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In this issue

Outcomes of predator control

Cover photo: Kākā, photo by Neil Fitzgerald

Editorial: Predator freedom – then what?

In 1989 a rather strange but charming film, *Field of Dreams*, was released in which Kevin Costner plays a farmer who builds a baseball diamond in the middle of one of his corn fields. He does this because a mysterious voice tells him, 'If you build it, he will come' ('he' being an old baseball player). Some time later the film's catchphrase morphed into an ecological concept – the Field of Dreams Hypothesis – which suggests that if a suitable habitat can be created, species will colonise it and function will be restored.

Fast forward to today and New Zealand's ambitious efforts to rid the country of the most harmful small predatory mammals by 2050. This initiative is largely based on the assumption that, in the absence of those predators, native species will thrive once more and be able to recolonise much of their previous ranges. But will they? Is predator freedom enough, or are there other factors that we will need to manage for our biodiversity dreams to be realised? In this issue of *Kararehe Kino* we highlight research into the importance of habitat at both local and landscape scales, and whether the ecological outcomes from our existing predator-free sanctuaries can guide our restoration management into the future.

Our first article describes how Rachelle Binny and a large group of collaborators compared the biodiversity outcomes from 16 ecosanctuaries across New Zealand that exemplify a range of predator control regimes. Their findings provide vital guidance on and understanding of where and how much control effort needs to be invested and what else we need to do to maximise the gains from that effort. We then have two accounts of how pest control and habitat characteristics can interact to influence the recovery of populations of iconic native species. In the first, Jo Carpenter considers the factors that prevent kererū populations returning to historical numbers, when flocks were reported to have obscured the sun. Then Corinne Watts and colleagues describe how the physical characteristics of a habitat (dense, regenerating gorse) can act to protect the rare Mahoenui giant wētā from predation. Ironically, as this pest plant matures and the habitat becomes more dominated by native vegetation, wētā may become both less protected and more difficult to detect by standard surveys. Corinne goes on to describe a novel survey method that holds promise for detecting wētā under such conditions.

Our next articles expand the perspective on habitat by considering how landscapes beyond sanctuaries can support the expansion of native bird populations. Olivia Burge investigates how the characteristics of the sanctuaries themselves and the surrounding landscapes can influence the chances of establishing new populations, and John Innes, Neil Fitzgerald, and a suite of collaborators look at how understanding of the movement traits of forest birds can help conserve and restore their populations across landscapes. Restoration-friendly landscapes will need suitable, predator-free habitat patches spaced at distances no greater than the maximum gap-crossing abilities of the bird species we hope to restore.

Neil also describes an early-stage project that is investigating kākā movements across the landscape. Initial data show that the birds can travel hundreds of kilometres from their Waikato home and traverse much of the upper North Island. In a sister project, Anne Schlesselmann and colleagues are considering how our management of threatened birds that breed on braided riverbeds needs to take a wider perspective than just managing predation at nest sites. Focusing on South Island pied oystercatchers and combining traditional breeding studies with state-of-the-art tracking technologies, they hope to build a more complete picture of where the birds travel and what they do outside of the breeding season to better guide their long-term management throughout their range.

Our final article, by Grant Norbury, describes how predators' perception of the landscape itself can be modified to protect native birds. Grant, working with colleagues from Sydney University, saturated the environment surrounding ground-nesting bird colonies with bird scent cues. Predators appear to quickly learn that scents don't necessarily indicate the presence of potential prey and effectively give up on them as a food source, leading to increased survival of the real birds and their nest contents.

Two themes are apparent throughout all the articles in this issue of *Kararehe Kino*. The first is that we probably need to think beyond just the removal of predators if we want to ensure the successful recovery of our native birds and other wildlife across New Zealand's landscapes. The second, exemplified by all the research described here, is that collaboration between researchers, management agencies, and other organisations is vital in supporting the research that will guide and underpin successful conservation management.

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Biodiversity outcomes in ecosanctuaries

As New Zealand strives to become predator free, ecological restorations ('ecosanctuaries') offer a glimpse into the future for native species if pests are successfully eradicated from the mainland. Over 80 ecosanctuaries, implementing multi-species pest mammal control for ecosystem recovery objectives, now exist across New Zealand's mainland and offshore islands. While individual projects have reported local predator control successes, so far their collective contribution to the restoration of native biodiversity has remained unclear.

Researchers from Manaaki Whenua – Landcare Research (MWLR) Rachelle Binny, John Innes, Andrea Byrom (New Zealand's Biological Heritage National Science Challenge), Neil Fitzgerald, Robbie Price and Roger Pech recently joined forces with researchers at the Department of Conservation (DOC), University of Canterbury, and Te Pūnaha Matatini to undertake a national meta-analysis (a technique that combines the results of several independent studies to answer big questions) of ecosanctuaries and their biodiversity outcomes. Over the past 17 years MWLR has run annual ecosanctuary workshops to facilitate contact between practitioners and act as a conduit for science into the national ecosanctuary network. The relationships established through these meetings laid the foundations for a data-sharing collaboration among 27 ecosanctuaries, including projects led by community trusts, regional councils, and DOC, who contributed close to 80 biodiversity data sets surveying hundreds of species for this national meta-analysis.

National meta-analysis

By combining data across a large number of projects, the team were able to compare the broad biodiversity trends occurring under five major regimes of pest control on New Zealand's mainland: (1) ring-fenced ecosanctuaries, where all small mammal pests (typically except mice) have been eradicated; (2) peninsula-fenced ecosanctuaries that achieve initial eradication then must protect against reincursions via the fence ends; (3) unfenced mainland islands where pest numbers are suppressed to varying degrees; (4) large-scale aerial possum-focused control (e.g. using 1080 toxin); and (5) large-scale ground-based possum-focused control (e.g. trapping and/or poisoning). The first three regimes are intensive and costly approaches to pest control and typically cover small areas between 25 ha and 3400 ha. The fourth and fifth regimes are less intensive but can cover much larger areas over 10,000 ha.

The meta-analysis used 447 biodiversity response measures (e.g. bird, invertebrate or seedling counts) from 16 ecosanctuaries: four ring-fenced, three peninsula-fenced, and nine unfenced mainland islands. From each response measure an 'effect size' was calculated for each year since the start of intensive multi-species pest control, up to a maximum of 20 years. This effect size measures the size of biodiversity benefit from pest control relative to doing no control. A total of 3543 effect sizes were combined in order to show the overall biodiversity benefit across multiple projects.

Do native flora and fauna benefit from control?

The team found strong evidence of the long-term benefits of pest control for native birds, invertebrates, and vegetation in all five regimes (Figure 1). The greatest benefits were found in fenced ecosanctuaries where pests had been eradicated. Under regimes where pests were suppressed, ecosanctuaries conferred greater benefits for birds and vegetation, albeit over a smaller management area, than did large-scale, possum-focused control regimes. In all ecosanctuary types, bird populations recovered most rapidly over the first 5 years of sustained pest control. After this time the effect sizes levelled off in unfenced mainland islands but continued to grow each year in fenced ecosanctuaries.

Deeply endemic bird species (those unique to New Zealand and have evolved here longest) are particularly vulnerable to pests because of traits such as flightlessness, ground nesting, and highly specialised diet. The team compared outcomes for deep endemic bird species (e.g. kiwi, hihi, kōkako) with more recent native species (species whose ancestors arrived in New Zealand more recently, but are also found elsewhere in the world, such as silvereye) and with introduced species (e.g. chaffinch). Deep endemics had most to gain from pest control, with complete eradication or sustained suppression of pests to very low levels providing the best outcomes. There were smaller or no benefits for recent natives, which are generally less sensitive to pests. After about 7 years of being pest-free, deep endemics were abundant enough to out-compete exotic bird species, and populations of the latter typically declined.

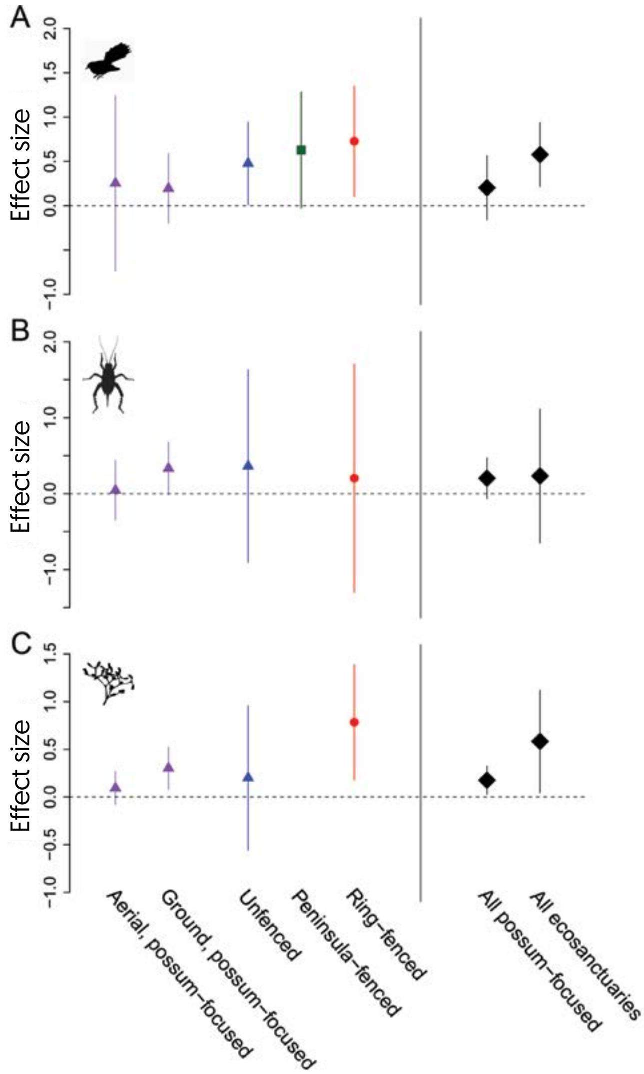

Figure 1: Biodiversity benefits in ecosanctuaries are generally greater than for large-scale possum-focused pest control. The graph shows mean effect size estimates and 95% CIs for (A) native birds (up to 4 years of control), (B) invertebrates (up to 6 years of control), and (C) mammal-sensitive vegetation (up to 11 years of control), under five regimes. When this effect size is a positive number it indicates a benefit from pest control, an effect size of zero indicates pest control is having no effect, and a negative effect size indicates a negative response to pest control. The dashed black line indicates no effect of pest control. CIs intersecting zero indicate no statistically significant difference from a zero effect.

Results within invertebrate communities were more of a mixed bag. Pest control benefited some endemic invertebrates such as wētā, while other invertebrate groups, such as beetles, declined. These declines might be due to increased predation by recovering bird populations or by non-targeted pest species such as mice, which are frequently found at higher densities in intensively pest-managed projects.

For native vegetation, the benefits of pest control were mainly found in species that are sensitive to small mammals; for example, those that suffer over-browsing of foliage by possums or seed damage by ship rats. As plant communities establish and progress through successional stages, their changing structure promotes the survival of different species and ecosystem services (i.e. the benefits of healthy ecosystems, such as pollination or soil formation). Restoration of vegetation is therefore a fundamental building block for ecosystem recovery, and the enhancement of vegetation within ecosanctuaries will also be contributing to the benefits found in bird and invertebrate communities. Richness (the number of species present) of native bird species was highest in fenced ecosanctuaries, while projects with large components of human-modified open-country habitat favoured exotic bird species.

Knowledge gaps

The review revealed some important knowledge gaps in ecosanctuary monitoring. Most long-term monitoring studies were of bird populations, while other taxa were under-represented. In particular, further monitoring is needed to clarify outcomes for frogs and lizards. These species are particularly vulnerable to predation by house mice, and other studies have suggested that lizards may only benefit from pest control if low mouse densities are achieved. This has important implications, particularly for fenced ecosanctuaries where mouse densities are typically high. Where invertebrate, lizard, and vegetation monitoring had been done, it was often only within the pest-managed area or was started after pest control began. This meant changes in managed populations couldn't be benchmarked against changes in unmanaged areas. The effects of other mammalian predators, including feral cats and hedgehogs, within unfenced mainland islands couldn't be measured due to a lack of standardised monitoring.

Management implications

The findings from this study provide extensive new evidence that invasive pest control is an effective, often essential, approach to restoration and that eradication is the most effective regime for achieving biodiversity benefits. This is important for confirming whether conservation objectives are being achieved, and for justifying the use of resources or approaches to pest management, both within individual projects and at national level. Tracking the trajectories of restoration over time also informs decisions on when active management (e.g. translocations, plantings or pest control) should be maintained, intensified or scaled back. The study revealed how much pest control is needed to benefit different taxa by assessing the relationship between the density of ship rats that remained in ecosanctuaries after pest control with the outcomes that were achieved for endemics, recent natives, and introduced bird species. In general, a threshold of 15% post-control ship-rat tracking index (an average over the season immediately prior to the biodiversity survey) should be achieved in order to observe a benefit to bird species, and benefits increase as indices approach 0%. However, this threshold will differ for specific bird species, and this is a focus of current work by the team.

As New Zealand works towards becoming predator free by 2050, an understanding of the relative benefits of pest eradication versus suppression will be critical for designing an effective national strategy for the restoration on New Zealand's mainland. While new approaches capable of achieving and maintaining pest eradication at very large spatial scales are developed, the results of this study inform decisions about where and when we should aim for eradication to safeguard New Zealand's most vulnerable species and where less vulnerable species can be sufficiently protected under suppression-focused regimes, which are less intensive but can cover much larger areas.

This work was funded by the Ministry of Business, Innovation and Employment. The team is grateful to the 27 ecosanctuaries for sharing data for these analyses, and to the wider ecosanctuary community for their support of this work; full acknowledgements are provided in the papers noted at the end of this issue of *Kararehe Kino*.

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Solving the kererū puzzle: predator freedom is only part of the answer

Mātauranga Māori from Tūhoe Tuawhenua elders records kererū occurring in flocks so large they eclipsed the sun (Lyver et al. 2008). But over the past 200 years, numbers have declined rapidly due to habitat loss and predation by introduced mammals. To what extent are deforestation and predation by introduced mammals still affecting kererū today? A team of researchers, led by Jo Carpenter, gathered and analysed data from three different sources to find out.

First, Anne Schlesselmann collated data from studies that had observed kererū nests. Across 397 nests monitored, most failed due to predation by ship rats, possums, or stoats. Kererū only lay one egg per clutch, typically on a precarious platform constructed of loosely woven twigs. Most eggs never had a chance to hatch before they were eaten by ship rats or possums. However, intensive pest control made a difference: at sites where both ship rats and possums were controlled to low numbers, kererū nesting success was substantially improved compared to sites with either no pest control, or where only rats or possums were controlled.

Second, Rachelle Binny analysed a data set of kererū observations collected from 11 sanctuary sites to test the hypothesis that fenced sanctuaries, such as Maungatautari or Orokonui, which have eradicated most pests, would result in increased numbers of kererū being observed. Here the researchers found a puzzle: despite the fact they had good evidence that mammalian predators reduced kererū nesting success, and that pest control improved it, kererū numbers did not always increase in predator-free sanctuaries. Although kererū increased at a few sites, the sanctuaries that had eradicated rats, possums, and stoats did not have obviously better outcomes for kererū than unfenced sanctuaries. It seems that a second factor prevents kererū recovery at some sites after pests have been removed. One possibility is that some sanctuaries only encompass small areas of forest and therefore do not have enough habitat to sustain high numbers of kererū even though pests are controlled. The research demonstrates how important food and forest are to kererū, as well as whether there are pests. Controlling pests in areas with very little suitable kererū habitat is therefore unlikely to result in more kererū.

Third, the team wanted to get a nationwide picture of the factors that influence where kererū are found. Susan Walker analysed the 1969–1979 and 1999–2004 results from the *Bird Atlas of New Zealand* to see how kererū distribution related to environmental factors such as road density and forest cover. The *Bird Atlas* collated data collected by birders and citizen scientists over several years in an effort to sample the whole of the country. By comparing records from the 1970s with the later records, the team showed that kererū distribution was closely related to the amount of intact forest available, although kererū also occurred in urban areas, where the wide range of plants probably provides them with more food than in unforested landscapes. The analyses also showed that kererū declined between the two time periods in the South Island, but not in the North Island. The reasons underlying this were unclear, but it could be that kererū manage to hang on in the North Island's diverse podocarp forests, where pests usually maintain more constant levels, but struggle to cope with the short-lived, yet extreme, irruptions of ship rats and stoats that occur in South Island beech forests. Currently, keen birders are recording bird sightings across the country for the 2019–2024 *Bird Atlas of New Zealand*. The results from that effort will be important in understanding whether kererū are still declining in parts of New Zealand.

Overall, the results showed that predation by mammalian pests is the primary issue for kererū within large, intact, forests. Controlling possums and ship rats to low densities in these places is likely to increase kererū nesting success and to result in increased numbers of kererū. However, in areas that have suffered significant loss of forest, such as Canterbury and Hawke's Bay, forest area is likely to be the biggest factor preventing kererū recovery. Kererū are one of the world's largest pigeons, so they need a diverse range of high-quality food throughout the year to thrive. A combination of both intensive pest control and plentiful kererū kai will be needed before we can begin to restore the massive flocks of the past.

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Actions towards the recovery of a gentle giant – the Mahoenui giant wētā

The arboreal Mahoenui giant wētā (MGW) once lived in the epiphytes of tall tawa forests of the King Country and Waikato and is considered taonga by the local iwi. Predation pressure from introduced mammals means that the Mahoenui Giant Wētā Scientific Reserve (MGWSR), near Mahoenui in the King Country, now contains the only remaining natural population of MGW. The giant wētā appear to have survived at the reserve because the spiky introduced woody shrub, gorse, has provided protection from mammal predators. In addition, feral goats and cattle browse the gorse, creating a refuge for MGW in the dense foliage. Since the 1980s MGW have been translocated to a number of other locations but have only established at two sites (Mahurangi Island and Warrenheip) and are establishing at one site (Maungatautari) where mammals are in low densities or absent. However, there is a level of uncertainty about whether these translocated populations can persist.

MGW have been monitored annually at the MGWSR to assess population trends since 2004. The MGW population appeared stable until 2012, when fewer were detected and the search time required to find MGW increased. This decline has continued, and in 2016, with concerns being raised for the long-term survival of MGW at the MGWSR, a review of MGW management led to the formation of the DOC MGW Advisory Group, which triggered a collaborative research project to investigate pressures on MGW in the reserve. This research was led by DOC with Victoria University of Wellington and Manaaki Whenua – Landcare Research (MWLR).

Mahoenui giant wētā.

As part of the research project, survival rates from radio-tracking studies in native and gorse vegetation revealed that MGW inhabiting native vegetation were nine times more likely to be preyed on than those in gorse. MGW are primarily vulnerable to predation by rats, and the dense, young gorse that provides protection from this pressure is becoming less common due to natural vegetation succession processes, fewer goats browsing on the gorse, and the impact of gorse mites. This habitat change continues despite browsing from some goats and cattle, which is encouraged in the MGWSR to try to maintain the gorse dominance and preferred gorse habitat.

In addition to radiotelemetry studies, four mammal pest species (ship rat, mouse, feral cat, and possum) were trapped at MGWSR and their stomach contents analysed to identify potential predators of the MGW. Wētā were the most common invertebrate eaten by ship rats but, using conventional techniques based on morphology, only a few remains were able to be identified to species level. Wētā were also found in some mouse stomachs, while possums consumed wētā less often. The development of novel DNA barcoding techniques has the potential to identify invertebrate prey from mammalian stomach contents. We used these techniques to identify prey fragments extracted from ship rat stomachs as cave wētā (99% accuracy) and possibly MGW (73% sequence identity).

Maintaining suitable gorse habitat within the MGWSR to protect MGW is not feasible due to the practical and legislative difficulty of managing a goat herd and the presence of gorse mites. Gorse habitat is also vulnerable to fire, which is exacerbated by the effects of climate change. Instead of working to maintain gorse to protect MGW from predation, DOC, in consultation with local iwi, began

Two inked tracking cards (with adult MGW prints present) are rolled around the inside of the tunnel.

Round tunnel (length 50 cm, diameter 8 cm) tested for detecting Mahoenui giant wētā in vegetation at Warrenheip.

rodent control in 2019, and in 2020 a network of traps was established to target mustelids, hedgehogs, and feral cats. Predator abundances are monitored using a network of tracking tunnels and game cameras. In addition, an iwi-led exploration of the possibility of funding a predator-proof fence is under consideration as a precautionary principle. MGW have a 2–3-year lifecycle, so any positive effects of the pest control on MGW abundance would most likely become evident after several generations (i.e. 5–6 years later). It is therefore imperative that the MGW population be monitored using an effective technique to enable the effectiveness of this new management regime to be evaluated.

The current method of MGW monitoring involves searching vegetation in plots. However, as the young dense gorse becomes tall 'old man' gorse and eventually succeeds to native vegetation, searching becomes ineffective at detecting MGW. In addition, large areas of the MGWSR are now already dominated by native vegetation and cannot be surveyed for this reason.

Footprint tracking tunnels are routinely used in New Zealand to both detect and monitor populations of small mammals, but they also record other animals, including insects. Wētā leave distinctive and easily recognised footprints on tracking tunnel cards, and these are now routinely used to monitor wētā, particularly giant wētā with their larger footprints. In 2019 a small trial of 'round' tracking tunnels (originally developed for monitoring mice up trees) to detect MGW in native regenerating vegetation was instigated at Warrenheip, a 16 ha forested, pest-fenced sanctuary near Karapiro, Waikato, with a translocated population of MGW. The round tracking tunnels were successful (mean tracking rate = 54%) for detecting adult MGW within native forest where vegetation is greater than 2.5 m in height. However, juvenile MGW footprints were difficult to distinguish from other wētā species present (e.g. Auckland tree wētā). Round tracking tunnels are currently being trialled by DOC to monitor MGW in gorse and native vegetation at the MGWSR and potentially provide a robust method to detect MGW in native vegetation and more efficiently in gorse.

Lastly, in addition to the actions outlined above, DOC has recently facilitated a captive rearing programme for MGW at Otorohanga Kiwi House. If successful, the captive rearing programme will breed MGW to enhance existing translocated populations and potentially provide founders for the establishment of further wild populations.

The recent research carried out has greatly increased our knowledge of MGW. By combining research with management actions, we anticipate an increase in MGW population densities in the MGWSR and that MGW will be sustained in the long term, both there and at the translocated population sites.

This research was led by DOC in collaboration with MWLR (funded by DOC and Strategic Science Investment funding from the Ministry of Business, Innovation and Employment) and Victoria University of Wellington.

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Going beyond PF2050: the importance of habitat

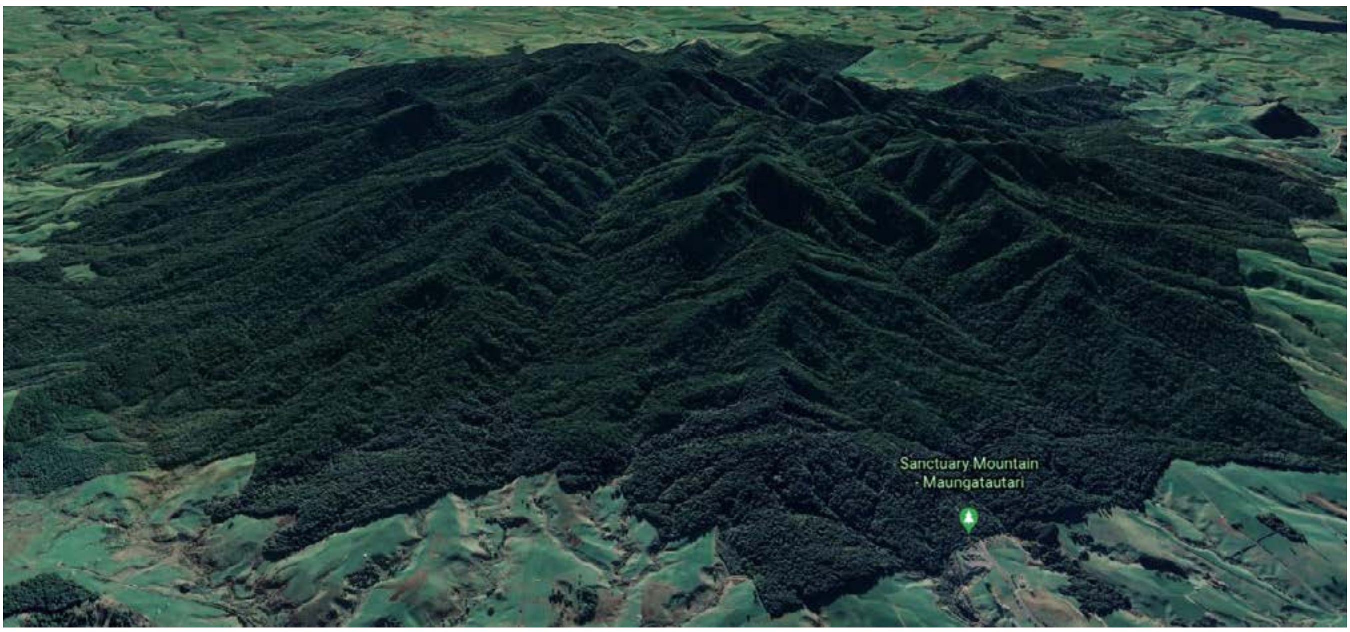
Fenced ecosanctuaries are expensive to establish but allow persistence of birds that are predation-sensitive. Once predators are removed from a fenced ecosanctuary they find it very difficult to reinvade because the specialised fencing keeps them out.

Predator Free 2050 (PF2050) is an ambitious project to eradicate key mammalian pest predators, such as stoats and possums, in New Zealand. These predators have been identified as a key threat both to native bird populations where they still exist and to their recovery elsewhere.

We undertook a scenario analysis as follows: What if PF2050 is successful? Will fenced ecosanctuaries act as 'arks' from which birds will spill into the newly predator-free landscape? Or does the typical location of fenced ecosanctuaries (near urban areas, often surrounded by grassland, urban areas or water) mean that forest birds will either be unable to disperse, or if driven to disperse, will end up in low-quality habitat?

We were able to examine future scenarios by comparing ring-fenced ecosanctuaries to mainland island ecosanctuaries that are unfenced and that we expected to be closer to (or within) larger tracts of forest. We also compared both ring-fenced and unfenced sanctuaries to peninsula-fenced ecosanctuaries, which are cheaper to fence because they use water on several sides instead of a full perimeter fence, but are likely to have less habitat for forest birds, because of all the water.

Figure 1. Map of fenced ecosanctuaries (green – includes both ring- and peninsula -fenced sites) and unfenced 'mainland islands' where extensive predator control is undertaken (orange buffers are mainland islands included in this research; pink buffers are those that are not). Buffers are 50 km, which is the radius we considered for birds not limited to forest.



A view of Maungatautari, the biggest fenced ecosanctuary in New Zealand, and the mainly grassland areas that surround it.

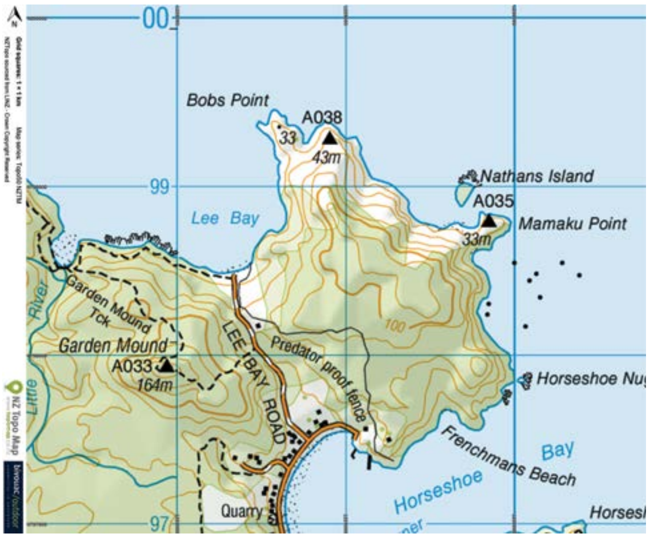
We found low levels of high-quality habitat around many fenced ecosanctuaries. There was no high-quality habitat at all around some ecosanctuaries for several bird species, particularly for 'strongly gap-limited species' – birds that cannot cross gaps in habitat (such as paddocks) if they are larger than around 1 km. This means that even if predators are removed from landscapes around fenced ecosanctuaries, these landscapes are still not really 'bird-friendly' in terms of habitat.

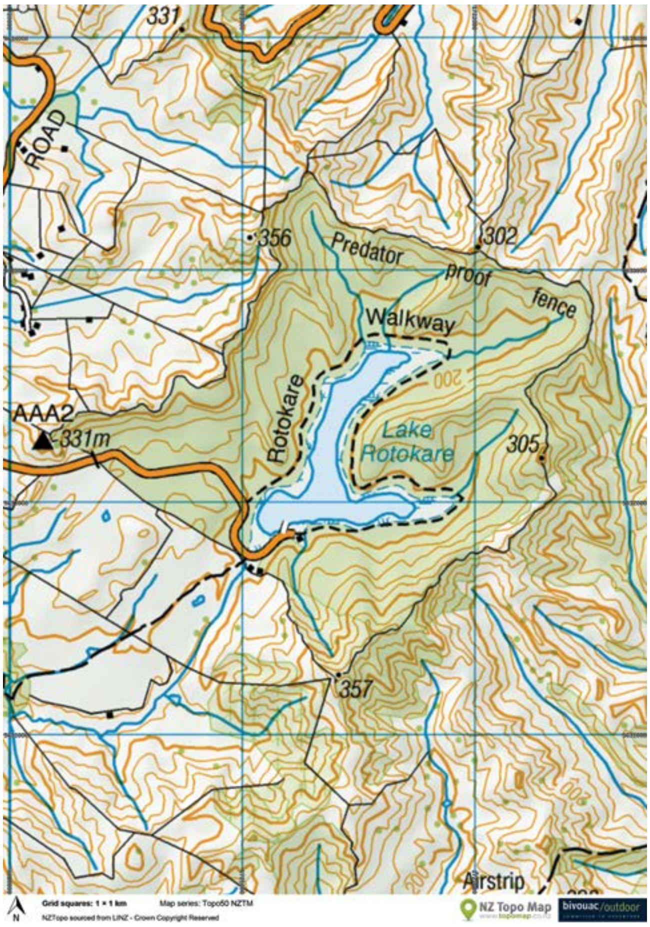
Ecosanctuaries on peninsulas (with reduced fencing costs) tended to have relatively less high-quality habitat than unfenced ecosanctuaries and ring-fenced sites. We found that the habitat around peninsular ecosanctuaries was also more fragmented than in unfenced ecosanctuaries and ring-fenced sites. Therefore, the reduced fencing costs at peninsular sites need to be balanced against them having less total high-quality habitat, on average, beyond the ecosanctuary.

But it's not all bad news. There are opportunities for restoring landscapes around fenced ecosanctuaries, particularly for mobile birds (that can fly around in non-forest landscapes); for example, mānuka/kānuka areas that could revert over time to taller, more species-rich native forest and could be further enhanced by strategic plantings. There are also opportunities for planting food trees on farms to provide extra resources for birds during leaner times of the year. However, the restoration of forest bird populations is unlikely to be achievable in the landscapes around many fenced ecosanctuaries in the short term as there is just not enough forest in our agricultural landscapes to support them.

More generally, decisions about where to locate ecosanctuaries need to consider both the ecosystems within and surrounding the site, and whether habitat around the site is within travelling distance of the site, for the birds of interest. We are aware that Brook-Waimārama, a relatively recently established fenced ecosanctuary, took these factors into account when planning their sanctuary, which is a great start.

Most ecosanctuaries have been founded by local people in the landscapes that have meaning for them, which means they that are often near urban areas and further from large tracts of forest. However, there would be conservation benefits for ecosanctuaries to be located with regard for regional and national conservation strategies, including a consideration of connectivity. Forest birds such as robins, kākā, kākāriki, and tūī are known to leave safe, pest-managed ecosanctuary sites, and so both habitat establishment and mammal pest control are already needed outside nearly all existing ecosanctuaries. Increased planting of new native forests will be needed in most of lowland New Zealand for many years to come, even when PF2050 is successful, to allow native birds to expand their distributions beyond current sanctuaries.





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Forest bird movements and sociality

New Zealand's original forested landscape has been greatly fragmented since human arrival, so that now only highly mobile birds can move freely across deforested, mainly pastoral, lowland landscapes. Free movement across landscapes is desirable because it enables birds to find mates and new habitat, and to recolonise isolated sites from which a species may have disappeared. However, free movement can also be disadvantageous for birds. Special endemic forest birds such as North Island (NI) kōkako, kākā, kākāriki and toutouwai/robins are abundant on the mainland only in small ecosanctuaries where mammal predators are highly controlled. If dispersing birds move from such safe sites to surrounding unmanaged forests, they are not likely to survive – the 'source–sink' paradigm.

Connectivity between forests is therefore a double-edged sword. It is helpful when all the connected habitats are safe for the species concerned, but unhelpful if one or more destination sites are unsafe.

Manaaki Whenua – Landcare Research (MWLR) researchers John Innes and Neil Fitzgerald worked with colleagues from the Museum of New Zealand Te Papa Tongarewa, Massey University, and Parker Conservation to review what is known about forest bird movement behaviour. They searched publications and talked to experts to collate all available accounts of how far forest birds have been observed to cross pasture and water gaps between forests, and to collate accounts of the diets and social systems of birds that might explain how and where they move.

One early conclusion of the researchers is that robust information about the movement of most forest birds is scarce, and gap-crossing distances are unknown for some species. Observed movements may be of exceptional individuals in unusual circumstances and may not apply to most birds in a population. Readers should note that the following accounts are generally based on few observations and should be regarded as provisional until more observations are made.

Using current data, they classed four species (NI kōkako, pōpokatea/whitehead, tīeke/South Island (SI) saddleback and NI brown kiwi as strongly gap-limited, being not known to cross water or pasture gaps between forests larger than 500 m. A further eight species (mohua/yellowhead, titipounamu/rifleman, pīpipi/brown creeper, weka, tīeke/NI saddleback, kakaruwai/SI robin, toutouwai / NI robin and miromiro/tomtit) are moderately gap-limited, not observed to cross 5 km gaps.

The remaining 16 forest birds range widely and readily across forest gaps larger than 5 km over water or pasture.

North Island kōkako is one of only a few New Zealand forest birds unlikely to cross a 500 m gap between adjacent forests.

This 'weakly gap-limited' category includes nectar-, fruit-, and seed-eating species such as kākā, kākāriki, kererū, tūī and korimako/bellbirds. These species are known to be wide-ranging, presumably to find seasonal foods based on flowering and fruiting patterns that are variable across landscapes. This category of bird also includes predatory birds such as kāhu/harrier, kārearea/falcon, and ruru/morepork that hunt over large areas, as well as pīpīwharauroa / shining cuckoo and koekoeā / long-tailed cuckoo, which migrate 5000-plus km annually from Pacific islands to breed in New Zealand forests.

Most insectivores defend territories year-round, although some species, such as pōpokatea/whitehead, mohua/yellowhead, tauhou/silvereye, red-crowned kākārirki and hihi/stitchbird are territorial in the breeding season but more mobile outside it, sometimes forming mixed-species flocks that year-round territorial birds such as pīwakawaka/fantails and riroriro/grey warblers may join. Winter flocks may offer protection from predators, or extra food because flocks disturb prey or are more efficient at finding food than scattered individuals.

The fruit- and nectar-feeders and carnivores that were noted above to be good gap-crossers tend to defend only small spaces around the nest in the breeding season, but otherwise overlap feeding sites with others of the same species, and they range widely in the non-breeding season. These mobile species, such as kererū and kākāriki, historically formed huge flocks that are absent today. It is now fascinating to contemplate the behaviours and ecological roles of such flocks, and they deserve research.

Significance for conservation

Although some forest birds are strongly gap-limited and so cannot move freely between remaining forest fragments, the researchers do not think this absence of connectivity is a critical problem yet for New Zealand conservation. This is because the main widespread factor that limits bird populations is safety from mammalian predators and the forest areas that can cost-effectively be made safe on the New Zealand mainland at the moment are quite small. A recent review of ecosanctuaries found that their average area was about 700 ha.

In fact, connectivity can be a disadvantage at a site if dispersing birds inadvertently depart safe, pest-controlled sites to travel to unsafe sites where pests are not controlled. In the longer term, if an ecosanctuary site such as Zealandia or Maungatautari becomes 'full' of birds, then it is desirable that adjacent habitat be made as safe as possible for the individuals dispersing over the fence.

A conundrum is that establishing new wildlife corridors by planting may take many years, so it is understandable that there are already many initiatives around New Zealand to establish such linkages. These include the North-West Wildlink, Forest Bridge Trust, and Eastern Bay Songbird projects around Auckland, and others between Pirongia and Maungatautari in the Waikato and between Taranaki mounga and New Plymouth in Taranaki.

Translocated birds face the same connectivity conundrum as untranslocated ones. Valuable translocated birds may disperse away from safe, pest-controlled areas in large, forested landscapes, and end up in adjacent sites with uncontrolled pest mammals and greater predation risk. Early in the period of population establishment it may be helpful if the site is *not* connected to adjacent unprotected places; later, when the population has grown, such connectivity may be valuable.

More research is needed on the movement of New Zealand forest birds, and improving technology (such as smaller transmitters) and tools (such as genetics) should assist this.

Ideally, pest-managed sites in New Zealand need to be large enough to accommodate bird dispersal. The few current estimates of such ideal areas are vastly larger (10,000–50,000 ha) than the current mean ecosanctuary area (c. 700 ha). The major current need is therefore for pest control tools that can operate at very large scale. However, in the long term we also need new wildlife corridors to increase habitat area in fragmented lowland landscapes, so that strongly gap-limited species can move safely between adjacent habitats.

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John Innes

Neil Fitzgerald (MWLR) and Peter Dilks (DOC) extract a NI kākā – a big mover across landscapes – from a mist-net near Hamilton, part of a collaborative study of kākā movements. Watching for other birds is Terry Greene (DOC).

Wandering Waikato kākā

Kākā are one of the largest, most iconic, and at times noisiest forest birds of New Zealand's three main islands, yet their movements around the landscape are not well known. Kākā (together with kea and kākāpo) belong to a family of parrots found only in New Zealand. Having no close relatives outside New Zealand, a large body size, and nesting in cavities are traits kākā share with the most predator-sensitive of our forest birds. Although forest loss has greatly reduced kākā habitat, their main contemporary threat is from stoats and, to a lesser degree, possums. Stoats not only kill chicks, but also females that cannot escape the nest cavity, and this can lead to male-biased populations, which may persist for decades, unable to breed and sliding towards local extinction. Kākā are most abundant on pest-free offshore islands such as Te Hauturu-o-Toi / Little Barrier Island and Kapiti Island, and in mainland ecosanctuaries such as the Waipapa Ecological Area at Pureora, but outside of these sites numbers are thought to be in general decline in both the North and South Islands. Understanding dispersal and seasonal movement of kākā beyond these areas is needed to develop more effective management prescriptions.

Kākā are usually associated with mature native forest and sites near their island strongholds, so highly modified rural Waikato is far from typical habitat. However, for many years during the winter non-breeding season, kākā have routinely visited sites near Hamilton and Morrinsville. Until recently the source of these birds has been a mystery. Before kākā were reintroduced to Maungatautari ecosanctuary in 2007 the nearest mainland breeding population was at Waipapa, 75 km south of Hamilton. Otherwise, offshore islands free of pest mammals, such as Little Barrier Island, Great Barrier Island, and Mayor Island / Tūhua are the nearest populations.

During September 2020 and July 2021 a team from MWLR and DOC fitted GPS and VHF tags to 25 kākā near Morrinsville and the outskirts of Hamilton. The VHF tags allow staff to track the birds on the ground for detailed observation of feeding and other behaviour. The solar-powered GPS tags send regular, accurate location data to the researchers, revealing movements over large scales and potentially long time periods. In the first year of the study GPS data were obtained from five tagged kākā for between 7 weeks and 6 months. This information showed they ranged over a few kilometres until October, when they began leaving the Waikato wintering sites and moved much larger distances, mostly north (Figure 1). Two kākā moved to Little Barrier and Great Barrier Island by early summer, and two more were last recorded at adjacent mainland sites. One of these birds travelled well over 1000 km – moving from Hamilton to Great Barrier Island, back to Hamilton, then to Little Barrier Island before returning to Hamilton – over a period of 19 weeks. Only one bird moved south from the capture location, spending summer near Maungatautari.

A kākā captured near Hamilton with a GPS/VHF backpack.

Emma Williams

Neil Fitzgerald fitting a GPS tag to a kākā captured near Hamilton.

Neil Fitzgerald

A GPS tag being fitted to a kākā captured near Hamilton.

Observation of the tagged birds showed that they spent a lot of time within dense tree canopies, cryptically resting or stripping bark to feed on sap. The low light conditions in these situations proved challenging for the solar-powered GPS tags, but the researchers hope modifications made to the tags deployed in 2021 will help to extend their life. Future work will also begin to unravel the possible drivers of these seasonal movements. Are they pre-breeding youngsters, or breeding adults between nestings? Of the tagged birds, 60% were juvenile and 72% female. In many other birds a greater proportion of females and young migrate, possibly due to competition for food. Is seasonal food availability a driver of kākā movement too?

These results indicate that the spillover of kākā from pest-free islands and mainland ecosanctuaries can extend hundreds of kilometres to places where they face diverse new predation and non-predation threats.

This study will continue for another 2 years. The team will follow all tagged kākā, study their feeding at both ends of their travel routes, and try to resolve whether any of these travelling birds attempt to breed at their northern destinations, from where (presumably) they were fledged.

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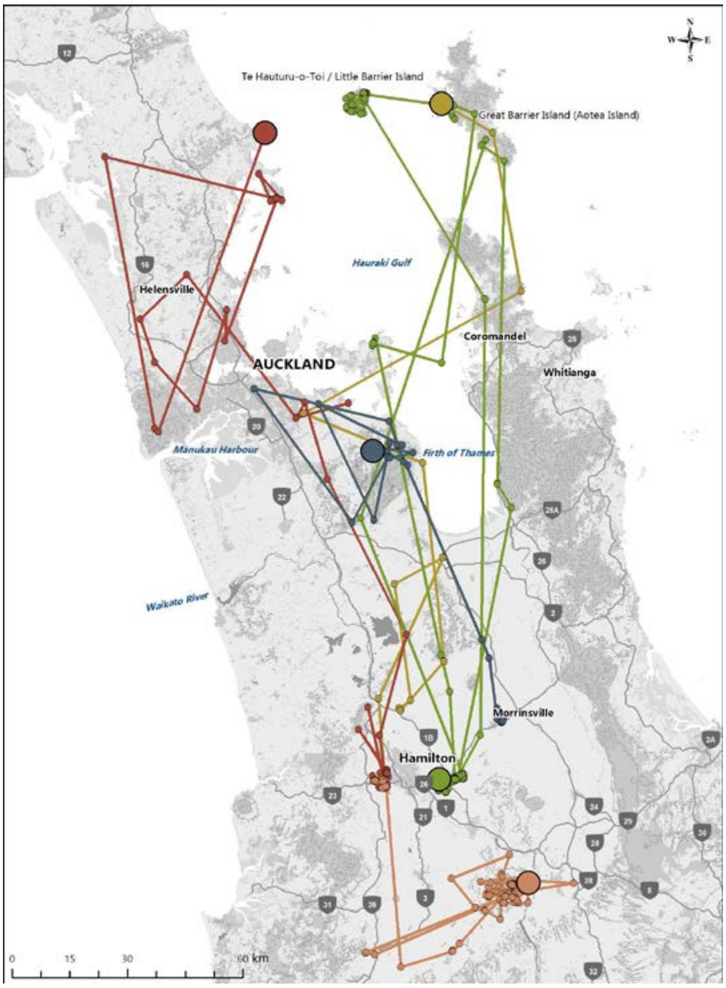

Figure 1. Long-distance movement of GPS-tagged North Island kākā captured around Hamilton between September 2020 and March 2021. Colours represent different birds. Logged locations are shown as small circles, and the last known location for each bird is a larger circle.

Getting it right: where and when is pest control needed to maximise the survival of migratory braided river species?

Measuring wing length of a chick to follow growth and assess time to fledging.

Every spring thousands of birds make their inland journey to their breeding grounds, and for the first time it is possible to follow some of them in real time. A multi-year research collaboration between Manaaki Whenua – Landcare Research (MWLR), DOC, and the Ornithological Society of New Zealand (OSNZ) is focusing on tōrea / SI pied oystercatcher, a striking black and white bird with stout, bright orange legs and a long bill. Over 60 of these handsome birds are carrying next-generation tracking devices that communicate via the cellphone network with researchers. This technology yields fascinating detailed insights and provides a pathway for better year-round protection for the birds.

Tōrea and other migratory native birds enjoy the coastal life from late summer and most of winter, but use the braided river and dryland ecosystems of the central South Island for breeding and raising their young before returning to the coast. Unique to New Zealand, all of these species are declining and classed as threatened. One of the main threats is introduced mammalian predators at their breeding grounds, even though most birds are only there for a few months each year. A major challenge for effective conservation management is to understand how population dynamics are linked to the myriad threats at different places and times, such as on migration routes and at wintering sites. To help understand these relationships, this research on tōrea is being used as a case study for other braided river birds. Crucially, the project demonstrates the potential for a national partnership between researchers, management agencies, citizen organisations, kaitiaki iwi, and landowners to inform the conservation of mobile species across New Zealand. As the birds move around and link sites, so must management.

Research led by MWLR aims to integrate tracking, band re-encounter/re-sighting data, and breeding, survival, and movement data in a spatial population model to determine the drivers of population dynamics. Such a population model will provide, for example, the pathway to assess how the major predator-management programmes being done by Environment Canterbury (ECan), Toitū Te Whenua Land Information New Zealand (LINZ), and DOC in breeding habitats contribute to national population outcomes of iconic braided river species. By using GPS tracking technology, the data gathered will also directly inform the aims of DOC's research partners in assessing the importance of flyways and wintering sites. In addition, this research closely aligns with the aims of OSNZ and many community groups to contribute to conservation management. Band re-sightings from citizen scientists are invaluable for contributing to better understanding of the survival and movements of individuals.

The MWLR research team kicked off the fieldwork in the upper Rangitata Valley last spring, where, for the past 6 years DOC have carried out landscape-scale predator control. During the breeding season (July–February), DOC staff have been using a mix of kill- and live traps to reduce mammalian and avian predators, with the aim of increasing the reproductive success of threatened migrant species. MWLR are using the Rangitata Valley as a site to understand reproductive success and survival across farmland and river habitat in breeding grounds with predator control in place. In the future, the project will expand to a site without predator control, to allow comparison.

The field team monitored more than 60 nests across farmland and riverbeds, with the results so far suggesting the effectiveness of predator control. Only five nests were lost to predators, and nest success was relatively high compared with prior research in areas without predator control.

Chicks leave the nest shortly after hatching and are very cryptic, so technology, in the form of tiny radio-transmitters, was used to locate broods regularly. In this way it was possible to locate dead chicks that otherwise would have been missed and closely track the growth of live chicks. Once chicks were larger than 300 g and almost able to fly, it was possible to attach a GPS tag to some of them. By tracking the first migrations and movements of these birds over time, it is possible to learn about dispersal between breeding sites. To understand survival across the annual cycle, a mix of old-school and new technology came into play. Coloured bands are cheaper than GPS transmitters but provide much coarser information. They allow an estimate of survival through re-sightings and provide information on some local movements, but not the flyways between sites, so 20 breeding adults were fitted with GPS transmitters to fill in gaps in our knowledge of movements and survival.

Importantly, the project was also looking at the relative predator densities in the Rangitata Valley using cameras. Although the number of predators removed through trapping is recorded each year, any remaining predators have the potential to inflict damage. With improvements in camera technology it is possible to detect the whole suite of mammals present, from species as large as cats to

GPS tags have already provided valuable insights into the timing of migration, duration, stop-overs, and flyways linking breeding and wintering sites throughout the year. In the long term they will also provide data on survival, particularly of fledglings.

those as small as hedgehogs. Early results have shown that hedgehogs, despite being the most commonly trapped animal, are still relatively abundant in farmland, requiring new tools to suppress populations to lower levels. By using indices of residual pest densities it is possible to work out how much pest control, and for which species, is needed to make a difference in outcomes for native birds. The next step for the MWLR-led component of this research is to expand the research into areas without predator control.

Complementary GPS tagging and banding by DOC and Birds NZ on wintering grounds has been done over the past autumn and winter months. Early results show some remarkable movements once birds have taken flight. Already, tracks indicate some key national northward and southward flyways, as well as the sheer extent of the North and South Island habitat network that supports wintering tōrea. In the future this information will enable better protection year-round and ensure population trends can be turned around.

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Fake clues: using misinformation about odour to protect rare bird species

Dr Grant Norbury preparing a camera trap, Tekapo

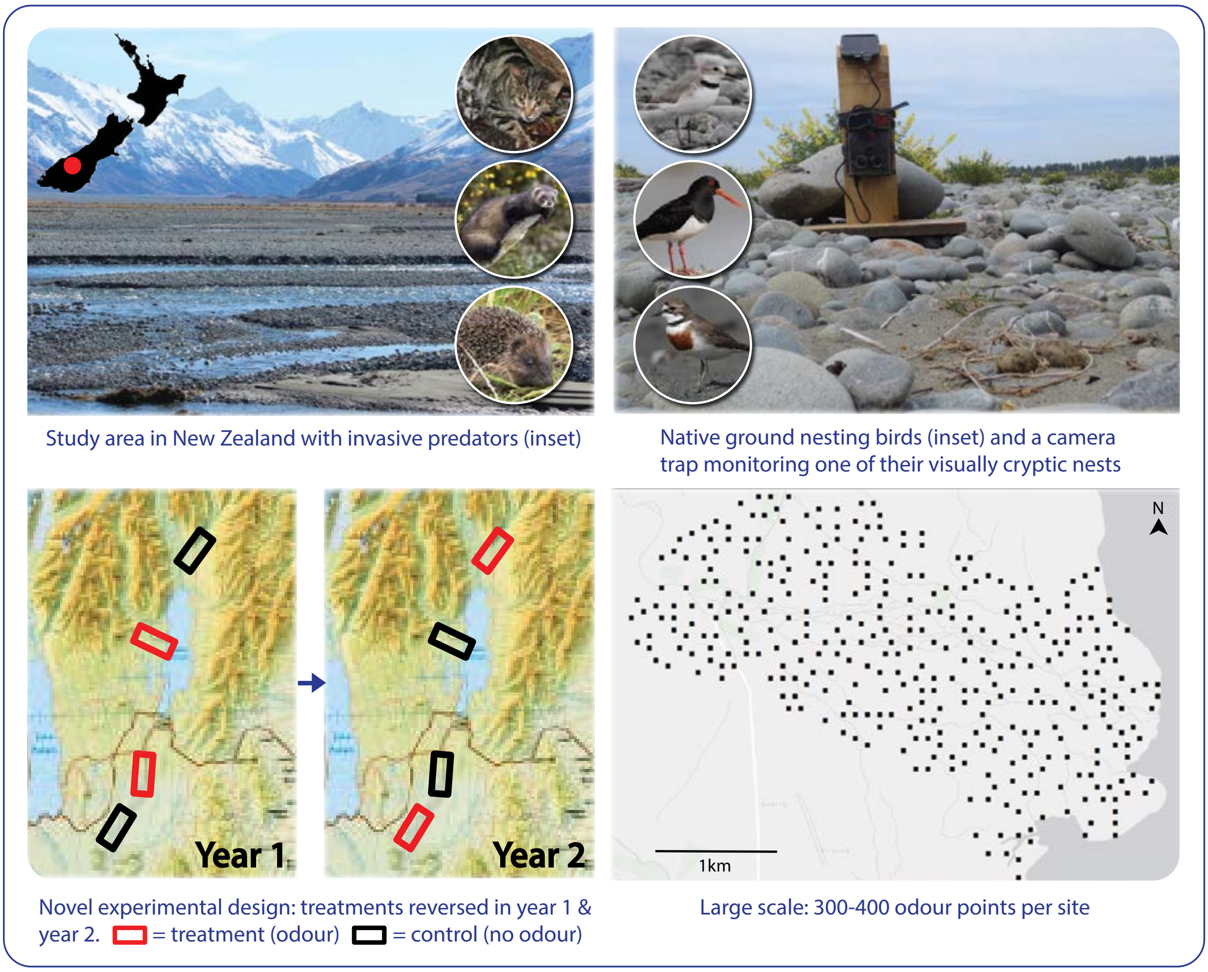
Photos show (top to bottom left) camera trap images of ferret, hedgehog and cat encountering odour pastes; (top to bottom right) the same species preying on bird eggs.

Mammalian predators frequently rely on smell as their main cue, enabling them to detect food from a distance. Smell is – usually – a reliable strategy for food location.

As part of long-running research into the behaviour of introduced mammalian predators in New Zealand and Australia, researchers from Manaaki Whenua – Landcare Research (MWLR) and the University of Sydney asked whether it might be possible to manipulate predator behaviour by using misinformation. Could we use unrewarded prey odour cues to fool predators and make them ignore real prey cues? If we could make predators less efficient at hunting, might we also make them miss real prey?

Over two nesting seasons the researchers tested the response of cats, ferrets, and hedgehogs to false odour cues at nesting sites for three shorebird species – banded dotterel (tūturiwhatu), wrybill (ngutu-parore) and SI pied oystercatcher (tōrea). These native bird species nest on the ground on braided rivers in Canterbury and are highly vulnerable to predators.

The researchers made odorous pastes from the carcasses and feathers of readily available birds – such as chickens, quail, and black-backed gulls – and tested whether repeated exposure to these odours would affect the predators' behaviours. They set out the pastes at 300 to 400 points across nesting sites every 3 days for 5 weeks before the birds arrived to nest, and for 8 weeks thereafter during the nesting season. Predators' behaviour was then compared to that at sites without paste. Camera traps were used to monitor predators' interest in the paste, and to monitor the survival of nests at sites with and without odour paste. In the second



The study area showing the study species (predators, top left, and native ground-nesting birds, top right), the experimental design with treatments reversed at each of the four sites each year (bottom left), and the scale of the deployment of the 300–400 odour points at each site (bottom right). (Photo credits – background images: Grant Norbury, Manaaki Whenua – Landcare Research)

nesting season the paste/no-paste sites were swapped to increase the reliability of the results.

All three types of predator were attracted by the paste odours, but ferrets and cats, in particular, quickly lost interest after 12–18 days when there were no prey associated with the scent cues. By the time nesting started, interactions with odour were only 5–9% of their initial values. Hedgehogs began emerging from hibernation shortly after the study began so their interest in the odour initially increased, given they were very hungry, but their interest quickly declined thereafter. As a result, when the birds arrived to nest, the predators had already habituated to unrewarded bird odour cues and ignored bird odour, including that of the real birds.

Effects on nest survival were striking for all three bird species: compared with untreated sites, odour treatments gave a 1.7-fold increase in chick production over 25–35 days and doubled or tripled the odds of successful hatching. Protecting nests laid in the first third of the nesting season gave a disproportionately greater benefit because their survival is naturally higher than for nests laid later. For banded dotterels, the researchers modelled the effects on population growth and estimated that this intervention could result in a 127% increase in population size in 25 years of annual odour treatment, compared with population declines with no treatment.

The method would never replace lethal control and is a niche approach best suited to small areas of vulnerable biodiversity where lethal control methods are difficult to implement, or where the social licence to use lethal methods is absent. The method also opens significant opportunities in other countries where lethal control of native predators is not an option.

Lead researcher Dr Grant Norbury worked with colleagues at the University of Sydney, Dr Catherine Price and Prof Peter Banks, who developed the idea. Dr Norbury says that this field experiment shows that altering perceptions of prey availability offers a novel, non-lethal approach to managing problem predators, and 'could significantly reduce predation rates and produce population-level benefits for vulnerable prey species at ecologically relevant scales, without any direct interference with animals.'

This work was supported by a New Zealand Ministry of Business, Innovation and Employment Endeavour Fund Smart Ideas Grant.

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Catherine Price and Peter Banks (University of Sydney)

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