sites in the Paemahi area, operating for 33 days before and after 1080 baiting in June 2017.

	Total no. of deer photographed				Total no. of possums photographed		
	Pre-1080	Post-1080	*% reduction*		Pre-1080	Post-1080	*% reduction*
EDR-1080 areas	173	107	*38.1*		191	0	*100.0*
Cascade	102	51	*50.0*		99	0	*100.0*
Kaipō	71	56	*21.1*		102	0	*100.0*
No-1080 areas	294	164	*44.2*		13	13	*0.0*

Clements Mill	108	45	*58.3*		3	9	*–200.0*
Tiki tiki	186	119	*36.0*		10	4	*60.0*

However, the team wanted to look further into the issue of possible 1080 effects on the sika deer population in the Paemahi area. Based on camera sightings they estimated deer density across the region using three different extrapolation methods. Next, they conducted systematic ground searches over the baited area and counted and collected tissue for poison residue analysis from any deer carcasses they found. This provided a more detailed picture: 11 dead sika deer were found after the 1080 bait drop and all had 1080 residues. Averaged for the area as a whole, this equated to 1.6 carcasses per square kilometre, and accordingly the team estimated that approximately 10% of the sika population would have succumbed to 1080 poisoning. While this figure is at the upper end of the expected mortality if EDR is effective, the result did serve to illustrate an important point: for a high-density population such as that in the Paemahi area, 10% incidental deaths from a 1080 bait operation is likely to be negligible for the population of deer, with sika numbers likely to recover rapidly through increased reproduction and fawn survival as the result of more available food.

Daytime photo depicting a sika deer hind.

Night-time photos depict a possum (arrowed) approaching a sika deer.

Night-time photos depict a possum (arrowed) passing close to a sika deer.

So the project was a success in apparently killing 100% of the targeted possum population while sparing 90% of the valued sika deer. However, the original aim of the control operation was to reduce the level of bovine tuberculous (TB) in local wildlife, so what did these results tell the team about TB? First, TB had not been recorded in the area since the 1990s, and since the detailed necropsy of 32 wild animals found after the 1080 operation (20 possums and 12 deer) found no TB lesions, we calculated a 30–78% probability that the disease had already been eliminated (using the Proof-of-Freedom modelling framework (Anderson et al. 2013). This was not enough to declare freedom from TB, but enough to predict that a similarly effective repeat 1080 operation in the same area in 3 years' time would be likely to achieve the sought-after 95% probability of localised TB eradication.

Secondly, analysis of the trail camera data allowed the team to observe interactions between wildlife species. In one sequence a possum was seen to pass close to a sika deer, and some mutual interest was exhibited between the two species (although no direct contact took place). This is just one isolated occurrence, but it supports the long-held belief that deer acquire TB from infected possums by their inquisitive investigation of the latter (e.g. nuzzling, sniffing objects of interest on the forest floor), and such behaviour is the major route of TB transmission between the two species.

It would appear that EDR can be relied on to limit incidental by-kill of sika deer in poison control operations, in addition to its already-known bait-aversion effects on red and fallow deer. Grant, Graham and other TB researchers now have a starting-point from which they can estimate the likelihood of TB persistence in the Paemahi area, which will help the next steps for full TB eradication there. The use of trial cameras has been highlighted as a promising new means of monitoring changes in pest populations following poison baiting, representing a longer-term 'set-and-forget' approach to pest monitoring than the more labour-intensive current means of setting, collecting and analysing chew cards, or setting, checking and recovering animals from leg-hold traps.

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Improving possum capture rates by modifying leghold trap sets

Double-coil spring leghold traps are used to capture possums for pest control, fur recovery and population monitoring. For monitoring, a standardised method (described by the National Pest Control Agencies; NPCA 2015) for setting traps is used. Traps are bedded into the substrate, approximately one hand width from the trunk of a tree, and with the trap dog (latch) nearest the tree. The trap chain is stapled to the tree and a blaze of flour and icing sugar (5:1 mix) is spread on the tree behind the trap to act as a visual and food lure to encourage possums to approach and step on the trap. However, research has shown that on their first visit to a trap set that follows this protocol, only 40–50% of possums are caught.

To increase capture rates of possums, fur trappers have advocated a range of changes to traps and sets, including hazing (placing rocks, sticks or logs beside the trap to act as a fence) to guide possums over the trap, covering traps in case possums visually avoid stepping on them, or using traps that have larger trigger plates for the possums to stand on. Although these modifications might increase capture rates, there are no data to support their use.

In 2013 TBfree New Zealand commissioned Bruce Warburton and Grant Morriss to investigate ways to improve possum capture rates. Early field testing compared the capture rates of standard NPCA trap sets with those with a large trigger plate, double traps, covered traps, and hazed traps. Unfortunately, these trap-set modifications did not improve capture efficiency. Surprisingly, standard sets caught the most possums overall.

A trap set as outlined in the NPCA protocol (NPCA 2015)

A hazed set (i.e. using sticks or rocks placed alongside the trap to guide the possum onto it)

Standard Victor No. 1 (left) and Victor No. 1 with large trigger plate (right)

A double set (i.e. two traps set as a pair to increase the probability of a possum stepping onto a trap)

A modified trap set with a ring of lure and a flat, unbaited chewcard set as a visual lure

Side approach avoiding trap

Subsequent examination of video footage of possums encountering traps as part of another project indicated that possums do not always

directly approach the lure by stepping on or over the trap, but instead often reach around the tree from the side of the trap. Given covered traps did not improve capture rates, reaching around the tree was probably not possums trying to avoid the trap. Hazing was used to try to force possums to approach the lure by stepping on or over the trap, but video footage again showed that some possums still climbed over the hazing material and avoided capture. The results from this trial and examination of video footage indicated that placing lure behind the trap on the trunk of a tree might not be the best solution for maximising capture rates.

With this in mind, Bruce and Grant trialled sprinkling lure in a ring around the trap on the ground so that a possum would encounter a food source before the trap, no matter which direction it approached the trap from, and during feeding had an increased chance of stepping on the trap plate. In addition, white, flat, unbaited chewcards were nailed to both sides of the adjacent tree to act as a visual lure to attract possums to the trap site. An extra card on the back of the tree aimed to pique the interest of possums approaching the trap from the blind side of the tree.

During field tests in one moderate and two low possum density sites in Canterbury more possums were captured with this modified set compared to standard NPCA trap sets. This trap set provided a 30% increased capture rate, which should improve the effectiveness of detection surveys where currently possum bites are frequently recorded on chewcards or wax tags, but follow-up trapping is unsuccessful at capturing possums.

The initial work was funded by OSPRI through their TBfree programme, with later testing funded by the Ministry of Business, Innovation and Employment.

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Reference:
NPCA 2015. Possum population monitoring using the trapcatch, waxtag and chewcard methods. *Best practice guideline publication no. A1.* Wellington, National Pest Control Agencies.

Winners and losers in the battle for New Zealand's biodiversity

New Zealand's (NZ's) sanctuaries play a critical role in mainland restoration, as exemplars of what can be achieved when pests are controlled to low numbers. As well as managing pests, reintroducing missing indigenous species and inspiring communities in local conservation, some sanctuaries also monitor biodiversity and present an incredibly valuable opportunity for improving our understanding of biodiversity responses to pest control.

However, despite decades of work in sanctuaries, there is a surprising deficit of published scientific information from these sites. Monitoring is often time consuming and costly, and sanctuary managers rarely have the resources to employ scientists to collect and analyse data, meaning that only a few sanctuaries (such as those situated close to universities) publish their work. In addition to sanctuaries, considerable credit is owed to staff in the Department of Conservation's (DOC's) mainland island projects, where extensive long-term biodiversity and pest monitoring have been conducted for over two decades to test different control techniques and conserve native biota.

South Island robin.

Recent work to assess the biodiversity outcomes from NZ sanctuaries by Rachelle Binny and her colleagues has involved a huge collaborative effort, with data being shared by 23 sanctuaries and three DOC 'mainland islands'. Sites range in area from a few hundred hectares to several thousand, and span a range of habitats across the North and South Islands. Monitoring data gathered at these sites over the last two decades on a wide range of flora and fauna are being collated using a diverse array of monitoring methods and measures. By combining information across multiple sites, this work aims to provide new insights that couldn't be gained by considering any one site alone.

Collating the data has been challenging because it is so variable – different people want to measure different things in different ways – which has highlighted the need for clear leadership on the use of 'standard operating procedure' techniques and measures for monitoring. As Predator Free 2050 (PF2050) ramps up and new conservation projects pop up across NZ, a consistent approach to monitoring both

pests and native biota, and better sharing of such data, will allow agencies, communities and individuals to readily combine their data in order to contribute to the national picture.

A range of different measures commonly used in New Zealand to monitor birds, lizards, frogs, invertebrates and vegetation (e.g. bird-call counts, nesting success and forest canopy health) are being analysed. Early results from a meta-analysis of these data suggest benefits for biodiversity within NZ sanctuaries, across a range of flora and fauna. As might be expected, greater benefits are seen within sanctuaries surrounded by a pest-proof fence, where all mammal pests (except mice, typically) have been eradicated, compared to unfenced mainland islands where at least some pests remain but are controlled to low levels. However, while the populations of some species respond very positively to pest control, the populations of some other species show only small benefits, or in some cases even decline. In other words there are winners and losers.

The predator-proof fence surrounding Maungatautari Reserve.

Another interesting trend emerging from the data on bird responses is that the 'winners', or those that benefit most strongly, tend to include our long endemic species (e.g. kiwi, North Island kōkako and stitchbird/hihi), with weaker benefits observed in more recently endemic species (e.g. tui and tomtit). The 'losers' in this case are introduced species or 'recent natives' (e.g. grey warbler, silvereye and fantail), whose populations often show little change or even decline in response to pest control. These trends are not necessarily a bad thing, and may reflect a natural restructuring of ecological communities when the threat of predation by pests is reduced. Ecosystems are incredibly complex and predation is not the only factor limiting threatened populations. Habitat, competition and other factors also play key roles, and it is becoming increasingly important to fill the knowledge gaps around the effects of these factors alongside predation so that realistic conservation objectives can be set and achieved. For example, very little is known about the naturally occurring densities of native populations in the absence of pests.

This research will improve understanding of the broad biodiversity outcomes from pest management and is relevant for conservation managers and policy makers. As control efforts expand across NZ, reliable and comparable measures of effectiveness for each of the currently available control strategies are needed. The cost of each regime is, of course, another important factor to consider. Overall we hope this work will highlight the importance of continued support for NZ's sanctuaries, both pest-fenced and mainland islands, and of ongoing allocation of resources for towards monitoring biodiversity and pests using standardised techniques.

The motivation behind the PF2050 mission is not mainly about killing pests. It is about conserving NZ's unique biodiversity before it is lost. As PF2050 drives pest control efforts to spread and intensify across the country, it is critical that the resources being invested in achieving the predator-free goal are justified, and that understanding of the biodiversity outcomes from pest control is improved so that realistic expectations can be set around what success would actually look like for PF2050.

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Community group finds no increase in rat numbers as possum numbers are reduced

Competitor release is an ecological interaction in which controlling or eradicating one pest species causes another competing species to increase in number. For example, in some New Zealand forests, after possums and ship rats are controlled with widespread toxic baiting ship rat numbers climb higher than before control. This is because ship rat populations recover more quickly than possum populations and

benefit from reduced competition with possums for foods such as seeds, fruit and invertebrates. When abundant, rats can prey heavily on indigenous species, potentially undoing some of the conservation benefits of possum control.

The Otago Peninsula Biodiversity Group (OPBG) has been working to eradicate possums over the Peninsula since 2011 to protect biodiversity, along with lifestyle and economic values. The Peninsula is very different from the forests where competitor release of rats has been shown: it has residential communities, steep pasture, exotic trees, and pockets of indigenous shrub and forest.

Possums, identified by the OPBG and the community as the most controllable animal pest, were the group's first target. The OPBG removed possums with toxic bait (in bait stations) and traps, starting at the tip of the Peninsula and working towards the suburbs of Dunedin. The main possum knockdown operations were done in March to June 2011 (northeast end of Peninsula) and December to April 2013 (southwest end) (Figure 1). These operations were followed by mop-up and hot-spot possum removals that are ongoing.
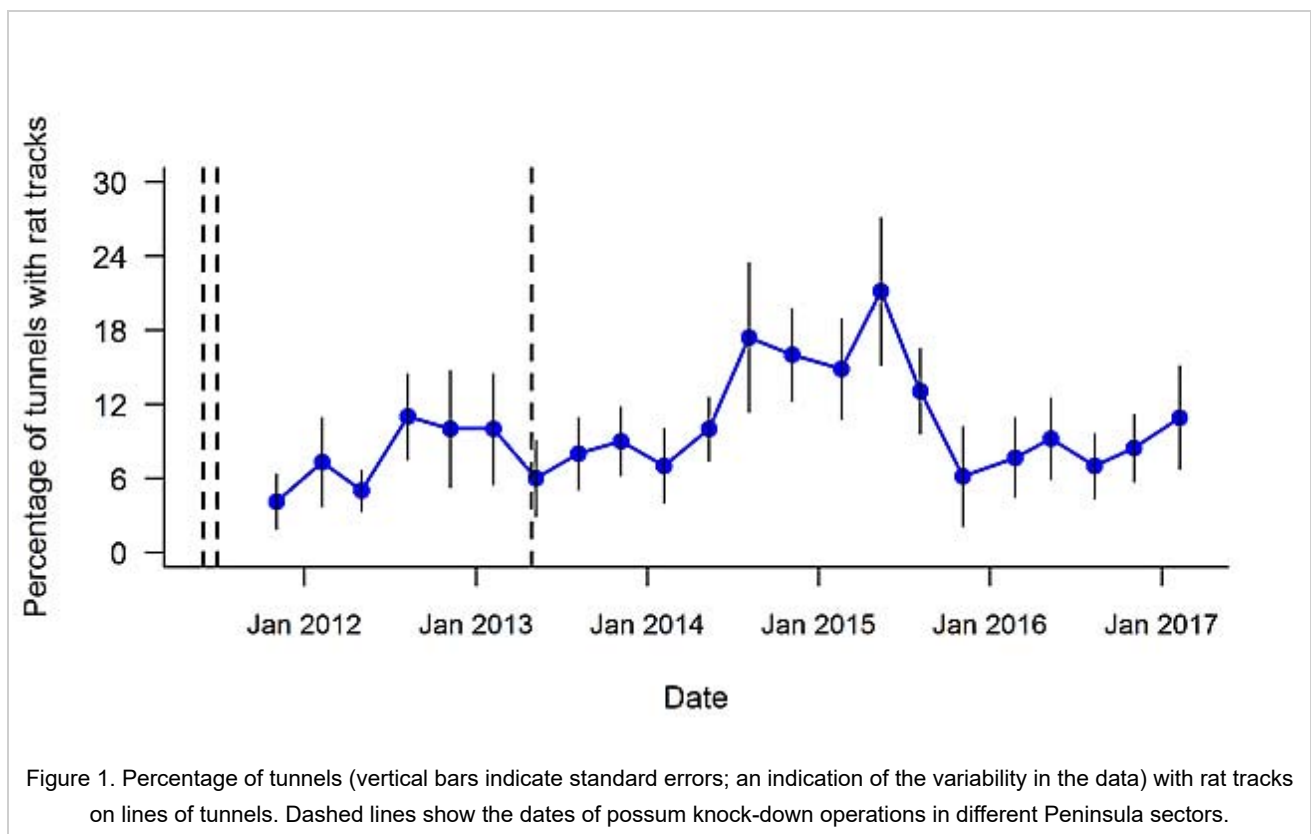

Peninsula resident Alf Webb sets up a tracking tunnel on the Bacon Street line.

OPBG founding trustee Moira Parker was concerned that a rat population increase on the Peninsula could undermine the benefits of possum removal, particularly as ship rats are one of the most important predators of birds' eggs and nestlings in forest fragments and urban and peri-urban environments. With Rik Wilson, Cathy Rufaut and Deb Wilson, she established a network of inked footprint-tracking tunnels to test for changes in rat numbers on the Peninsula, and these were checked on a single dry night every 3 months for 5 years. The proportion of tunnels containing rat tracks on each line of tunnels was used as an index of rat abundance – ship rats and Norway rats combined, as the two species cannot be distinguished from their tracks.

The OPBG removed 11,300 possums between 2011 and the final rodent monitoring session in February 2017. They estimated that in some parts of the Peninsula possum density reached 20 per hectare prior to control.

Peninsula rat tracking over time

The proportion of tunnels with rat tracks fluctuated annually and seasonally (Figure 1), as is typical of rat populations in New Zealand, and varied among the 13 lines of tunnels (Figure 2) due to differences in habitat, land use, and pest control by landowners. However, statistical modelling showed that the rat tracking rate was not related to the number of weeks since possum knockdowns. The group concluded there was no evidence that 5 years of possum control had caused the rat population to increase.

Figure 1. Percentage of tunnels (vertical bars indicate standard errors; an indication of the variability in the data) with rat tracks on lines of tunnels. Dashed lines show the dates of possum knock-down operations in different Peninsula sectors.
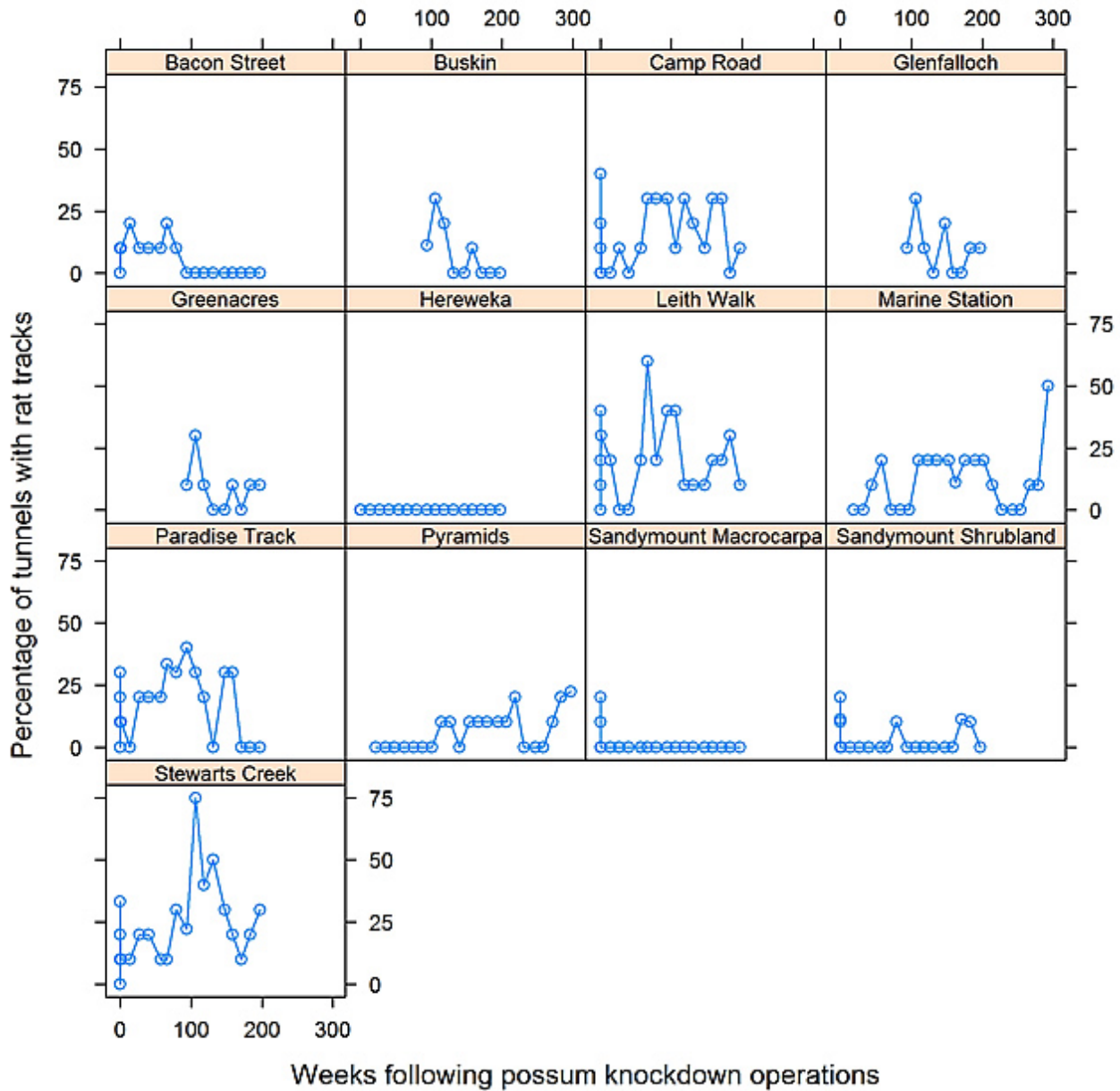
Figure 2. Percentage of tunnels tracked by rats on each line of tracking tunnels.

Why was competitor release of rats not evident on the Peninsula?

The OPBG project differs in several ways from earlier studies that showed competitor release of ship rats after possum removal. These differences may explain why findings on the Peninsula contrast with earlier research results.

First, foods competed for by possums and rats in the diverse Peninsula habitats would be very different from those in North Island forests. It may be that the diets of rats and possums on the Peninsula overlap less than in forest.

Second, Peninsula possum control operations were targeted at possums and did not kill many rats. In the earlier studies, surviving ship rats were released also from competition with rats that had been killed by aerial baiting. Perhaps only after both mammals become scarce do remaining rats have sufficient food to stimulate rapid reproduction and population growth.

Third, possum removal from the Peninsula with trapping and bait stations has been relatively gradual compared with that following aerial baiting. Progressive possum control could affect the movements and diets of both possums and rats and prevent competitor release of rats, or make it difficult to detect.

Finally, ship rats are the predominant rats in forests and shrubland, whereas Norway rats are often urban, on farms, or near water, but the OPBG did not determine which species of rats left footprints in the Peninsula tunnels. Given the Peninsula's patches of forest and

shrublands, long coastline, streams, farms and villages, both rat species may have tracked the tunnels. Differences in their ecology and behaviour could obscure the relationships between tracking rates and time since possum control.

Future monitoring on the Otago Peninsula

The tracking data provide a baseline to assess the outcomes of future Peninsula predator removals. For example, if further rat control is implemented, these data could be used to test for changes in tracking rates of rats and of other species that tracked the tunnels, including house mice (which can increase in numbers following ship rat removal), and indigenous skinks and geckos.

Coprosma shrubland at the Marine Station tunnel line.

For other groups considering similar projects, a modified monitoring design may be better able to detect consistent long-term rodent population changes. First, focusing on one or a few habitats of interest, such as indigenous forest fragments, would reduce between-habitat differences in rodent tracking rates. Second, comparing rodent numbers on both pest removal and non-removal sites would allow site differences to be separated from the effects of pest control. Finally, using additional monitoring devices (such as chewcards) alongside tracking tunnels could help confirm whether differences in rat tracking rates are related to the presence of possums or other pest species.

Information about the OPBG can be found at www.pestfreepeninsula.org.nz. Reports on the rat-tracking study and other Otago Peninsula projects can be found at www.pestfreepeninsula.org.nz/?page_id=596

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Emerging invasive species: global rises resulting from increased accessibility of new sources

Thousands of species have been introduced into regions outside their native ranges by humans, and many have become permanent additions to local faunas and floras. The number of these established alien species has markedly increased worldwide during the past two centuries. Our ability to predict the identity of future invasive alien species is largely based on knowledge of *prior* invasion history. Therefore, emerging alien species — those never encountered as aliens before — pose a significant challenge to assessing biosecurity risk. Consequently, understanding the temporal trends, origins and spread of emerging alien species is pivotal to improving prevention and risk assessment tools.

House sparrow.

The observed growth in the numbers of alien species has been largely attributed to increases in the drivers of alien species introductions, such as import volumes and human mobility, and rising establishment rates due to land degradation. However, the number of alien species in a region may also be affected by changes in the accessibility of source pools of species in their native range. For example, 'historical' alien bird introductions (AD 1500–1903) were largely driven by European colonial expansion and thus mostly drawn from birds originating in Europe and European colonies. Conversely, 'modern' bird introductions (1983–2000) primarily relate to introductions via the pet bird trade and are species native to regions close to key trade hubs. These new source pools provide many new potential alien species as old source pools start to deplete (the proportion of new alien species in a source pool declines with every newly introduced species), thereby

maintaining the rate of alien species establishments in new regions.

Disentangling the factors underpinning the introduction of alien species will improve our understanding of past invasion dynamics and result in better-informed predictions of future invasion risks. To do this, Darren Ward and his colleagues created a database of more than 45 000 first records of just over 16 000 alien species to investigate the occurrences of emerging alien species worldwide. A 'first record' is the date an alien species was first recorded as present in a country. Included in the database were vascular plants, vertebrates (mammals, birds and fish) and invertebrates (insects, crustaceans and molluscs).

The team found that the distribution of alien species was highly skewed, with the majority of species (58%) having just a single first record (one country) in the database. By contrast, 26 species had more than 50 first records, with the top five being the domestic pigeon (first records in 197 countries), longhorn crazy ant (134), big-headed ant (92), house sparrow (87), and European rabbit (82). The vascular plant with the highest number of first records was Canadian horseweed (40).

Even after many centuries of invasions, the rate of emergence of new alien species is still high. For example, the team showed that during 2000–2005 one-quarter of first records in a country were of species that had not been previously recorded elsewhere as alien.

The number of emerging invasive species cannot be solely explained by increases in well-known drivers, such as the amount of imported commodities from historically important source regions. Instead, these dynamics reflect new, expanding trade networks, along with environmental change. Overall, up to 16% of all species on Earth (depending on the taxonomic group) qualify as potential alien species.

These results suggest there remains a high proportion of emerging alien species yet to be encountered, with future impacts that are difficult to predict. Biosecurity risk assessment approaches that rely less on prior invasion history will need to be prioritised.

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Reference:
Seebens H et al. 2018. Global rise in emerging alien species results from increased accessibility of new source pools. *Proceedings of the National Academy of Sciences* **115**(10): E2264–E2273. doi: 10.1073/pnas.1719429115

Using unrewarding prey cues to reduce predation

New Zealand's endemic fauna evolved in the presence of avian predators that hunt using sight. As a result, our fauna is visually cryptic but has few defences against introduced mammals that hunt primarily using smell. Olfactory predators are novel to New Zealand, creating a mismatch between visual defences and olfactory hunting strategies. The results have been devastating.

So, can anything be done about this mismatch? Fifty years ago Robert MacArthur, Eric Pianka and Merritt Emlen working in the USA introduced the notion that predators are constantly making foraging decisions to maximise their energy intake. Hunger forces them to focus only on rewarding cues and to ignore unprofitable cues that waste energy. Therefore, cryptic prey should be ignored if more easily detectable prey are available.

University of Sydney ecologists Catherine Price and Peter Banks tested whether this idea could be used to protect prey by deceiving predators into ignoring odour cues of visually cryptic species. They exploited the fact that mammalian predators hunt mostly at night, using their sense of smell. The researchers scattered bird faeces and feathers over 1 ha plots of Sydney bushland for 1 week before putting out quail eggs in artificial nests. They found that wild rats 'habituated', or lost interest in the odour of the faeces and feathers after only 3 days. Once habituated to the odour, rats were not interested in searching for nests even when they contained eggs. As a result, clutch survival increased by 62% over a short time period.

Grant Norbury and his team decided to test the method across a New Zealand landscape with real prey and multiple mammalian predator species. First, the team extracted odour from chicken, quail and black-backed gull feathers. The odour concentrate was mixed with Vaseline to enhance its longevity. They then ran laboratory and outdoor pen experiments with mice, ferrets and hedgehogs to confirm they lost interest in the bird odours after repeated exposures. Importantly, most animals appeared to 'generalise' between odour types, meaning that if they became habituated to one bird odour they became uninterested in odours from other bird species. This meant odour from widely available birds could induce lack of interest in bird odours in general, including vulnerable native species.

Typical braided river habitat in the Mackenzie basin where the field experiments were conducted

The team then embarked on an ambitious field experiment. They chose four study sites (mean size 960 ha) along 4–7 km lengths of braided riverbed in the Mackenzie basin, South Canterbury. The prey species were native shorebirds – mostly banded dotterels, but also wrybills and South Island pied oystercatchers. Their nests are highly vulnerable to a suite of introduced generalist predators (cats, ferrets, stoats, hedgehogs and rats), but these birds are secondary prey to other prey species (rabbits, in the case of cats, ferrets and stoats, and invertebrates in the case of hedgehogs and rats) – an important prerequisite, as predators do not rely on secondary prey for survival.

In 2016 the team applied bird odour at two of the sites for 5 weeks before the breeding birds arrived (i.e. the 'priming' phase), and for 12 weeks thereafter. Every 3 days a small amount of odour was applied to rocks at least 100 m apart at 300–400 randomised points across each site. Simulation modelling showed this deployment regime allowed predators to encounter the odour repeatedly (30–115 times per predator) during the priming phase. No odour was applied at the other two sites. Eighty motion-triggered cameras were used to monitor predator interactions with the bird odour on the treatment sites, and another group of cameras and tracking tunnels were used on all sites to estimate predator abundance.

Overall predator interactions with the odour were low (3.9 per 100 camera nights), but were nearly five times higher than where odour was absent, and some individuals were highly attracted to it. Low interaction rates were expected, as previous studies show only a minority of predators – called rogue animals – kill most native birds. Importantly, predators showed declining interest in the unrewarding bird odour as the priming phase progressed.
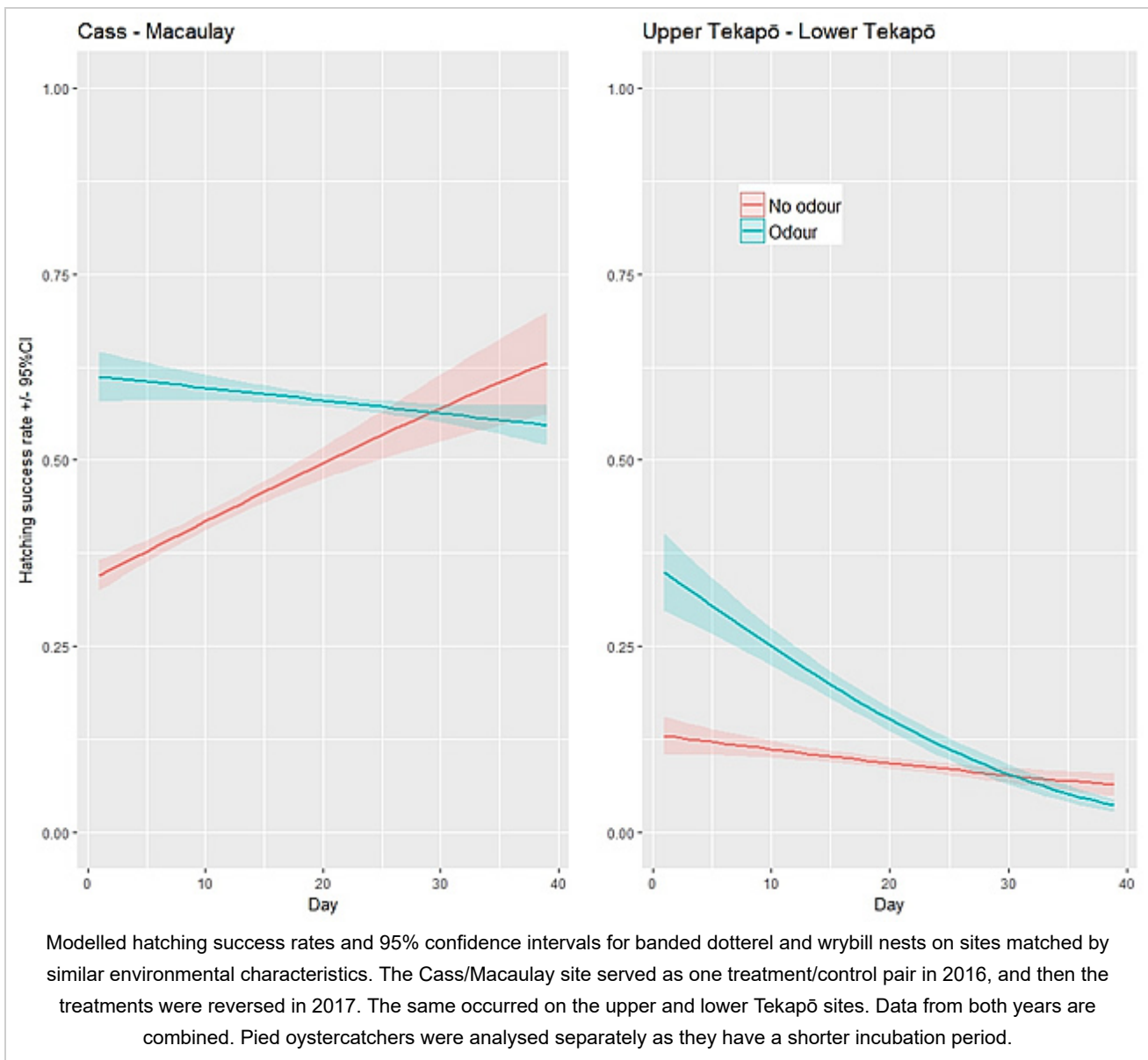
The ultimate measure of success, however, was whether the birds bred more successfully where the odour was applied. Wildlife Management International Limited ornithologist Nikki McArthur and four colleagues monitored the outcomes of 470 clutches (81% from banded dotterels) across the four sites for two breeding seasons. Cameras confirmed which predators were responsible for failed nests, with two-thirds predated by hedgehogs. The 2016 results were encouraging, but Grant knew from past studies that hatching success is variable in time and space. Therefore, in 2017 the team swapped the treatment and control sites, and found that the results swapped over as well, confirming the positive treatment effects.

Hedgehog eating banded dotterel eggs in the Mackenzie Basin, Canterbury

So, what happened? Hatching success rates, combined for both years, were significantly higher on treatment sites, but only for the first month or so (Figure). This waning was expected as predators eventually found food rewards associated with real nests. For banded dotterels and wrybill, hatching success was, on average, 37–104% higher on the treatment sites over the first 25 days. For pied oystercatchers, hatching success was 71% higher overall on the treatment sites over the first 32 days.

These results show that this new technique can boost chick production by about 40–100% during a 25–32 day 'window of opportunity' without removing a single predator. This result is further boosted by the fact that, without any intervention, survival of chicks born early in the season is typically significantly higher than for those born later (Aalbert Rebergen, unpublished data). Therefore, protection of early clutches results in more chicks fledging than protection of late clutches. Importantly, this technique is likely to target those predators that inflict the most damage on prey populations but may evade control programmes.

Modelled hatching success rates and 95% confidence intervals for banded dotterel and wrybill nests on sites matched by similar environmental characteristics. The Cass/Macaulay site served as one treatment/control pair in 2016, and then the treatments were reversed in 2017. The same occurred on the upper and lower Tekapō sites. Data from both years are combined. Pied oystercatchers were analysed separately as they have a shorter incubation period.

The team was now confident the method had merit as a management tool for reducing the predation of native species. So where to next? The long-term aim of the project is to identify the components of bird odour that predators respond to, and synthesise them in the lab. Grant would also like to explore the use of drones for deploying odour more cost-effectively in large, open habitats. Finally, the same principle of unrewarding cues could be applied to other types of cues, such as sound. The begging calls of chicks, for example, attract stoats. It may be possible to deploy recordings of begging chicks before nesting begins to habituate stoats to this cue, thereby providing a period of greater chick survival. These are research topics for the future.

The 'nationally vulnerable' wrybill, one of three species monitored during the field experiments

The obvious question people might ask is how this method is any better than existing lethal control methods? The answer is that lethal methods cannot always be applied everywhere, especially overseas where problem predators might be native and protected. Also, it is common sense for New Zealand to develop an array of methods to protect vulnerable wildlife, because (1) predators soon learn to avoid single methods that are repeated over and over, and (2) different methods suit different circumstances. For example, the unrewarding cue method could be applied during vulnerable periods, such as breeding seasons or during translocations. Also, areas that are prone to rapid re-invasion by predators are more suited to the method described here because it does not involve removing animals.

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Public participation required for the broad-scale eradication of electric ants from Queensland

Electric ants (*Wasmannia auropunctata*) were first detected in the Cairns area in northern Queensland in May 2006, near to a World Heritage-listed rainforest. This was the first record of an established incursion of this species in Australia, whose native range is South and Central America. The electric ant is considered by the Invasive Species Specialist Group of the International Union for Conservation of Nature to be one of the world's worst invasive species. Since 2006 the Queensland Department of Agriculture and Fisheries (DAF) has been detecting and removing infestations with the aim of total eradication.

The potted-plant trade is thought to be the pathway of the initial incursion and subsequent movement of electric ants around the Cairns area. Detections of localised infestations have been made by public reporting, sniffer dogs and lure surveys, and surveillance of green-waste disposal sites. The ant is only 1.5 mm long, so people usually only detect it when bitten. The goal of DAF is to have all known infestations eliminated by the end of 2018.

The next step will be to conduct additional surveillance to either detect surviving nests or to be confident that all infestations have been removed. Dean Anderson of Manaaki Whenua was engaged to work with Gary Morton of DAF to address the following three questions:

1. What is the most cost-effective allocation of resources to the four available surveillance techniques?
2. Given no further detections, when can we can be 95% confident that eradication has been successful?
3. What is the approximate cost of surveillance to confirm success?

Dean developed a spatially explicit surveillance-data model to quantify the probability of electric ant eradication given negative surveillance results. The model is applicable only when all known infestations have been destroyed and surveillance returns no detections. The total eradication area was 24 350 km^2, of which 14 442 km^2 was deemed to be at risk of infestation (Figure). The variation in risk of surviving nests across the control area was incorporated by creating a map that partitioned risk into non-, low, medium, high and extreme risk areas (Figure). The relative risk areas were defined based on land cover and use, and distance to locations of previous infestations. Waterways and forests were considered non-risk areas.

Eradication area about Cairns and the relative risk of ant presence
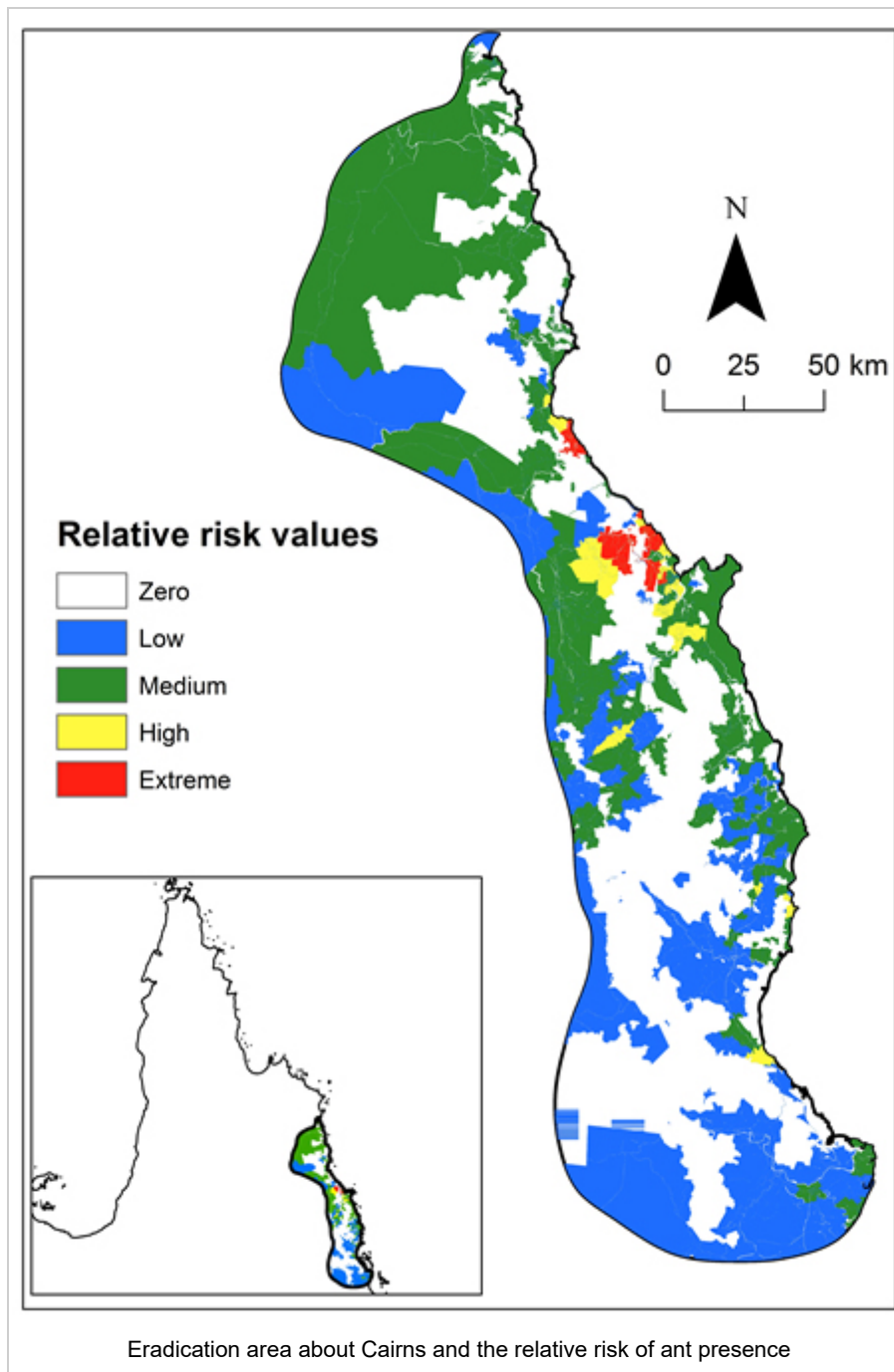
The time and cost to achieve a minimum 0.95 probability of eradication for 24 management strategies was assessed, and the one with the lowest cost was deemed to be the most cost effective. The first strategy reflected the current effort deployed by DAF, in which 30% of the total area was surveyed by the four surveillance methods. The probability of detecting an ant colony in a 100 m^2 area using sniffer dogs, lures, public reporting and green-waste surveillance was 0.9, 0.5, 0.12 and 0.03, respectively. While dogs and lures had relatively high probabilities of detection, they were only able to cover approximately 0.02% of the total area, whereas public reporting and green-waste surveillance covered more than 29% of the total area. The current DAF strategy required 7 years of surveillance with a field team of nine individuals, and had a total cost of AUS$ 9.9 million.

Although sniffer dogs and lure surveys had relatively high probabilities of detecting ants, increasing the area covered by these methods did not decrease the time to successful eradication and increased the overall cost. The most cost-effective strategy retained the current investment in sniffer dog and lure surveys, but increased the number and visiting frequency of green-waste disposal surveillance sites, and also increased community engagement (i.e. seeking and responding to public reports of electric ants). This modification increased the probabilities of detection of public reporting and green-waste surveillance to 0.35 and 0.11, respectively. The annual catchment area covered by green-waste surveillance increased from 100 894 ha (7% of the total area) to 879 219 ha (61% of the total area). Using this strategy, and assuming no further detections, eradication success could be declared in 4 years with a total cost of AUS$6,844 million, or a 31% reduction in total cost of the current strategy.

A sniffer dog seeking electric ants

This analysis clearly shows that any broad-scale eradication effort will require surveillance techniques that annually cover very large areas. In this case, taking advantage of public participation and non-specialised surveillance techniques (i.e. searching green-waste disposal sites) proved critical for detecting infestations and confirming eradication success. The highly sensitive techniques of sniffer dogs and lure surveys are not to be dismissed, but should be reserved for the surveillance of high- and extreme-risk areas.

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