Pūtaiao

MANAAKI WHENUA SCIENCE SUMMARY / ISSUE 16 / NOVEMBER 2023

The art of the matter

Biodiversity and beating invasives

Pūtaiao

Science for our land and our future

Tēnā koe and welcome to Issue 16 of *Pūtaiao* ('science' in te reo Māori), our quarterly publication showcasing the work of Manaaki Whenua.

In this issue we dig deep into our work on weed control, outline our recent progress in eradicating the wiliest of pests, and reveal the power of cartoons for communicating our science. Among other stories we've discovered how to boost kiwi chick survival against harmful bacteria, chased possums over bridges – and used genomics – to trace how they move across landscapes, and developed new guidelines for ecosourcing tree seeds in Aotearoa New Zealand. We hope you enjoy the issue.

If you wish to be included on the mailing list for *Pūtaiao*, or to find out more about any of the stories, contact Manaaki Whenua's Senior Communications Advisor, Kim Triegaardt: triegaardtk@landcareresearch.co.nz

Cover image: Helping non-scientist conservationists understand the effect of mast events on predators, Manaaki Whenua researcher Jo Carpenter is using graphic illustrations in a multi-pronged approach to ensure the results of her study, which have direct applications for conservation practitioners, would get picked up and implemented. *See the full story on pg 13.*

ISSN 2703-3864 (Print) ISSN 2703-3872 (Online)

Natural enemies take charge in weed biocontrol

The sheer number and potential impacts of weeds in Aotearoa New Zealand are staggering. At least 1,800 plant species are naturalised, and more than 350 are considered environmental or productive-sector weeds.

Decades-long research has been generating solutions for landscape-scale weed management through developing novel biological control tools. The scope and scale of the work has seen Manaaki Whenua establish itself as a global leader in weed biocontrol.

Science Team Leader Dr Angela Bownes says weed biocontrol has been practised in Aotearoa New Zealand for nearly 100 years. It has an excellent track record for safety and success at suppressing weeds, which has helped to maintain and increase its social licence to operate.

"This is reflected in the accelerating pace at which new agents are released here, which is in stark contrast to the stagnant or slowing pace in other countries. It's also in contrast to the slowed-down pace of agents released against arthropod pests in Aotearoa New Zealand."

"We are currently progressing biocontrol solutions, all at varying stages in the research process, for 12 weed species in New Zealand and 10 species in the Pacific, all concurrently," she says. Within the past 4 years Manaaki Whenua has released four new biocontrol agents against four target environmental weeds in Aotearoa New Zealand, and five new agents against four target weeds in the Pacific.

Most recently, Manaaki Whenua's weed biocontrol group has been working to improve a decision-making tool for prioritising weed targets for biocontrol that was first developed for Australia by Manaaki Whenua scientists in 2008. "The framework is innovative in that it not only factors in weed importance," says Angela, "but also predicts the likelihood that biocontrol

Entomology technician Arnaud Cartier inspecting the progress of African tulip trees' natural enemies in Manaaki Whenua's Invertebrate Containment Facility in Lincoln.

will be successful. It also provides a ballpark cost, based on plant traits and experience in other countries."

Recent added functionality improves how weed importance can be scored, considering their distribution and impacts across a range of habitats, as well as socioeconomic pressure to control certain species, and the ease and cost of control using existing methods. Regional councils were able to use the updated tool to rank 158 nominated weeds to help inform funding decisions made by the National Biocontrol Collective (NBC), a consortium of 15 regional councils, unitary authorities, and the Department of Conservation (DOC).

The next improvement planned for the tool is likely to be a sensitivity/risk level for different ecosystem types in which these weeds occur, including whether they occur in protected areas. Another aspect that will be explored is predicting the risk of replacement weed succession, which also needs to be considered during priority setting. "A data-driven method that flags replacement weed issues would offer additional robustness to decision-making," says Angela.

Currently, field surveys are being used to determine when multiple species need to be tackled concurrently, such as in the Cook Islands, where grand balloon vine (*Cardiospermum grandiflorum*), mile-a-minute (*Mikania micrantha*), and red passionfruit (*Passiflora rubra*) are spreading, and in Vanuatu, where three pasture weeds, prickly solanum (*Solanum torvum*), wild peanut (*Senna* spp.), and hibiscus burr (*Urena lobata*), are making life difficult for farmers.

A key challenge for the sector remains the ability to quantify the economic value of biodiversity benefits from weed biocontrol in natural environments. "We recently conducted a holistic economic analysis for weed biocontrol in New Zealand demonstrating a phenomenal benefit to cost ratio of 73:1 for all weeds and of 110:1 for productive sector weeds alone," says Dr Ronny Groenteman, Senior Researcher and Programme Leader for a multi-weed biocontrol project funded by the Ministry for Primary Industries (MPI) and the NBC.

"We are using these results in discussions with primary industries about becoming financial members of the NBC, as well as in our discussions with MPI about the potential next tranche of funding for weed biocontrol," Ronny says. Funding will enable the initiation or continued assessment of the suitability of 17 arthropod and pathogen candidate natural enemies for 12 target weeds in Aotearoa New Zealand. Support from the NBC is also backing Aotearoa New Zealand's first weed biocontrol programme for an aquatic weed, lagarosiphon (*Lagarosiphon major*).

The team is looking to apply a multi-criteria analysis, which can incorporate cost-benefit analyses, to the biological control of heather (*Calluna vulgaris*) in Tongariro National Park.

They hope this will support the positive ecosystem outcomes that emerged from a long-term study of chemical control versus biocontrol of heather in the park.

"We demonstrated that after 5 years of either herbicide application, biocontrol, both in combination, or neither, that both herbicide and biocontrol were equally highly effective at controlling heather but resulted in different (and complex) trajectories of vegetation recovery," says Senior Technician Paul Peterson. "However, biocontrol, overall, benefited native vegetation recovery more than herbicide treatment."

"This demonstrates how important it is to go beyond measuring success as just reducing weed abundance, which has for a long time been the key measure," says Ronny. "There is still much to understand about the long-term responses of additional elements in the environment (soil microbiome, herbivores, insectivorous birds, rodents, etc.) to weed removal. For example, would invasion by exotic grasses following heather biocontrol encourage mammalian pests?"

A key focus for the team is to develop research programmes built on a tikanga approach to weed biocontrol. Manaaki Whenua's Weed Biocontrol group is working with Te Tira Whakamātaki to incorporate mātauranga into weed management efforts that go beyond just biocontrol.

The group is also hoping that future funded work will allow them to focus on systematically and strategically developing biocontrol for weeds early on the invasion curve.

Key to the success of the group's work is the fact that Manaaki Whenua's weeds programme remains free of any sector alignment. Its work model with the NBC is unique globally, and ensures research directly responds to scientific challenges. This enables researchers to seek novel approaches to weed problems.

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Weed busting success in Rarotonga

There was a satisfied sigh across Rarotonga recently. Two visits by Manaaki Whenua researchers to the Pacific island had revealed that the natural enemies introduced over the past few years to attack various weeds were all performing, or beginning to work, as expected.

The team was most interested in the leaf-mining flea-beetle (*Paradibolia coerulea*) and the gall-forming mite (*Colomerus spathodeae*), which target African tulip tree (*Spathodea campanulata*), a fast-growing tree that is widespread throughout the Pacific region and ranked in the top 10 of the worst invasive species in the world.

During a monitoring visit in the Avatiu Valley and the Takitumu Conservation Area, researchers used a drone with a claw to sample African tulip tree and check for beetle damage up in the canopy. (The damage from gall mites is easy to spot.)

Manaaki Whenua's Paul Peterson says the drones are part of an experimental project looking at different methods to map invasive weeds and the impact of natural enemies. "We are trialling the use of satellite imagery (50 cm resolution), imagery from an aeroplane (10 cm resolution), and drone close-up imagery (less than 4 cm resolution).

"As well as using RGB [visible] photography, the team also collected multi/hyperspectral imagery [to capture light reflected that can't be seen by the naked eye] and LiDAR. It is likely that a combination of these methods will be used to produce the weed distribution maps for future impact assessment studies," says Paul.

Previous releases include the red postman butterfly (*Heliconius erata*) to target red passionfruit, and the balloon vine rust fungus (*Puccinia arechavaletae*), which is the natural enemy of the balloon vine. Within 6 months of the release of the fungus on Rarotonga in December 2017 there had been a 90% decrease in balloon vine cover in some areas. Within 2 years of the releases the total percentage cover of the vines at the 20 release sites declined from over 75% cover to under 30%.

On a recent visit to Rarotonga, Manaaki Whenua researchers Dr Alana den Breeyen, Temo Talie, and Stephanie Morton worked with Rarotonga's National Environment Service and the Te Ipukarea Society to collect samples of the red postman butterfly for an evolutionary study to see if this butterfly maintains its bright warning coloration over time in a more benign environment.

Taking tech to the battle of weeds involved using drones equipped with either grab claws or cameras, and bench-top hyperspectral measuring equipment able to interpret imagery of target areas collected by drones, aeroplanes and satellites.

A red postman butterfly - an agent released for red passion vine (Passiflora rubra) *for long term evolutionary studies to see if the butterflies evolve/adapt colouration over time on Rarotonga in comparison to their native population in Ecuador.*

An African tulip tree seedling showing signs of the gall mites at work. Each gall (technically an erineum) can contain hundreds of mites that crawl out and either move to a fresh area on the same plant or disperse over longer distances in the wind.

It's heavy work getting through the thick forests of Rarotonga.

The bright orange-red flowers and yellow frilly edges of the African tulip tree that is threatening to overwhelm the forests of Rarotonga.

Understanding weeds powers future research

While Aotearoa New Zealand positions itself as a global leader in battling pest species, our research teams focused on weeds understand that effective weed management relies on bringing information and people together. This is often only achievable through good underpinning data and longer-term collaborations.

Manaaki Whenua Principal Researcher in Ecosystem Ecology Dr Duane Peltzer says an intimate understanding of weed biology and ecology sets the stage for future weed research. “Providing useful information for weed management means understanding the causes and consequences of weed invasion, and an essential component of this is understanding weed impacts,” he says.

Directly measuring the impacts of the approximately 1,800 naturalised plant species in Aotearoa New Zealand is prohibitive, so Manaaki Whenua researchers have explored using trait-based approaches as a better way to predict which weeds are likely to have greater ecosystem effects. For example, how do the functional traits of invaders compare to those of native species, and can co-invasions or interactions among species amplify or dampen weed effects?

The first step was to complete an inventory of the Aotearoa New Zealand native and naturalised flora to highlight the overall distinctions between naturalised versus native plants in taxonomy, growth form, life history, and leaf traits, as an estimate of the vast potential of the naturalised flora to affect our native ecosystems

“This inventory filled a key gap in fundamental data needed to inform decision-making and suggests the focus of further research,” says Senior Researcher Dr Angela Brandt. “It informed the Parliamentary Commissioner for the Environment’s 2021 *Space Invaders* report.”

Manaaki Whenua researchers also teamed up with collaborators from Australia, Singapore, and the US to propose a trait-based framework to evaluate potential mechanisms for the environmental impacts of co-occurring weeds that could be different from when those weeds occur alone.

“Interactions between invaders may be positive or negative, potentially amplifying or dampening an invader’s impacts on communities and ecosystems,” Angela says. “Selecting individual species for management could result in no biodiversity gains from weed control, or even produce unintended consequences such as competitive release of a subordinate, and possibly worse, weed.”

This work suggests some key ways in which future research can best support management decisions, including partnering with managers conducting weed removal activities to test approaches for different weed combinations. One possible approach is to target multiple weed species simultaneously, as was done when collectively releasing biocontrol agents for three invasive vines in the Cook Islands (see pages 2-4).

Wilding conifers provide an exemplar for developing more integrated,

Measuring the girth of wilding pines. Image: Brad White.

evidence-based management. The 'Winning Against Wildings' programme funded by the Ministry of Business, Innovation and Employment (MBIE), which ran from 2016 to 2021, gathered primary data on spread risk and impacts on biodiversity, developed new control tools, and integrated this knowledge through spatial forecast and social-ecological approaches.

The research showed that without management, invasion proceeds by about 5% per year but control costs increase by around 30% per year. "This was flagged as a concern, because wilding conifer reinvasion in places that have been managed was identified by landowners and managers as a major issue," Duane explains.

"This issue is poised to explode because national funding has gone from a high of $33 million in 2022/23 to a new base of $10 million per year in 2023/24, with no new investment case likely for the next 2 years."

Manaaki Whenua is involved in a current MBIE Endeavour programme led by Scion ('Vive la Resistance') to tackle this challenge. These research programmes on wilding conifers have been successful in planning and prioritising national and regional decision-making due to Manaaki Whenua's major collaborative efforts across research institutions (including Scion, Lincoln University, and the University of Canterbury), coupled with research partnerships through the National Wilding Conifer Control Programme (NWCCP) and the Wilding Pine Network.

The structure of the NWCCP provided a valuable implementation pathway for outputs from these research programmes and is viewed as a success across government. But there is no equivalent programme or collective for the hundreds of other weeds being managed across Aotearoa New Zealand, and learning from this model could be essential as the threats from weeds worsen with climate and other global changes.

Weed effects often take a long time to manifest, so threats from weeds and the need to control them are often seen as less urgent than other issues, such as extreme weather events and pest animals. However, it's much more cost-effective and environmentally sustainable to control weeds before they become widespread; for example, the benefit-to-cost ratio is 38:1 for wilding conifer management.

"Our goal is to fill evidence gaps and support decision-making needs for weed management that occurs earlier on the invasion curve, which would support uptake of the Parliamentary Commissioner for the Environment's recommendations for tackling emerging weeds. An integral part of this is becoming better Te Tiriti partners in biosecurity and ensuring social licence for weed management decisions," says Angela.

"Our focus for future work is how can we help effect a shift to more proactive weed management across the biosecurity system."

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Native reforestation: standing our ground

Native reforestation on marginal agricultural land has the potential to contribute to both climate adaptation and mitigation. Native forests are known to be resilient stores of carbon and are resistant to extreme climatic events – an increasingly important component of Aotearoa New Zealand's climate mitigation efforts.

Reforestation of former agricultural land through natural recolonisation by native trees is the best option for achieving native reforestation at scale given the prohibitive costs of tree planting. Reforestation through natural processes also reduces the chances of unintended consequences (especially replacement of naturally non-forested landscapes) relative to plantation forestry .

Pink areas indicate marginal agricultural land where natural reforestation is likely to occur following retirement of land from production. Over 3 million hectares could be reforested in this way.

But which types of trees are quickest to recolonise once the farmland is taken out of production? Are they species that rely on seeds being wind-dispersed, or those spread by animals or birds? Are the successful colonisers more able to withstand browsing? And can this knowledge be used to boost recolonisation processes?

These questions sound simple, but in practice they are very difficult to answer because forest successions take decades or even centuries. To overcome this problem, a common approach is to study many plots of different-aged stands of trees in a 'space for time' substitution. However, this approach is prone to problems, because older stands may occur in different environments from younger stands, so it is hard to separate the effects of stand age from the effects of environmental variations.

In response, researchers at Manaaki Whenua, led by Dr Norm Mason, undertook a 'dynamic stand reconstruction' approach at 14 sites across Aotearoa New Zealand where former agricultural land has been reforested. Taking measurements of tree stand age and growth rings, traits such as tree height, seed weight and seed dispersal, and the palatability of the leaves to browsing animals, 128 forest plots were studied across the 14 sites. Altogether, nearly 2,500 samples from 30 different tree species were included in the analysis, enabling patterns of tree succession to be established.

The results showed that the earliest-arriving tree species did not rely on animal or bird dispersal, had smaller leaves, and a chemistry that made them unpalatable to browsers. Later arrivals tended to have seeds brought in by birds and were more palatable.

One explanation for this is that unpalatable trees repel herbivores, thereby later allowing palatable species to establish. Another possibility is that Aotearoa New Zealand's long history of grazing means surviving remnant patches of forest, from which trees spread, tend to contain more unpalatable species. The results for seed dispersal are probably due to birds being more likely to visit sites where woody cover has already established.

Either way, the findings suggest that controlling mammalian herbivores (such as deer and goats) and enhancing seed dispersal by birds may be important management interventions to accelerate natural reforestation at former agricultural sites. "Our study suggests stand reconstruction could be a useful tool for studying forest successions in New Zealand and it would be interesting to apply it to more sites to explore how factors such as climate and distance to forest affect the arrival of tree species during natural forest successions," says Norm.

"In other work we've estimated that over 3 million hectares of marginal agricultural land could undergo natural forest succession if retired from production. We're also exploring the potential for information sources such as the LUCAS [Land Use and Carbon Analysis System] land-use map to reveal historical patterns of natural reforestation."

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Beyond Myrtle Rust: final meeting for a collaborative programme

The Beyond Myrtle Rust programme held its fifth and final Advisory Group and Annual General Meeting on 12 October. The meeting was a celebration of all the hard work done over the past 5 years.

The day boasted 16 talks on a variety of topics – including potential biocontrol agents, environmental drivers of myrtle rust infection, kaitiakitanga and Māori-led solutions, disease behaviour, and the management of myrtle rust in natural areas. Presenters and attendees hailed from Crown Research Institutes, research organisations, iwi, government organisations, and universities. There were also two student presentations, one on seed-borne endophytes of pōhutukawa and one on the importance of aka vines to Māori.

The diversity of the topics and organisations represented at the meeting highlighted what Programme Leader and Manaaki Whenua Senior Researcher Dr Mahajabeen Padamsee calls one of the most critical successes of both the programme and of myrtle rust research generally in Aotearoa New Zealand: collaboration. "The work presented has been reliant on past work and on continued collaborations with colleagues across New Zealand and Australia, who are all passionate about protecting our myrtles," says Maj.

This sentiment was echoed by attendee and speaker Dr Beccy Ganley, principal scientist at Plant & Food Research and leader of the national programme Ngā Rākau Taketake, which is administered by the New Zealand's Biological Heritage National Science Challenge. "Being part of myrtle rust research has been the best example of collaboration I have experienced so far in my career and an exemplar of how research should be done in New Zealand," says Beccy.

Beyond Myrtle Rust will conclude in June 2024, but researchers will be sharing everything they've learned over the course of the programme on social media in the months to come. If you're curious about their outputs, please follow them on Twitter/X, Instagram or Facebook.

Using animal behaviour to eliminate the last survivors and achieve predator freedom

“Just like a teenager,” says Manaaki Whenua researcher Dr Kyla Johnston, ”he’s too lazy to do anything.” The video Kyla is reviewing shows a stoat quite content to just lie in front of a trap and not do much.

Kyla has hours and hours of video to watch as she and her research colleagues try to measure stoat ‘personality’ traits in an attempt to understand why some recalcitrant stoats are able to evade traps and other devices intended to eliminate these invasive predators.

The researchers have developed a novel behavioural technique to quantify the responses of ‘average’ and ‘survivor’ stoats to a range of control devices and novel situations. It is the first time wild mustelid personalities have been quantified, which sees the team notching up another success in the ongoing search for a way to meet the goal to get Aotearoa New Zealand predator free.

‘Predator freedom’ is one of the country’s top priorities for protecting native biodiversity, yet complete eradication of possums, mustelids, and rats would be prohibitively expensive using current pest control methods. Current invasive predator control tools can remove most individuals in a target population but always leave some survivors.

“Individual differences will influence whether an animal goes into a trap, how it responds to scent lures, or indeed any management action,” says Manaaki Whenua Senior Researcher Dr Patrick Garvey. “These potentially important aspects of individuality, including difference in life histories, motivations and personalities, may undermine the effectiveness of any pest control program. Therefore, it is critical to understand individual variability in pest responses as we move towards predator freedom in Aotearoa.”

“If we focus on the ‘average’ pest we fail to mitigate the damage done by ‘rogues’ (those individuals that cause disproportionate impact) and ‘recalcitrants’ (those individual animals we know avoid standard control measures),” he says. “These two groups of pests are the ones that cause most damage and are very expensive to remove.”

And it is to those survivors that Manaaki Whenua’s ‘Eradication Science’ MBIE Endeavour programme is shifting the focus of its research. For the first time, researchers are looking away from reducing pest populations and towards cost-effectively eliminating the last few surviving individuals. Understanding the behaviour of those survivors, and what motivates them, will guide the development of better-targeted control tools.

The ‘Eradication Science’ programme is the first worldwide to apply animal personality research to pest animal management. It seeks to reveal the behavioural characteristics contributing to some individual pests surviving control, and how we can manipulate those behaviours using novel cues and combinations of cues to overcome these survival behaviours.

Within the programme, researchers are focused on four different research aims:

- identifying the behavioural traits that distinguish survivors from the ‘average’ individual in uncontrolled possum, stoat, and rat populations
- testing a range of cues that alter predators’ perceptions of risk and reward
- investigating kaupapa Māori and kaupapa Moriori aspirations and approaches to pest control/eradication
- using field trials to quantify improvements in control device efficacy based on the findings, but with broader areas and longer timeframes.

Four years into the programme, researchers are chalking up remarkable success. They have tested the responses of stoats to various audio lures – including prey distress calls, other stoats’ calls, and predator vocalisations. Stoats responded strongly to some of these cues including one notable success, where a stoat that evaded capture for months was lured into a trap using the sounds of baby stoats, that was collected for lure trials in the Eradication Science programme.

The potential to protect this intellectual property is being explored as it could potentially be used across a wide range of species and applications.

In a follow-up to this research, the team is testing whether a range of visual, sound, and scent cues are able to increase the interaction rates of recalcitrant animals (possums, stoats, and rats) with control devices. They will then field-test the most promising combinations of cues to measure their effectiveness in removing recalcitrant predators. This work includes evaluating the costs of novel versus standard approaches to eradication.

In an aligned project, Manaaki Whenua is investigating the effectiveness of non-lethal (sound) cues in changing predator ranging behaviour by focusing on cat movements in and around urban reserves.

Moving from exploring sound to scent, Dr Patrick Garvey is focused on developing an effective predator lure by creating a synthetic replicate of the natural predator odour of ferrets, the largest mustelid species in Aotearoa New Zealand. This was trialled in three large-scale conservation programmes, with stoat capture rates doubling at these sites when the lure was used. Iwi partners in Taranaki have recently begun a trial with the Manaaki Whenua lure to reduce the impacts of stoats on native biodiversity.

Researchers have also discovered that female stoats are more trap-shy than males. It has been suggested differences in capture success rates

Patrick Garvey at a study site in Hawke's Bay, North Island.

between male and female stoats relate to encounter probability, as males with their larger home ranges are likely to encounter more traps. However, female stoats are much more trap-resistant, with trap recalcitrance greatest for 'shy personality' female stoats. Female recalcitrance could be a fundamental issue influencing stoat control efforts country-wide.

It's not just stoats and ferrets under the spotlight. Possums, rats, and cats have all been subjected to field and pen behaviour studies.

For example, research in collaboration with the University of Canterbury has demonstrated 'social learning' in possums, whereby 'observer' possums learned to solve a puzzle device by observing a 'demonstrator' possum in an adjacent pen. If predators can learn about control devices in the same way, social learning could impede predator eradication campaigns.

And contrary to a popular maxim, it seems that fortune does not favour the bold. Control methods usually remove the boldest animals from the population. Groups of rats captured from sites with a history of control with toxic baits in stations were shyer and less willing to engage with various devices than rats from sites with no history of control. Bait stations are, therefore, a selective tool when used for rat population control.

The 'Eradication Science' programme is an ambitious endeavour, which only works because of the massive amount of collaboration between Manaaki Whenua teams, stakeholders, and management agencies. For example, the research component looking at why some possums survive standard baiting operations was complex and time-critical. All potential mechanisms needed to be investigated, including behavioural differences, microbes (such as bacteria, fungi, viruses, and their genes, which naturally live on and inside bodies), diet, demographics, feeding behaviour, and movement data. This involved a complex study design, animal capture, handling, transport, husbandry, and behavioural assays before transport back to the capture locations, all done prior to a DOC aerial baiting operation.

These programmes have solidified Manaaki Whenua's long track-record of quality research into vertebrate pest control techniques.

Observing how stoats move and connect is part of ongoing research trials on animal behaviour.

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HTTPS doi.org/10.1016/j.anbehav.2023.05.010

Creating "cultural licence to operate" in pest control

Key to making research programmes successful is ensuring we have the social and cultural licence to operate says Kairangahau Māori Mahuru Wilcox.

Researchers at Manaaki Whenua have been working closely with four groups (Ngāti Porou, Tūhoe Tuawhenua Trust, Hokotehi Moriori Trust, and a northern Taranaki collective including Ngāti Mutunga, Ngāti Tama and Ngāti Maru), who are undertaking small and large-scale pest control projects. "A kāhui Māori process has given us the support of Māori experts and knowledge holders to co-develop approaches that are culturally acceptable to tangata whenua and draw on traditional and current knowledge of pest control strategies," says Mahuru.

Through a series of wānanga with our iwi and imi partners, mātauranga aligned with pest control has been shared, along with the aspirations of Māori and Moriori in this area. Discussion included different types of lures (some of which were used historically for snaring kiore), the influence of maramataka on animal behaviour, how to undertake pest control using local tikanga to ensure the safety and success of those in the field, as well as local environmental tohu that can be used as early warning systems for mast seasons.

"All of this has helped inform a kaupapa Māori and Moriori-based pest control framework", say Mahuru.

"The framework can support iwi and imi as they develop local pest control strategies and projects, and serves to monitor success beyond the number of pest animals killed. Success for many of our iwi and imi includes wider benefits to communities, traditional knowledge transmission, and ways to reconnect tangata whenua with their lands, taonga, and each other."

Graphic illustrations tell rats' tales

Finding ways to share research so it cuts through a cluttered media environment is an ongoing challenge. Researcher Dr Jo Carpenter has embraced a growing demand for graphic illustrations to tell stories, and has turned her most recent research findings visual.

Jo took a multi-pronged approach to communicating the results of a 2-year field study aimed at understanding what drives rat outbreaks in Aotearoa New Zealand's forests. Initially she created a video abstract, and then collaborated with graphic illustrator Sarah Maybe Little to create a comic strip that could be shared on social media, published online, and shared with schools. From the cover...

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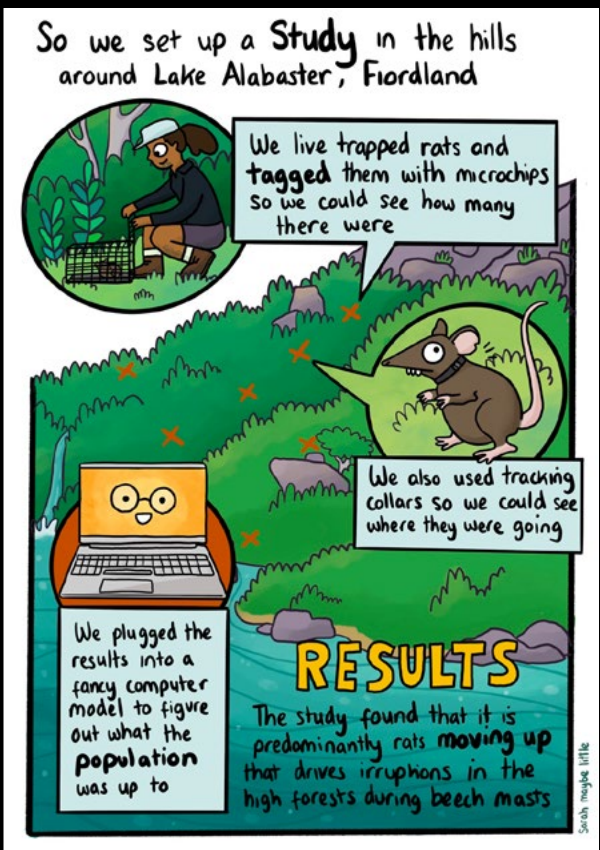

Tracking vertebrate pests using landscape genomics

The challenge in keeping an environment free of predators is to make sure any remaining populations of animals in other areas don't reinvade. For Manaaki Whenua's genomics researcher Dr Andrew Veale, this means making use of technology to ensure researchers understand how predators move around their environment and using those answers to guide pest management.

"In the past, traditional genetic methods have been used to compare the similarities between populations of animals, involving tens of genetic markers," says Andrew. "Now, with modern genetic sequencing methods, we are moving the field to look at pedigrees of animals to understand individual movement."

Investigating how target species move at a landscape scale to better understand reinvasion pathways and how to use management tools and, potentially, natural barriers to block them, will be key to meeting Aotearoa New Zealand's attempts to eradicate mustelids, rats, and possums by 2050.

The first stages of this work have involved a series of large, site-based programmes where various combinations of pests are targeted for local elimination. Individual-based landscape genomics is a novel field and one of many strategies used to identify relationships between environmental factors and the genetic adaptation of organisms in response to these factors. Manaaki Whenua has several landscape genomics programmes underway for almost all pest mammals in Aotearoa New Zealand, which are world-leading in terms of their methods and applicability.

Studies using landscape genomics for possums in Aotearoa New Zealand include one for OSPRI (the national agency responsible for eliminating bovine TB) in Westland, one for Towards Predator Free Taranaki, and another study for Predator Free Hawke's Bay aimed at understanding whether possums can be eliminated from a peninsula.

In the study for OSPRI, researchers used chew cards to survey possums on farmland and in forest on both sides of a river. Andrew says the possums were then captured for DNA genotyping. "We sequenced the genomes of 280 possums and calculated their pairwise relatedness, which indicated extremely high genetic differentiation between possums on each side of the river – with two exceptions. The exceptions were captured within 350 m of the only bridge within the study area, indicating they had probably crossed the river using the bridge."

A 'hybrid' possum with an intermediate genotype was also captured in the same place, indicating one of its parents had probably also crossed the bridge. "We found that the river forms an almost complete barrier to possum movement, but the bridge appears to permit some movement of possums across the river," says Andrew.

The study showed no long-distance dispersal from the deep forest, where TB is prevalent, to the farmland, leading researchers to conclude the source of TB infection to cattle in the area is probably through stepwise possum-to-possum transmission rather than long-distance dispersal.

"From these results we were able to provide OSPRI with specific management recommendations for their control programmes to minimise the spread of TB from possums to livestock in this region," says Andrew.

On Mount Taranaki, DNA sequencing showed that wide rivers with continuous flow stopped possum reinvasions, unless there were any bridges or points of canopy closure over the river. These acted as potential invasion points that would need to have vigilant control measures concentrated on each side of the breach.

Researchers were able to supply specific maps showing areas of reinvasion risk to assist Toward Predator Free Taranaki to create zero possum density zones. "If successful, this region will be the largest area of the mainland managed for possum elimination," says Andrew.

The dispersal story is quite different for stoats and weasels. After using landscape genomics to investigate mustelid movements on the Taranaki ring plain, researchers found that no landscape features affected stoat or weasel dispersal. They also travel long distances, sometimes, in the case of stoats, as far as 40 km. These results show that predator control needs to be maintained over large landscape scales to decrease reinvasion.

"From the genetic evidence in this study, and based on what we know about stoat biology and from other stoat eradication programmes, it appeared likely that most recruitment is from surviving residents in a control area rather than immigrants, so detecting and removing residents remains the primary concern for managers," says Andrew.

There are many more ongoing studies in this research area, including possums on Māhia Peninsula, rats in Wellington, wallabies across the country, and stoats on Waiheke Island, in Fiordland, and in Wellington. Manaaki Whenua is creating novel methods to address these fine-scale questions of movement and aims to create a generalised system for planning such studies based on the ecology of each species.

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Understanding possums brings researchers closer to better management processes.

Trusting their gut

A kiwi chick emerges from its egg at Willowbank Wildlife Reserve, Christchurch.

A hygiene hypothesis that children are more vulnerable to diseases because sterile outdoor play areas lead to a lack of microbe diversity could be a similar factor in struggling Ōkārito kiwi (*Apteryx rowi*) populations.

With only 700 Ōkārito kiwi (rowi) left in the wild, the birds are in serious trouble, with their population steadily declining 2 to 5% a year. For the past two decades Operation Nest Egg (ONE) has ensured 95% of eggs in the hatchery resulted in a live chick, but despite their healthy start in the hatcheries some kiwi fail to prosper once they've been released into the wild.

Manaaki Whenua Senior Researcher Dr Manpreet Dhami and postgraduate students Priscilla San Juan and Stephen Rowe hypothesised that if exposure to microbial diversity correlates to the development of a well-functioning immune system in humans, there was no reason it shouldn't be the same in kiwi. It was time for a closer look at the kiwi gut microbiome.

Priscilla's earlier gut microbiome research showed that faecal samples from Brown kiwi raised at the National Kiwi Hatchery Aotearoa in Rotorua had lower microbial diversity and a different composition from wild samples. "The hatchery residents had drastically different microbes in their guts," says Manpreet.

The gut microbiome is a highly diverse community of microorganisms that coexist within the gastrointestinal tract and are responsible for many important biological processes on behalf of their host. A healthy microbiome is essential for digestion, nutrient uptake, pathogen resistance and immune regulation, to name just a few functions.

The challenge was how to introduce diverse communities of microorganisms through a natural diet in a sterile environment. The researchers suggested the answer to the problem was to let them eat dirt! Dirt that had a little something extra added.

Soil samples taken from the Ōkārito Lagoon on the West Coast were used as a food additive for a treatment cohort of rowi chicks at Willowbank Wildlife Reserve in Christchurch. "The idea was to look at what happens when you introduce soil from the kiwi's original rohe, where the eggs come from, into their diet," says Stephen. "We have been feeding the soil to half the kiwis in the cohort to see if the soil microbes can be assembled sooner in the gut of the birds. In effect, giving the birds a probiotic."

Faecal and soil samples were then collected for community metabarcoding to determine how the microbial community changes in the kiwi over time, and if there were any correlations between these changes and the health outcomes of the rowi.

Initially adding unsterile soil seems like an easy fix and good news for the birds, but it comes with a caveat. Hatcheries can't just use any soil in a chick enclosure. Soils also harbour deadly pathogens that can cause severe and even fatal illnesses in kiwi chicks, such as aspergillosis, coccidiosis, and candidiasis. Aspergillosis is of particular concern because it is a common mould that grows on sphagnum moss, which is often used as compost, and it's a kiwi killer.

Stephen's research demonstrated a simple yet effective PCR-based method for qualitative testing to screen for soil-based contaminants. It will be a cost-effective routine screen for wildlife sanctuaries, which will help meet their aims to bump up the numbers of kiwi and release an ambitious total of 10,000 kiwi into the wild by 2050.

"The end goal for both these projects is to find a way to put good microbes back into the kiwi to give them the best possible start to life," says Manpreet.

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HTTPS doi.org/10.1186/s42523-021-00109-0

Working across knowledge systems to co-design workable outcomes

From the outset, New Zealand's Biological Heritage National Science Challenge (BioHeritage) has been committed to reshaping how mātauranga Māori and Western science intersect. How it has gone about this has become a study in itself.

In a recent article sharing lessons learned, Manaaki Whenua researcher Dr Melissa Robson-Williams and environmental management consultant and former Manaaki Whenua researcher Dr Ronlyn Duncan revisited the evaluation of its co-design process commissioned by BioHeritage in 2020.

"Doing co-design and co-production is challenging, resource intensive, and outcomes do not always translate into action," says Melissa. "Evaluations of processes are needed to identify what enables and constrains 'co' efforts."

The 2020 evaluation focused on the co-design process that established the foundations of BioHeritage's Strategy 2019–2024. It identified nine foundations for co-design success: leadership commitment; financial resources; a realistic timeframe; organisational capacity; diverse, knowledgeable, and experienced participants; clear values, rules of engagement, and output expectations; power sharing; skilled facilitation; and a well-designed process.

Ronlyn and Melissa revisited the evaluation using co-design assessment principles and a knowledge governance conceptual framework. They identified BioHeritage's values, and how they were put into practice, as a critical factor contributing to its co-design successes. It was also found that, through its values, BioHeritage has been fostering systemic change across Aotearoa New Zealand's knowledge governance system. As such, it has been paving the way for the knowledge systems of mātauranga Māori and Western science to be brought together in authentic and equitable ways," says Ronlyn. "We have identified its actions as values-inspired knowledge practices."

"Serious efforts are being made in New Zealand to navigate the knowledge systems of mātauranga Māori and Western science," says Ronlyn. "BioHeritage provides a useful example of how that can be done. It did something really unique, which is important for other people to know about."

Their study also showed that while calls for research impact are shifting the relationship between science and society, the odds remain stacked against the acceptance of mātauranga Māori in a range of institutional spaces.

"These are tricky issues," Ronlyn says. "Acknowledging they exist is an important first step."

"Evaluations of co-design processes make such an important contribution to the emerging co-design literature," says Ronlyn. "Evaluations help us look back and understand how an intervention played out, and what difficulties were encountered and why."

The researchers were optimistic that co-design and co-production could lead to more impactful research outcomes by producing shared knowledge through purposefully designed collaborative processes or encounters.

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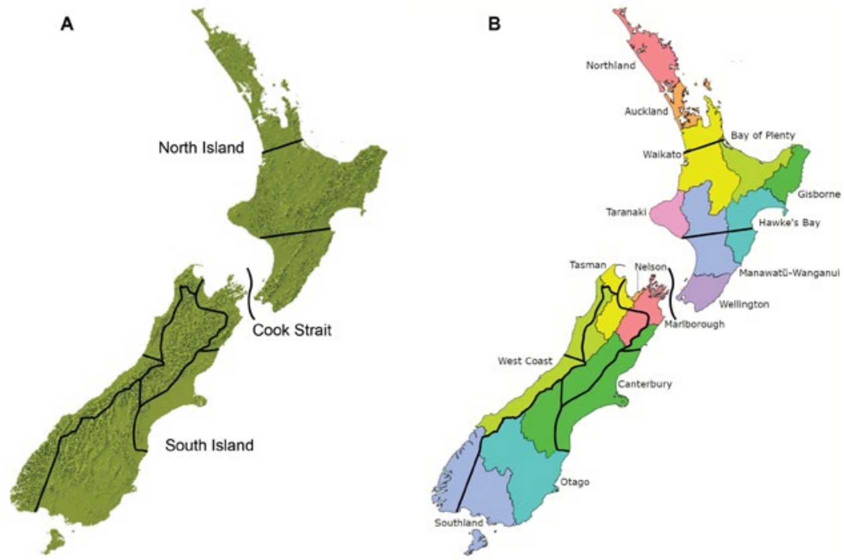
HTTPS *tandfonline.com/doi/full/10.1080/1177083X.2023.2227675*

bioheritage.nz/outputs/uploads-2019-04-lc3849_codesigning-for-research-impact-final-report-pdf/

New guidelines suggested for ecosourcing seed

When it comes to ecological restoration in Aotearoa New Zealand, obtaining plant seeds with a known local wild origin has been widely advocated and practised for the past 50 years.



Nine proposed eco-evolutionary regions for ecosourcing. A, Ecosourcing regions overlaid onto New Zealand topographic map. B, Ecosourcing regions overlaid onto Regional Council regions.

This approach, known as ecosourcing, ensures the seeds used for restoration come from nearby areas and maintain the genetic integrity of a plant species.

Now, researchers at Manaaki Whenua and the University of Otago say it's time to relax these strict guidelines if we want to build resilience into our changing environments. Instead, the researchers suggest creating nine broad ecosourcing regions, within each of which it is permissible to use seeds. They believe this will lead to improved restoration outcomes by increasing species and genetic diversity, mitigating the negative effects of inbreeding, and facilitating the genetic rescue of threatened species populations.

The concept of ecosourcing was introduced by Eric Godley in 1972 to address concerns about planting species outside their natural geographical range and into remnants of indigenous vegetation, which could disrupt their evolutionary trajectories.

This would lead to unsuccessful restoration outcomes due to poor environmental matches. "However, we believe that this approach has become overly restrictive," says Manaaki Whenua's Dr Peter Heenan. "Ecosourcing at a strictly local scale limits genetic diversity, confines species to their historical ranges, and reduces conservation options for threatened species," he says.

For instance, tree species in Aotearoa New Zealand that are commonly used in restoration projects have low genetic differentiation within populations because they readily interbreed throughout their range. The strict ecosourcing of tree seeds provides limited benefits. The researchers use the example of kānuka (*Kunzea ericoides*), previously thought to comprise several different species. Research by Peter and colleagues has revealed that kānuka shows geographical variation across Aotearoa New Zealand but no fine-scaled genetic variation.

Peter says it would be better to use larger ecosource areas instead of smaller ones, to help avoid problems associated with inbreeding and allow for a better match with a local environment. "To effectively protect and restore ecosystems, conservation efforts need to adapt to these changes in contemporary biotic landscapes that have been profoundly altered by climate change, habitat loss and fragmentation, species extinctions, the spread of invasive species, and the emergence of novel habitats," he says.

There has been considerable interest from regional councils, DOC, and community groups in how the new recommendations for enlarged seed-collecting zones can be applied to seed collection for future restoration projects.

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HTTPS *tandfonline.com/doi/full/10.1080/0028825X.2023.2210289*

Celebrating our achievements

IPEN's impact mahi wins Australian Evaluation Society award

The Impact Planning & Evaluation Network (IPEN) includes Manaaki Whenua's Ross Laurence (chair), Dr Daniel Milosavljevic, and Veronika Alexova, together with colleagues from the six other Crown Research Institutes (CRIs). IPEN's efforts to build research impact capacity and capability have been recognised by the Australian Evaluation Society with the 2023 Excellence in Evaluation Systems Award. This recognises the development of an exemplary integrated evaluation system, which in the case of CRIs is being used to improve the way research is planned and delivered.

It's only the third time an Aotearoa New Zealand entry has won in more than 20 years. IPEN Chair, Ross Laurence, says the award acknowledges what has "truly been a collaborative effort from passionate individuals across all seven CRIs. A group of people who openly shared ideas and experiences and were willing to go the extra mile for each other. It has proved the value of trust and true collaboration across organisations."

Kara Scally-Irvine (iPEN impact and evaluation specialist), Ross Laurence (iPEN Chair, Maanaki Whenua) and Sue Bidrose (iPEN sponsor, AgResearch CEO and Chair of Science New Zealand).

Rich Leschen elected Fellow

Dr Rich Leschen has been elected Fellow of the Entomological Society of New Zealand. Rich's early appreciation of natural history began with reptiles and amphibians, morphing into a lifelong fascination with beetles. He graduated from the University of Arkansas (MSc, 1988) and gained his PhD at the University of Kansas, before joining Manaaki Whenua's NZ Arthropod Collection in 1997. His research has focused on micro-Coleoptera and has resulted in an outstanding level of publications: over 195 journal articles, 12 books/monographs, and 65 book chapters, often accomplished with his extensive network of collaborators. He has named 270 species and 92 genera as new to science.

Rich Leschen

Sandra Lavorel recognised for climate change research

Research Associate Dr Sandra Lavorel was awarded the prestigious French Centre National de la Recherche Scientifique (CNRS) Gold Medal for her interdisciplinary research that regularly informs territorial planning and biodiversity management policies, and offers nature-based solutions for contending with global change. Sandra was recently based at Manaaki Whenua in Lincoln on a two-year secondment where she specialised in the functioning and dynamics of ecosystems, including the contributions that biodiversity makes to human life, and the societal and economic impact of its alteration by environmental changes.

Sandra Lavorel

Our role in cyclone recovery

Watching the destruction Cyclone Gabrielle wrought across the North Island in February was overwhelming. I grew up in Hawkes Bay and to see from afar my family and friends bear the brunt of the extreme weather was painful. To feel powerless to help in the moment is a truly humbling experience.

The reality is that the scale of the event means the healing process will span many years, so to be part of an organisation already playing a significant role in the recovery goes a long way towards making the contribution I couldn't at the time.

Manaaki Whenua can draw on a large body of data that encompasses the science of integration, economics, social, environmental, cultural, and policy-making to ensure relevant, resilience-building research. We believe the recovery approach should be deliberate and considered, and that it may require different approaches, including seeing a response through a te ao Māori lens.

As the clean-up continues it is clear much of the landscape in the worst-affected areas has effectively been 'reset'. Being able to compare land through our Sentinel-2 satellite imagery pre- and post-Gabrielle is a stark reminder of the landscape scale of the damage across Gisborne, Hawke's Bay, and northern Wairarapa. Of the 115 million tonnes of soil estimated to be eroded by landslides, approximately half would have entered waterways, and approximately 30% of that would have been deposited on floodplains. Much would have also found its way to the sea.

Programmes such as Smarter Targeting of Erosion Control (STEC) have significantly improved our understanding of spatial and temporal patterns of erosion, sediment-related water quality, and sediment mitigation. STEC supported development of models to predict the susceptibility of land to rainfall-triggered landslides and the likelihood landslides deliver sediment to streams. It allowed us to model the likely patterns of soil erosion and sediment transport under future climate change nationally and effectively 'fingerprint' eroded sediment to identify sources within catchments.

But as quickly as we want to get back to 'normal', it's going to be important to be thorough and take the time needed to make the right decisions.

One of those is what to do with exotic plantations in areas that perhaps are no longer in the 'right' places. Pine was often planted on erosion-prone pastoral hill country with a history of soil disturbance and because the policy of the day suggested it was the best erosion-control solution. This history and the multi-layered relationships that exist around it create a complex picture with no simple, immediate or a single solution.

Solutions need to fit the capability and vulnerability of the landscape much more finely than at present.

It will take years for the biodiversity of the region to recover, and the scoured ground will provide a canvas for weeds and invasives. Manaaki Whenua is proud to support the country's biggest bioinvasive team in the Southern Hemisphere. Our work in establishing natural solutions over chemical ones has been significant and is showing many successes.

Even more importantly, building back better is an opportunity to enhance local communities' futures. The recovery cannot just be economically focused but should support community-led engagement and iwi/hapū priorities and initiatives. Although we have the expertise, it is vital not to lose sight of what's important for the communities and mana whenua in the regions, and to marry our expertise with these needs.

Planting mānuka and kānuka, is an example of a transition mechanism that creates potential to evolve into bigger industries with intergenerational benefits. Allowing natural reversion in some places is another successional approach to developing resilience rather than quickly planting species that might have immediate impact but might give rise to unintended consequences in the future.

As the regions slowly recover, Manaaki Whenua is well placed to contribute in a role that gives mana and respect back to the environment, and incorporates the core principles of kaitiakitanga (guardianship), whakapapa (connectedness), and manaakitanga (care/support).

James Stevenson-Wallace
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