Manaaki Whenua
Landcare Research

ANNUAL REPORT / PART 1

We present our Annual Report in two parts. Part 1 provides an overview of Manaaki Whenua, highlights of our science that show the contribution we are making towards creating value for Aotearoa New Zealand (AoNZ) through our research, people and partnerships, and an update on our strategic directions. In Part 2 we present our directors' report and financial statements.

PDF versions of both Part 1 and Part 2 are available for download from the Manaaki Whenua – Landcare Research website: landcareresearch.co.nz/publications/annualreports

FRONT COVER: Misty trees, near Seddonville, beside the Mokihinui River, on the edge of Kahurangi National Park. Image: John Hunt

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Zig-zag fern looper moth (Ischalis fortinata) *on its larval host plant, the prickly shield fern* (Polystichum vesitum). *Image: Samuel Purdie.*

A word from our Chair and CEO

Welcome to the first of our Annual Reports reflecting "Te Āpōpōtanga", our organisational strategy for the coming years. Never has a focus on the future been so fitting – we must adapt fast in the face of a changing climate to ensure Aotearoa New Zealand's (AoNZ's) future is built on healthy social, economic and environmental realms. Our future must be one of partnership between tangata whenua and tangata tiriti – and for this reason we have taken our first steps in realising our Tiriti commitment in this past financial year. The organisation is experiencing real change in order to genuinely deliver our ambition of "Kia mauriora te whenua me tōna taiao". Change is not easy. The pandemic has shown us that when change creates new opportunities in some areas, inequities are reinforced in others. Our staff are our biggest asset – they have shown incredible adaptive ability during the past two years. This same empathy, curiosity and goodwill is now being applied to the challenge of realising our Tiriti commitment – we thank you all.

One of the hallmarks of the Manaaki Whenua approach is integration. We acknowledge that people are inseparable from the environment, albeit in differing roles. People drive action on climate change, the restoration of biodiversity and the curbing of invasive species. They also enhance soils and determine land uses, both of which impact water's quality and passage through to waterways. This past year we opened our Lincoln gathering place, Te Rauhītanga. Our new office building and "main street" deliberately integrate our staff from all specialties and skills, funnelling them to a central meeting place/ cafeteria. We thank Ngāi Te Ruahikihiki for your partnership on this journey, including your assistance with developing the cultural narrative that underpins integration at our head office.

This year our Board's Science Advisory Panel focused on our biological collections and databases. Included in this review was a hui on how Manaaki Whenua could be a better Te Tiriti partner in the way collections are managed. The hui concluded that our collections are an important taonga and that a "significant rebalancing" is required to give our Te Tiriti Māori partners greater oversight of, and connection to, the collections. This rebalancing was summarised by the notion that our collections approach needs to expand from one where we "collect, curate and classify" to include the commitment to also "connect, create and collaborate" with our Te Tiriti partners. This has set the agenda for a revised strategy across our biological connections and databases.

We have continued to drive research impact with our partners. The Smarter Targeting of Erosion Control programme has significantly enhanced landslide inventories at regional scale, with regional councils. Machine learning is then used to predict where landslides will occur in future based on topography, land cover and land type. The programme has also quantified the benefits of kānuka in a silvo-pastoral context, including soil stabilisation, animal shelter and preservation of pasture from smothering. Many of these attributes make it superior to poplar. With MPI and the NZ Agricultural Greenhouse Gas Centre we have been benchmarking soil organic carbon stocks at national scale. Meanwhile our online soil mapping resource S-map has continued to advance towards its goal of soil maps for all Aotearoa's productive lands. Included in this is our production of open-source software for where the samples should be located – this has been downloaded 700,000 times.

We also made many advances in enhancing biodiversity and reducing biosecurity impacts. We discovered that Myrtaceae tree species occur in 74% of New Zealand's forests. It is not yet clear how myrtle rust will impact each species, given they respond differently, but it is clear the Myrtaceae family has no equivalent to provide the multi-layer structures of indigenous forests. This includes long-term carbon storage. We continued to advance bio-control tools for wasps through a partnership with Te Kotahitanga mō te Taiao and The Nature Conservancy. We succeeded in introducing biocontrol agents for African tulip tree to the Cook Islands. The wilding conifer programme has developed many new tools that have become incorporated in the Good Practice Guidance used by the forestry industry. We began a partnership with Te Puka Rakiura Trust that aims to eradicate six predators in the largest global eradication from an inhabited island, enhancing biodiversity in the process and restoring the mana and mauri of

Rakiura according to Ngāi Tahu as kaitiaki.

Our subsidiary, Toitū Envirocare, and New Zealand's Biological Heritage National Science Challenge (which we host), are performing well, both focused on impact. Toitū achieved a milestone of 47.5 million tonnes CO_2-equivalent emissions certified or verified during the year – an achievement based on New Zealand and overseas companies seizing the opportunity to reduce their emissions.

In closing, we thank Richard Gordon, who retired as Manaaki Whenua's CEO of 10 years in May. We owe a huge debt of gratitude to Richard for laying strong foundations for a very successful implementation of Te Āpōpōtanga. Jane Taylor also concluded seven years as Board Chair. The combined commitment of Richard and Jane to leading with integrity was resonant throughout our organisation. Finally, we thank the collaborators, stakeholders and partners in our research. Without you, there would be no real-world impact.

Ngā mihi nui.

Colin Dawson – Chair

Dr Fiona Carswell – Acting CEO

30 September 2022

He kupu nā tō mātou Heamana me te Tumu Whakahaere

Nau mai ki te tuatahi o ā mātou Pūrongo ā-Tau e whakaata ana i "Te Āpōpōtanga", arā, tō mātou rautaki ā-whakahaere mō ngā tau e tū mai nei. Kātahi anō kua pēnei te hāngai pai o te arotahi ki te āpōpō - me tere tonu tā mātou tahuringa kia rite mō te ao e huri nei, e huri nei kia mātua whakarite e ahu mai ana te āpōpō o Aotearoa i ngā tū ao pāpori, ōhanga, taiao pakari katoa. Kia kotahi tā tātou hoe ki te āpōpō e tū mai nei, he pātuinga tangata whenua, tangata tiriti i runga i te whakaaro kotahi - nā reira nō te tau pūtea kua hipa nei kua hīkoi mātou i ā mātou tapuae tuatahi ki te whakatinanatanga o tō mātou paihere ki te Tiriti. Kua kaha rongo te whakahaere i te wheako o te panonitanga tūturu e taea ai tō mātou whāinga, arā, "Kia mauriora te whenua me tōna taiao" te whakatutuki tūturu. Ehara te panonitanga i te mea ngāwari. Nā te urutā kua kite mātou ahakoa hua mai ana ngā ara hou i te panonitanga i ētahi wāhi, i ētahi wāhi anō kua kaha ake ngā ngoikoretanga. Ko tō mātou taonga nui ko ā mātou kaimahi - i ngā tau e rua kua hipa kua whakaaturia mai e rātou te pūmanawa nui whakaharahara ki te ako me te whakarite anō. E whakamahia ana tēnei momo māramatanga, tēnei pākiki, ngākaunui anō ki te wero o te whakatutukinga i tā mātou paihere Tiriti - nō reira, tēnā koutou katoa.

Ko tētahi o ngā tino tohu o te tū mahi a Manaaki Whenua he kōtuitui, he whakakotahi. E whakaae ana mātou tē taea te whakawehe te tangata i te taiao, ahakoa he rerekē te tūranga a tēnā, a tēnā. Kei te tangata te mana kōkiri i ngā mahi mō te panonitanga āhuarangi, te whakaoranga o te kanorau koiora me te whakamatuatanga o ngā momo kīrehe e kaha whakararu nei. Ko tā tēnei hunga anō he whakapiki i te pai o ngā oneone, he whakatau hoki i ngā momo whakamahinga o te whenua, he mea papā anō ēnei mea e rua ki te kounga o te wai, otirā, ki tōna ara rere atu ki ngā arawai. Nō te tau kua pahure nei i whakatuwhera ai tō mātou wāhi huihuinga Lincoln, Te Rauhītanga. I mātua whakatauria kia noho hei mea whakakotahi tō mātou tari hou, me tōna "huarahi matua" i ngā kaimahi mai i ngā momo tohungatanga, momo pukenga hoki, me te ārahi i a rātou ki te wāhi huihuinga matua/wharekai. Ngāi Ruahikihiki, tēnei mātou ka mihi. Tēnā koutou i tū ngātahi mai hei hoa pātui i runga i tēnei haerenga, tae atu rā ki tō tautoko mai i te whakawhanaketanga o ngā korokī ahurea e ahu mai ai te kotahitanga i tō mātou tari matua.

I tēnei tau i arotahi atu tā mātou Paepae Tohutohu Pūtaiao a te Poari ki ō mātou kohikohinga, pātengi raraunga koiora hoki. I roto i te arotake nei i tū tētahi hui hei wānanga i ngā ara e pai ake ai a Manaaki Whenua hei hoa pātui Tiriti mō te taha ki te whakahaerenga o ngā kohikohinga. Ko te whakataunga whakamutunga o te hui, he taonga nui whakaharahara ō mātou kohikohinga, ka mutu, kia tautika anō te pae me tuku ki ō mātou hoa pātui Tiriti Māori te mana kia nui ake te tirohanga whānui, kia kaha ake anō hoki tā rātou hononga ki ngā kohikohinga. I whakarāpopotohia ai tēnei mahi whakatautika e te ariā kia whānui ake te āhua o tā mātou mahi kohikohi i tētahi kua "kohikohi, kua tiaki, kua kōmaka" te āhua ki tētahi kua tāpiri mai hoki te paihere ki te "honohono, te waihanga me te mahi tahi" ki te taha o ō mātou hoa pātui Tiriti. Nā konei i whakarite ai te rārangi take mō tētahi rautaki whakahou puta noa i ā mātou hononga, pātengi raraunga koiora anō hoki.

Kua kaha tonu tā mātou kōkiri i te papānga rangahau ki ō mātou hoa pātui. Nā te kaupapa Keonga Atamai o te Whakatika Horonga Whenua kua tino whakareia ngā rārangi taonga ki te taumata ā-rohe, ki te taha o ngā Kaunihera ā-Rohe. Mā konei ka whakamahia ai te akoako ā-rorohiko ki te matapae ki hea hora ai te whenua ā ngā rā e tū mai nei i runga i te mātauranga mahere whenua, te momo tipuranga, me te momo whenua. Kua inehia hoki te rahi o ngā hua o te kānuka ki roto i tētahi horopaki e pā ana ki te noho ngātahi o ngā mea katoa (silvo-pastoral), tae atu ki te whakataunga o te oneone, te maru kararehe me te tiakitanga o te tarutaru/otaota kia kore ai e tāmia. Nā te nuinga o ēnei pūmanawa kua nui ake tōna kaha i tā te poplar. Ki te taha o MPI me te NZ Agricultural Greenhouse Gas Centre kua whakarite paerewa o ngā whakaputu oneone māori ā-waro ki te taumata ā-motu te mahi. Kua haere whakamua tonu hoki tā mātou rauemi whakamahere oneone ā-ipurangi a Smap ki tōna whāinga, arā, ko ngā mahere oneone mō ngā whenua hua katoa o Aotearoa. I roto hoki i tēnei ko tā mātou whakaputanga o te pūmanawa rorohiko manawa hora mō ngā wāhi e kitea ai ngā tauira - kua 700,000 ōna tikiake.

Kua neke whakamua hoki mātou i ngā momo mahi whakarei i te kanorau koiora, whakaheke hoki i ngā papānga haumaru koiora. I tūhurahia e mātou ka puta te momo rākau Myrtaceae ki te 74% o ngā ngahere o Aotearoa. Kāore tonu i te tino mārama ka pēhea te papānga o te myrtle rust ki ia momo i runga i te mea he rerekē te urupare a tēnā, ā tēnā, heoi anō, he mārama te kitea kāore i tua atu i te whānau Myrtaceae mō te whakatupu i ngā hanganga whakapaparanga o ngā ngahere taketake. Kei roto i tēnei ko te whakaputu roa o te waro. I haere tonu ngā mahi whakapai ake i ngā utauta whakamatua-ā-koiora mō ngā wāpi mā tētahi pātuinga ki te Kotahitanga mō te Taiao me te The Nature Conservancy. I tutuki tā mātou mahi hoatu i ngā momo rongoa whakamatua-ā-koiora mō te rākau African tulip ki ngā Kuki Airani. Kua whakawhanaketia e te kaupapa tohanga māori i te koroī (wilding conifer programme) ngā tini utauta hou he mea kua kōkuhuna ki roto i te Aratohu Tikanga Pai e whakamahia ana e te ahumahi ngahere. I tīmata pātuinga mātou ki Te Puka Rakiura Trust e whai ana ki te whakakore i ngā konihi e ono i te whakakorenga whānui nui rawa i tētahi motu kāore ōna tāngata, nā roto i te tukanga ka whakareia te kanorau koiora, ka whakaoratia anō hoki te mana me te mauri o Rakiura e ai ki Ngāi Tahu, tōna kaitiaki.

He rawe ngā mahi a ō mātou āpitihanga, a Toitū Envirocare me Te Wero Pūtaiao ā-Motu mō te Koiora Tuku Iho o Aotearoa (ko mātou te kaihautū), ko te papānga te aronga nui o aua kaupapa e rua. I tutuki tētahi pae tata e Toitū o te 47.5 miriona manokiro (tana) pīhau ritenga-CO2 i whakamanahia, i manatokohia hoki i roto i te tau - he whakatutukinga tērā e ahu mai ana i Aotearoa me ngā ūmanga ki tāwāhi e rawhi ana i te wā ki te whakaheke i ā rātou pīhau.

Hei whakakapinga, rere ana ngā mihi ki a Richard Gordon, nō te marama o Haratua ia ka heke mai i te tūranga o te Tumu Whakahaere o Manaaki Whenua, 10 tau te roa. Kāore i ārikarika te kupu whakamānawa ki a Richard nāna te tūāpapa pakari tonu i whāriki mai kia rite anō mō te whakatinanatanga o Te Āpōpōtanga. Kua mutu hoki a Jane Taylor i ōna whitu tau i te tūranga o te Heamana o te Poari - nā te ngākau nui ngātahi a Richard rāua ko Jane i mātua whakarite he rangatira te āhua o te arataki puta noa i te whakahaere. Ko te kupu whakamutunga, ki ngā hoa mahi tahi, ngā kiri whaipānga, ngā hoa pātui hoki i roto i ā tātou mahi rangahau, tēnā koutou, tēnā koutou katoa. Ki te kore koutou, kua kore he papānga ki te ao-tukupu.

Nā māua iti nei me ngā mihi nui, nā.

Overview
Tirohanga whānui

We are the Crown Research Institute for our land environment and biodiversity – an organisation of 464 scientists, researchers, and experts supporting science who are dedicated to helping the people of Aotearoa New Zealand (AoNZ) understand and live well with our land.

Our Ambition

Kia mauriora te whenua me tōna taiao (make the life-force and vitality of the land strong).

This requires a positive reciprocal relationship between people and their natural environment – between iwi Māori and their ancestral lands.

Mauriora is the Māori concept of life-force and vitality. In Māori thinking mauriora requires the people to be connected with their ancestral lands. Māori trace their origins (whakapapa) to the land. The indivisible connection between people and their land is expressed in manaaki whenua – manaaki tangata (care for the land – care for the people). That phrase captures the reciprocity of the relationship. In non-Māori thinking the close relationship between the land and its people has a long history and we believe our ambition statement speaks for all ethnicities.

Our purpose

Science for our land and our future – *Ko te pūtaiao mō tō tātou whenua, mō āpōpō.*

Manaaki Whenua is a purpose-driven research community. Our research and innovation focus on understanding the land, life on land, and the relationship between people and the land. Manaaki Whenua works in partnership with others to achieve our ambition, which we cannot achieve alone. People's decisions and actions affect the environment, so the purpose of our work is that they should have understanding, capability and confidence to enable society and environment to flourish together.

Te Tiriti

We are committed to upholding the principles of Te Tiriti o Waitangi in all our activities. These principles are Partnership, Participation, and Active Protection of Māori interests, especially in the natural environment.

Our research impacts and outcomes

We focus on four areas of research impact:

- enhancing soils, water and land;
- restoring biodiversity, beating invasive species;
- action on climate change;
- people and environment.

Delivering impact with our partners

To achieve positive impact we work alongside Māori iwi as the Tiriti partner, central and local government, business and industries, community groups, and the global research sector.

Research capability

We invest in people to achieve excellence in our research, and to strengthen capability and collaboration. We create the right teams across the spectrum of fundamental and applied science. Our research is ranked among the leading environmental research institutes globally. We maintain capability to address national emergencies, especially in biosecurity.

Putting people at the centre

We aim to provide for health, safety, and well-being, for an equitable, diverse and inclusive culture, and for the future of work. Within this culture, we have worked with our people to define five behaviours that express our values in action:

Our behaviours:

Share freely and often
Kia rite tonu te tohatoha

Invite input from others:
Kia areare mai ōu taringa

Commit to excellence:
Whāia te iti kahurangi

Experiment to learn:
Mā tē he ka tika

Embrace diversity:
Awhi mai, awhi atu, tātou tātou e

Our strategic priorities

At a time of change in the environment, society, and economy, we have refreshed our 5-year strategic plan to focus on both short- and long-term priorities:

1. weaving the principles of Te Tiriti into our fabric
2. driving research impact with our partners
3. creating a sustainable environment for our people and research to thrive.

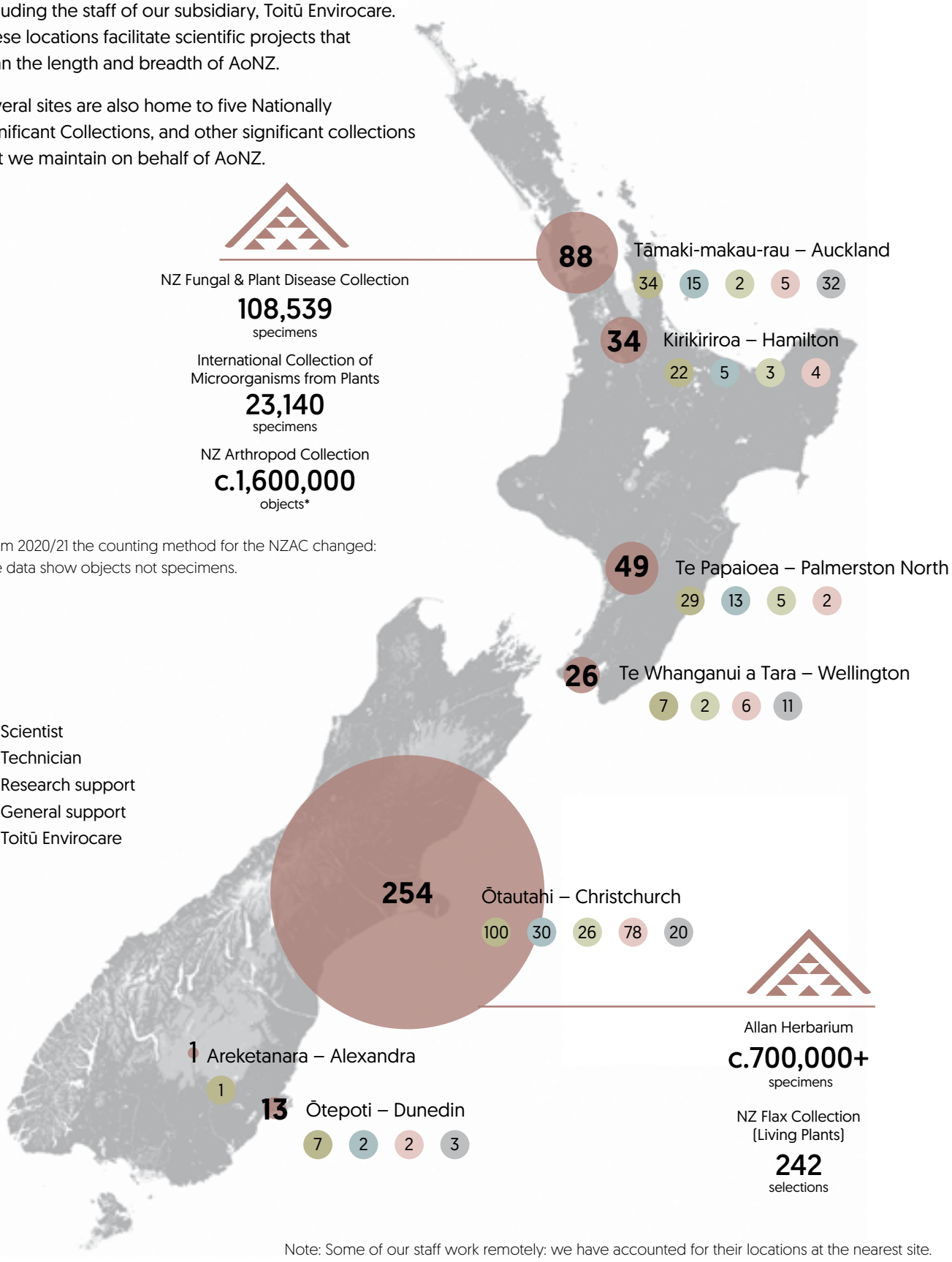
Our commitment to the United Nations Sustainable Development Goals

We align our work with 12 relevant UN goals. Our own climate action comprises our research on mitigation and adaptation; the climate leadership of our subsidiary, Toitū Envirocare; and actions to drive down our emissions and influence our sector.

Our locations

Our sites across AoNZ house 464 staff and research associates, including the staff of our subsidiary, Toitū Envirocare. These locations facilitate scientific projects that span the length and breadth of AoNZ.

Several sites are also home to five Nationally Significant Collections, and other significant collections that we maintain on behalf of AoNZ.

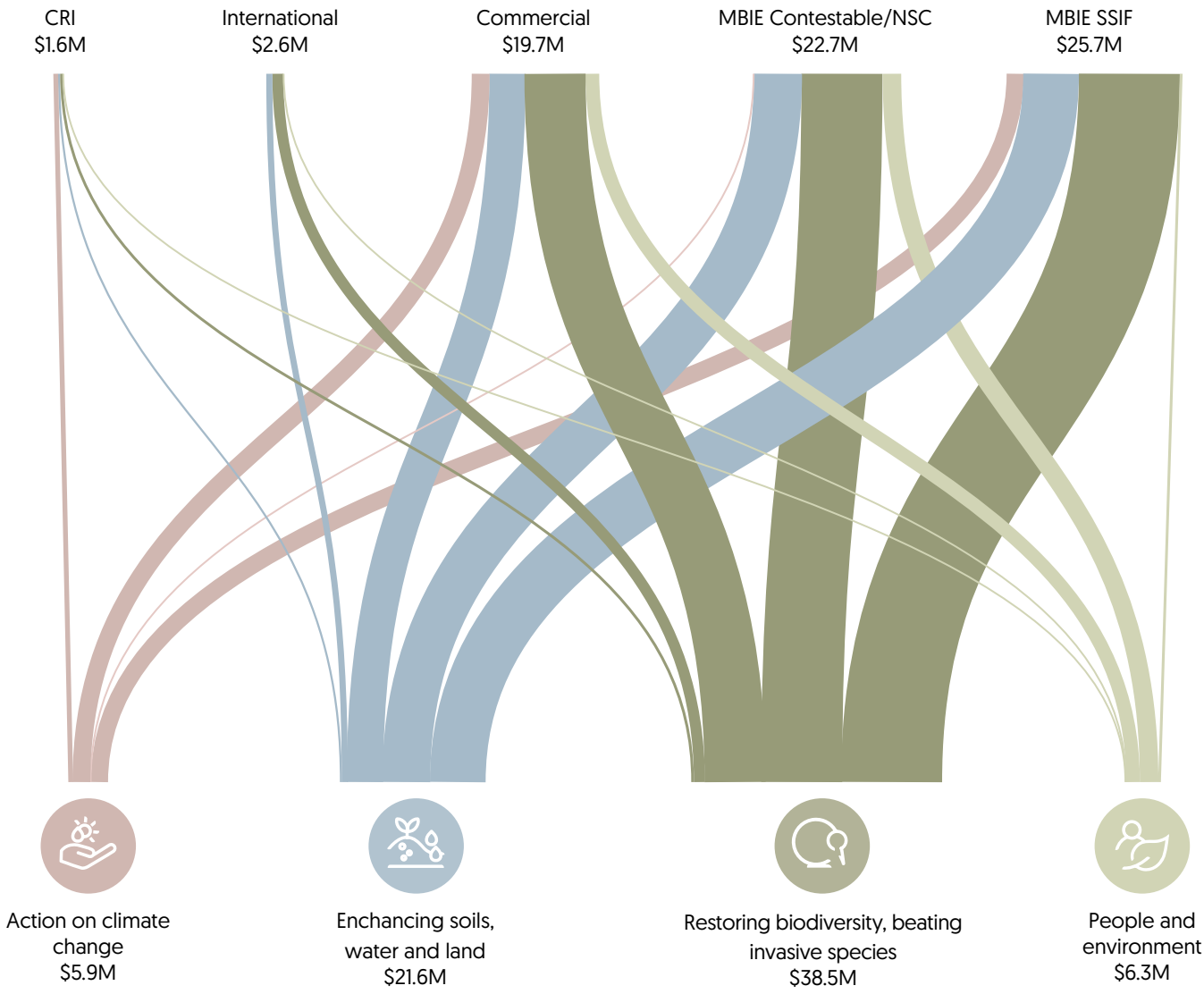


*From 2020/21 the counting method for the NZAC changed: the data show objects not specimens.

Note: Some of our staff work remotely: we have accounted for their locations at the nearest site.

Our investments in research impacts

Investment in our science, research, and technology comes from a variety of sources, including central and local government in AoNZ, industry, and international science collaborations. These investments power programmes across our four research impact areas. The following diagram is based on science revenue information for 2021/22 rather than on audited information.



Note: this diagram shows provisional revenue amounts for 2021/22. Full audited revenue amounts are shown in Part 2 of the Annual Report.

Collections and databases

Manaaki Whenua is the custodian of almost a third of AoNZ's Nationally Significant Collections and Databases. These include biological resources (e.g. reference species collections), cultural knowledge, and soil and land resources. They are important scientific, cultural, and historical public good assets. These collections provide base knowledge critical to improving the conservation of AoNZ's land-based biodiversity, including species of importance to Māori. They also provide important reference collections for identifying biosecurity risks.

In addition to our collections, we maintain a number of online databases and tools (many of which are nationally significant) that provide detailed information about our land, soils, biodiversity, biosecurity, and environment for use by our scientists and researchers, and for many other scientists, researchers, postgraduate students, government departments, regional councils, and industries across AoNZ and around the world

Tangata whenua also have an important connection to Manaaki Whenua's collections & databases. This is based on the relationship that tangata whenua have with their land, and extends to include anything collected, sampled or measured from that land. This connection is informed by the principles of Te Tiriti o Waitangi, the WAI262 claim and indigenous data sovereignty.

In recognition of this, we recently established an independent Te Tiriti Partnership Group (TTPG), comprising senior Māori from across a range of areas of expertise, to provide input and advice as we develop a Te Tiriti-led Strategic Plan for our databases and collections.

The terms of reference for this new group are to:

- consider the recommendations of the SAP review and develop, in conjunction with Manaaki Whenua staff, the strategic plan for their implementation and agree on priority actions and the allocation of SSIF to support them.
- engage in periodic reviews of progress of the priority actions, future priorities and funding allocations.
- act as a bridge into existing and new end-user communities (with a priority focus on iwi and Māori communities) to help raise the profile of the collections and databases.

The members of the group are drawn from across the AoNZ science ecosystem and include experts in tikanga Māori, indigenous data sovereignty, database and collection curation, Te Tiriti and Wai 262 claims.

We have already made actionable progress to co-design our future approach together. In July 2022 we held our first TTPG workshop, at which the group identified a number of themes. These will feed into the draft Strategic Plan, which we will take back to the group for further input and guidance. We envisage that in future years the group will convene annually to review our progress in implementing the Strategic Plan.

Towards a set of guiding principles for how we manage collections and databases

We continue to explore what it means to be Te Tiriti-led in how we manage our collections and databases. An example might be useful here. Occasionally researchers want to access our physical specimens from Aotearoa to do research for bioprospecting purposes or for other potential commercial benefit. In these cases we believe Te Tiriti places a high duty of care on us to "actively protect" indigenous rights and interests in those specimens. For this reason we are looking to adopt a guiding principle along the following lines: Access to, or use of, our collections for bioprospecting or other commercial research purposes will only be granted subject to confirmation that appropriate tangata whenua interests have been consulted and have given prior informed consent to the research activity. Other guiding principles are being developed and will be tested with the TTPG before being made more widely available.

COLLECTIONS

New Zealand Fungarium (PDD)

landcareresearch.co.nz/pdd

108,539	Specimens
178	Specimens sent
11	Loan requests responded to
190	Identification & enquiries
53	Visitors

New Zealand Flax Collection

landcareresearch.co.nz/harakeke

242	Selections
60	Orders sent
92	Visitors

International Collection of Microorganisms from Plants (ICMP)

landcareresearch.co.nz/icmp

23,140	Cultures
88	Orders sent
655	Cultures sent
240	Identification & enquiries
52	Visitors
202	Specimens cited[1]

New Zealand Arthropod Collection (NZAC)

landcareresearch.co.nz/nzac

c. 1.6M	Objects
17	Loan requests responded to
1,090	Identification & enquiries
14	Visitors

Allan Herbarium (CHR)

landcareresearch.co.nz/allanherbarium

c. 700,000	Specimens
406	Specimens sent
14	Loan requests responded to
856	Identification & enquiries
129	Visitors

DATABASES

National Vegetation Survey Databank (NVS)

nvs.landcareresearch.co.nz

18,374	Page views
12,3818	Plots
1,939	Datasets supplied
122	Data requests
741	Registered users
49	New datasets
1,001	Plots added

Ngā Rauropi Whakaoranga (Maori plant names database)

rauropiwhakaoranga.landcareresearch.co.nz

120,910	Page views[2]
2,408	Database records
35,841	Visitors

Land Resource Information Systems (LRIS)

lris.scinfo.org.nz

139,156	Page views
6,803	Data downloads
13,204	Registered users
44,163	Visits/sessions

[1] in scientific publications (based on Google Scholar).

[2] courtesy of Google Analytics.

Our context
Tō tātou horopaki

We know that AoNZ needs our science to solve growing environmental and social challenges. These challenges are complex, with large uncertainty, high stakes, and polarised views. Our role is to support and lead action with evidence-based understanding and capability, finding solutions from integrating our work with the work of others.

The context for our science begins with our Crown ownership and the expectations of our shareholding Ministers. The Government has laid out clear priorities for AoNZ that must inform our strategy and science priorities, including zero carbon and predator-free, and goals for freshwater.

To ensure our science stays relevant and on track to meet local, regional, and national needs, we adopt co-design principles wherever possible, including two Advisory Panels that draw on external expertise: one panel of scientists and one of stakeholders from government, iwi, industry, and the primary sector.

Beyond AoNZ, our internationally respected scientists are involved in global efforts to address the many challenges posed by climate change and sustainability.

Research Technician Ella Hayman and Dr Alex Fergus at Kaituna Valley Scenic Reserve near Christchurch. The reserve contains about 6 hectares of bush remnant with a few large mataī and kahikatea. An outstanding feature is a healthy even-aged stand of New Zealand ash/tītoki which dominates the forest. Image: Anouk Wanrooy.

New Zealand's science priorities

Manaaki Whenua supports the Government's commitment to an inclusive, sustainable, and productive AoNZ, and in turn our Minister, together with numerous Government strategies and policy statements, provides us with guidance on the Government's priorities for our land.

We take into consideration and contribute to relevant Government-wide initiatives and sector science strategies, such as the Ministry of Business, Innovation and Employment's (MBIE's) draft *Research, Science and Innovation Strategy* (*Kei Mua Te Ao*), and *Te Pai Kahurangi* (the CRI Review), in collaboration with appropriate organisations, iwi, agencies, and departments.

In 2021/22 we contributed significantly to the priorities for the Government that were expressed in our shareholding Minister's Letter of Expectation, as this report shows. We continued to fulfil the CRIs' role of maintaining AoNZ's strategic research and science capability in biodiversity, biosecurity, soil science, land-use planning, social, economic, bioinformatic, and climate adaptation and mitigation research. We maintained our scientific capability and built the resilience of our business and our people during the national Covid-19 response.

Our specific ministerial priority for Manaaki Whenua in 2021/22 was continuing to work alongside Plant & Food Research and ESR in developing the business case for an Auckland science centre at the Mt Albert site. This work includes working with MPI as plans for their future plant biosecurity capability and infrastructure emerge, which can be aligned with that centre.

Renuma Kumar and Sera Dau from CePaCT – the Centre for Pacific Crops and Trees, Suva, Fiji – have worked with Manaaki Whenua's Dr Ana Podolyan and Research Technician Caroline Mitchell on taro plant virus screening processes as part of the Pacific Seeds for Life project.
Image: Kim Triegaardt.

Stakeholder input

Manaaki Whenua's partner base is very broad because the natural environment touches every part of society. With a broad partner base comes a diversity of needs; but our partners have many interests in common. Our partners' interests in biodiversity, land, and water have remained consistent. Within the past decade, action on climate change has become a major theme.

By contrast, the complexity of our partners' needs has evolved quickly, and finding solutions is more urgent. Within a decade our partners have needed to integrate responses to multiple themes into their strategies, find new ways to engage with communities and address Māori aspirations, and manage higher levels of risk and uncertainty.

To understand the needs of partners more deeply we have established a range of forums with different target partner groups. These include an annual co-innovation workshop with primary sector and government partners, an annual iwi co-innovation workshop, and project-focused forums covering a range of audiences, including Design Thinking workshops with members of the public. Our target is to engage more research providers in joined-up efforts of this nature.

Our Board's **Outcome Advisory Panel** (OAP) provides advice to help us fulfil our Statement of Core Purpose through strategic alignment and collaboration with key users of our science. Membership of the panel spans the breadth of our major sectors, partners and research interests and consists of senior representatives from key stakeholder organisations in central and local government, iwi, the food and fibre industry, and business.

The Panel meets with our Senior Leadership Team to explore and clarify the needs of the natural resources sector, and provides high-level strategic advice to our Board of Directors. We continue to improve Māori input, connectivity, and our understanding of the needs of Māori, industry, and Government. Implementation of an engagement framework, its strategic alliances and plans, continues to progress with specific regional council and central government (MfE, DOC) plans now in place.

This year the Panel also explored the relationship of Te Āpōpōtanga strategic research goals with their organisations, providing valuable feedback on how it may connect and assist in their science needs. Future OAP sessions will drill down on the specific areas of interest and provide a valuable connection with the Board on contributing to broader iwi, government and industry direction.

Our **Science Advisory Panel** (SAP) brings an international scientific perspective, helping us evaluate our scientific excellence, explore emerging science needs, and develop research areas.

In 2021/22 the panel reviewed how we could deliver greater value from our biological Nationally Significant Collections and Databases. The review was in three parts; a remote evaluation of a submission we provided, followed by a 2-day hui with key Māori partners to explore what being a good treaty partner would mean for how we manage and run our collections and databases. Finally, we held a series of online meetings with a wider panel containing international experts from collections in Australia, the Netherlands, and the USA. A combined report with recommendations went to the Board in December and was endorsed by them to implement.

The main findings were that we:

- need a strategic plan for all the collections, with leadership from both Treaty partners and input from other externals (data scientists, industry, education, etc).
- need a vision for the role and future of collections, especially in relation to Māori.
- repatriate all or parts of collections while co-developing the strategic vision.
- move from collecting, curating and categorising to connecting (all knowledge systems), collectivising and creating (values, benefits, knowledge).
- increase accessibility, thereby reaching new audiences, including increasing the rate of digitisation, and providing one platform for all the data.
- grow connections (internally and externally) to increase visibility and impact of our collections.
- distinguish between research and curation in new hirings.

Following the review above, we have established a Te Tiriti Partnership Group (see page 10) to help us make strategic decisions about how we implement the recommendations from the review. The Group will help us prioritise the actions we now take, ultimately by approving the strategic plan we will present to them.

Our strategic priorities
O mātou whakaarotau rautaki

In 2017 we developed Strategy 22 – our strategic priorities for the 5 years to 2022. As we approach the end of that period, significant changes are occurring in our operating environment, so we chose to refresh Strategy 22 for a 2- to 3-year transition period.

Our Strategy 22 refresh has identified goals and priorities for the next 2–3 years. The desired outcomes of these are explained on the following pages.

Strategic goal 1.
Weave the principles of Te Tiriti into our fabric

Strategic goal 2.
Drive research impact with our partners

Strategic goal 3.
Create a sustainable environment for our research and people to thrive

An aerial view of our new buildings Te Rauhītanga [The Gathering Place] at the Lincoln site, officially opened in May 2022. The solar arrays provide base load power to the Godley building on sunny days.

Strategic goal 1

Weave the principles of Te Tiriti into our fabric

The Treaty principles will guide Manaaki Whenua to a balanced state of partnership; in finding inspiration and value while engaging science and mātauranga; in influencing our strategic leadership towards equitable outcomes; and in growing both the number of Māori in the organisation and our networks among iwi and hapū.

Current Focus

Kia Māia

Kia Māia (be brave) is our bicultural competency initiative, developing the skills and knowledge we all need to help honour our Treaty commitment.

Our current priorities are:

1.1 Bring external Māori into our leadership processes as partners, helping to shape our strategies.

In 2021/22 we established an independent Te Tiriti Partnership Group (TTPG, see also page 10), comprising senior Māori from across a range of areas of expertise, to provide input and advice as we develop a Strategic Plan for our databases and collections. In July this year we held an initial workshop with the TTPG at which they provided feedback on a number of themes they saw as needing to be addressed in our Strategic Plan. Based on this feedback, we are now developing the plan which we will present back to the group at our next workshop in November. We anticipate in future years that we will convene the TTPG on an annual basis to review progress on implementation of the plan.

1.2 Support iwi as kaitiaki through internal Māori leadership and co-leadership of our research.

In February 2022 we appointed three Kaihautū – senior Māori research leaders – across the three science impact areas of land, biodiversity and climate action. The Kaihautū have been working across our existing research portfolios to support Manaaki Whenua to deliver on its Tiriti commitment across these domains.

There is now a new expectation that each Portfolio Leader co-develops their 3-yearly Portfolio Strategy, Annual Portfolio Plan and overall SSIF allocations with one or more Kaihautū. This new approach is in keeping with the principle of increased Māori co-design and co-leadership of our research agenda as signalled in Te Āpōpōtanga and our Statement of Commitment.

The three Kaihautū are functioning as a team and operate effectively as integrators, from a te ao Māori perspective, of the research occurring in each of the portfolios.

1.3 Enhance participation of Māori in Manaaki Whenua through supporting new kairangahau (Māori researchers) into a research career with pathways to senior roles.

We continue to seek to grow our pool of senior, mid-career, and early-career kaiarangahau Māori. We are actively working to build the capability of our early career kairangahau in particular by providing both cultural as well as technical supervision and support in their areas of expertise.

This year we hosted six Māori students through our summer internship programme (Poipoia Kia Rere) and the campaign is already underway to host a similar or larger cohort for our 2022/23 summer programme.

One challenge is that demand for te ao Māori perspectives in the science and research sector exceeds the available supply of kairangahau Māori. For this reason we are exploring ways to externally source additional te ao Māori and kaupapa Māori research capacity where possible.

Our Kia Māia bicultural competency programme was rolled out to all staff this year with a range of Te Tiriti training, cultural awareness modules and te reo Māori learning opportunities. The objective is that all staff eventually achieve a cultural competency baseline that will equip them to better engage tangata whenua in the spirit of empathy and understanding of their respective roles as tangata Tiriti and tangata whenua.

We are working to embed programmes and project connections (through Vision Mātauranga projects and more broadly: see for example the update about āwheto on page 34) that help expose our Pākehā colleagues to iwi/Māori organisations so they gain experience and confidence in working in Māori settings to help achieve their taiao aspirations.

We are also creating or modifying investment instruments to facilitate mātauranga Māori research and Māori leadership. Our statement of commitment to Te Tiriti explicitly commits Manaaki Whenua to increase the proportion of SSIF-funded projects that are co-designed with Māori and under the leadership of the Manaaki Taiao (Senior Kairangahau Māori) Leadership Group.

Strategic goal 2

Drive research impact with our partners

Together with our partners we will prioritise AoNZ's needs from research (now and in the future) and develop strategic investment pathways. Research impact will be accelerated through user-centred developments. We will leverage data and digital technologies where they add value.

Current Focus

Collections & databases

We are developing a strategy that puts our commitment to Te Tiriti at the centre of a plan to increase the value of our collections & databases to New Zealand.

Our current priorities are:

2.1 Prioritise AoNZ's needs from research (now and in the future) together with our partners, and develop strategic investment pathways.

This year we have made significant progress in our partnerships via the TTPG (see page 10) and enabling and including a major shift in gear around the nation's predator-free goals (see page 34).

We have continued to work with partners to make our tools and resources more usable, for example partnering at a regional scale with Waikato Regional Council in the Hauraki and Hawke's Bay Regional Council on improving the use of LiDAR remote sensing technologies, and continuing to refine our S-map soil mapping capabilities.

2.2 Invest in our research and innovation in ways that accelerate its impact.

This will require a user-centred approach informed by our partners' world views. It will see new partnerships and new technologies.

This year, pathways to impact have continued to expand in many of our research activities, including notably for Toitū (see page 43). We have also made significant progress in the careful commercialisation of the novel rodenticide DR8, for which the building blocks for a commercial licencing agreement are in place.

2.3 Leverage data science and digital technologies to increase value for our users and customers.

Rapid changes in technologies have made data more accessible, but our focus will be on creating value rather than simply more information and tools.

Much of our research – from the widest remote sensing map to the smallest DNA sample – relies on digital tools and data. This year we formed a new Digital Leadership Group (DLG) to lead and enable Manaaki Whenua's digital future. The vision of this group is for Manaaki Whenua to embrace and leverage the disruptive power of digital technology in pursuit of high-impact research.

Supporting Manaaki Whenua's work requires that we provide access to suitable infrastructure, build capability to use digital tools and techniques, support staff with use of digital tools, develop data management strategies and tools, and manage the security of our information and data. The organisation is supported in this by our involvement in the New Zealand eScience Infrastructure (NeSI) and by the international REANNZ data-sharing network. However, the work that underpins these needs is currently managed in several different parts of the organisation.

The DLG will connect these parts and develop clear organisation-wide priorities for investment in our digital future.

We also have several formal governance needs across our data and digital assets. Archives New Zealand sets standards for information and records management, and the *New Zealand Information Security Manual* guides government organisations and sets specific expectations for governance of information and cyber security. These requirements will also be supported by the DLG.

In May 2022 we were able to act quickly to develop a new initiative with Microsoft's international AI for Good team, working on the improved detection of land use and forest cover change across AoNZ using high-resolution satellite imagery.

During the year we were instrumental in bringing the National Environmental Data Centre (NEDC) into being. Launched in April 2022 and powered by high-performance computing and increased data storage and analytics capability, NEDC is a collaborative CRI initiative that provides easy access to important national environmental data for science, government, local bodies, industry, business, iwi and Māori partners, and the public.

We also created a new collaborative home for all our taxonomic information – the Biota of New Zealand site, an amalgamation of the NZFlora, NZFungi, NZFungi2, and NZInverts datasets. As an indication of the importance and wide use of these datasets, NZFungi2 had more than 450,000 page views every year.

Strategic goal 3

Create a sustainable environment for our research and people to thrive

We will ensure our people have the right environment and personal development in which to work to their greatest potential, so that Manaaki Whenua fulfils its national role and sustains and grows its national and global impact.

Current Focus

Mahi Tahi - Working Together

Ensuring our research and support staff are working together as one team, supported by the processes and systems they need, to efficiently deliver high-impact research for New Zealand.

Our current priorities are:

3.1. Adapt global trends in the Future of Work to meet our needs in Manaaki Whenua.

The global pandemic has changed people's expectations of their place and style of working. This has coincided with changes in the social dynamics around equity and diversity, health and well-being.

Social media and online connectedness have transformed people's interactions, and the world faces exponentially increasing cybersecurity risk. The Future of Work recognises these changes and responds to changing workforce demographics and expectations.

As described on page 52 this year we have further refined our flexible working arrangements for staff to enable them to manage their work/life balance and their health during the Covid-19 pandemic and the 2022 winter flu season.

3.2 Be proactive in 'making our future' through the science system reset.

Government's far-reaching change in the research, science, and innovation sector will create opportunities and risks for our people and culture. We will pursue these opportunities and work hard to sustain what is valued by our people and partners – the strength of our community and external relationships.

In response to the government's green paper *Te Ara Paerangi / Future Pathways*, published in September 2021, we encouraged all our science and support staff to engage in the submission process and we submitted a detailed organisational response. As an organisation,

Manaaki Whenua welcomes *Te Ara Paerangi* and the opportunities it opens for creating a fit-for-purpose science system. We look forward to ongoing discussions with MBIE throughout the next stages of the system reset, and recommend that sector reforms are focused on creating impact for AoNZ. This will require a co-development approach with mana whenua, with the other Crown Research Institutes and with our stakeholders, partners, and clients with whom we have invested 30 years of relationship development.

3.3 Enhance our project lifecycle systems and processes using human-centred design and effective change management.

Over recent years the pressure has grown on our researchers to manage much more than simply their research. Our project lifecycle systems and processes (linking design to delivery of research contracts) should be reset to ensure we have the right people doing the right things with the right skills and tools.

In 2021/22, our internal Te Tūāpapa (The Platform) project, which aims to help our research and support staff to work together as one team, supported by the processes and systems they need, was redesigned from the ground up, incorporating aspects of human-centred design and Agile methods.

The vision of the redesigned project, now know as Mahi Tahi (Working Together) is as follows: Our research and support staff are working together as one team, supported by the processes and systems they need, to efficiently deliver high-impact research for New Zealand.

The project team held workshops across science and support roles, at which over 1,800 comments and ideas were received that explored new and better ways of working together. Project participants across the organisation were identified, and business analysts were appointed. A steering group was also formed, and a business case approved by the Board. One of the first tasks for the project team was to investigate whether or not a business solution being adopted by GNS and ESR would also be appropriate for our needs. This work is ongoing.

Our science
Tō tātou pūtaiao

Delivering on our core purpose, to fix the complex environmental problems facing AoNZ, requires exceptional science and research integrating a wide array of scientific disciplines.

Manaaki Whenua acknowledges mātauranga Māori (New Zealand indigenous knowledge) as a world view complementary to Western science. We believe that our work and impacts are enriched when we build understanding between scientific and Māori world views. Mātauranga Māori stands alongside our science in providing insights into our land and our future for all New Zealanders.

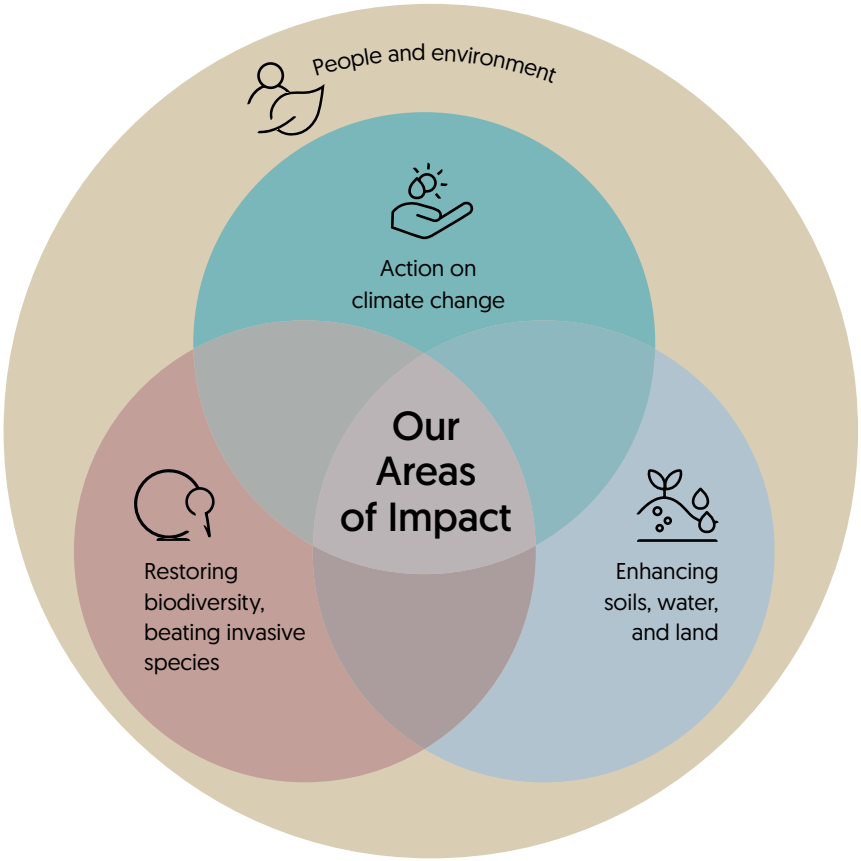
Dr Paul Mudge inspects pasture soil cores. Image: Dave Allen, courtesy of AgResearch.

Our four research impacts

Our four research impacts are designed to present our science and research in an approachable and meaningful way, for all people in AoNZ to engage with.

Much of our research work is focused where these four research impacts overlap. This integration is important to many of our partners, who must address issues collectively and not in isolation. Our partners address not only the integration of land, water, and biodiversity, but also the integration of social, economic, and cultural dimensions.

Our research in these four areas has 12 research outcomes, which are needed by our partners.



Our 12 research outcomes

1. Critical knowledge of the wealth, state, and trends in our biodiversity, soils, and lands informs natural resource decision-making
Our environmental data resources and foundational knowledge provide fundamental information for AoNZ's economy, environmental management, environmental recovery, and social development. Our data are used by policy makers and land managers across the country and further afield in the Pacific region to underpin wise choices and decisions about land use.

2. Hapū and iwi act confidently as kaitiaki of their whenua using science and mātauranga Māori
In a post-Treaty of Waitangi settlement landscape, iwi, hāpu, and whānau are repositioning themselves to enable active kaitiakitanga, from the bottom up and the top down. Across Manaaki Whenua, but particularly through our Manaaki Taiao rōpū [group] of kairangahau Māori [Māori researchers], we work with iwi, hapū, and communities to develop strategic planning, policy, and monitoring tools informed by mātauranga Māori and science to support kaitiakitanga. Over time we are building strategic partnerships with our Māori partners for mutual benefit.

3. Māori land trusts and incorporations achieve their aspirations for their land
Following Treaty settlements, Māori entities are increasingly important landholders in AoNZ. We aim to provide tools and enhance capabilities in partnership with Māori land trusts and other incorporations to support their management decisions.

4. Ecological restoration is guided by knowledge of past and present ecosystems
Our research provides baseline information to show how species and ecosystems respond to environmental changes and human activities, and to help inform conservation management plans and policies.

5. Land use, soils, and erosion are managed to improve freshwater quality
We undertake a diversity of research and consultancy projects, including fundamental understanding of erosion processes, landscape dynamics and response in a changing environment, erosion and sediment modelling, and tools for the control and mitigation of soil and land degradation.

6. Productive lands are regenerative at the landscape scale
We support the productive sector to make effective decisions to improve productivity, reduce costs, and operate sustainably as part of the drive towards a sustainable food and fibre sector.

7. Risk and harm from invasive organisms are mitigated
Our native biodiversity and our ability to derive income both from primary industries and from our unique landscapes are constantly threatened by invasive weeds, pests, and diseases. Our work enables AoNZ to better respond to biosecurity threats, reduce pest, weed, and disease impacts, and better protect our native taonga. Our expertise in predator modelling has also been crucial to AoNZ's response to the Covid-19 pandemic.

8. Biosecurity tools are available with social licence
We design and develop socially acceptable biosecurity tools for wildlife management, and for the control of invasive plant species.

9. Communities and regulators have adaptation pathways for climate change
We have built significant expertise, capability, and capacity and positioned ourselves as one of the leading science providers in AoNZ for climate risk, resilience, and adaptation research, with a growing international profile through high-impact publications and collaborations. Working with a wide range of stakeholders, we have developed new tools, frameworks, and processes to support adaptation planning, risk and resilience assessment, monitoring, and evaluation frameworks.

10. Greenhouse gas emissions and removals are managed to mitigate climate change
Sustainable land management to create climate-smart landscapes is an essential part of ensuring AoNZ reaches its climate emission targets. Our science enables the right decisions to be made and the right policies to be put forward to manage our greenhouse gas emissions now and in the future.

11. Environmental decisions are underpinned by advanced geospatial information
Mapping and regular monitoring of land cover and land use are critical to understanding environmental state, health, and pressures. Our nationally significant digital databases of land use are the authoritative information source for this work.

12. National environmental outcomes are improved by integrating social practice theory, policy tools, and economics.
Our team of social and economic scientists is the largest in the Southern Hemisphere dedicated to researching the human dimensions of environmental management.

Enhancing soils, water, and land

Soils are critical to our productive and natural landscapes, and their health is thus central to society's well-being. One of the greatest challenges facing regional and national agencies, and the food and fibre sector, is the integrated management of land and water to provide sustainable production, while simultaneously protecting downstream ecosystems and supporting diverse community and iwi values. Soils hold more water than our rivers, lakes, and aquifers. They are the pathways for pollutants from land use, and the source of sediment entering waterways from erosion. Soils are being lost by erosion from productive lands at unsustainable rates. Our work provides understanding of soils, capability to manage the effects of land use, and confidence to deploy mitigation approaches.

Selected highlights

Our online soil mapping resource S-map has continued to grow. We are working with 10 councils and MPI to extend S-map's coverage by over 2 million ha by 2025, with c.700,000 ha of new soils maps to be released during 2022.

Our Soils Portal, a comprehensive source of online information about AoNZ's soils for land managers, scientists, teachers and students, turned 10 years old this year and was completely upgraded, to coincide with World Soils Day in December 2021.

We successfully completed the first national winter forage crop map, using time-series satellite imagery with cloud cleaning and atmospheric and topographic corrections to make areas of winter forage more readily identifiable. This work will benefit land managers and policy makers concerned to understand seasonal patterns of land use change.

Senior Researcher Dr Adrian Monks presented to a combined meeting of Meridian Energy and Guardians of Lakes Manapouri, Monowai and Te Anau in October 2021. Meridian runs the Manapouri power scheme, and must report to the Guardians on the environmental effects of its operations. Our presentation summarised the results of investigations into the long-term effects of the 2019 high water event at Lakes Manapouri and Te Anau in which terrestrial shoreline vegetation was flooded when high rainfall caused large inflows into the lake. We showed that no long-term effects on the terrestrial vegetation arose out of this event, which provided reassurance to Meridian and its stakeholders that no change in the rules governing lake level management were required to manage future events.

Pedologist Dr Balin Robertson undertaking soil sampling in the Catlins, South Island. Image: Kirstin Deuss.

Multiple conference presentations in this research impact area included to the NZ Hydrological Society, Farmed Landscapes Research Centre (FLRC), and Environmental Forestry meetings. Our scientists also co-convened a session at the European Geoscience Union General Assembly.

Contract reports for Horizons Regional Council, Otago Regional Council and Our Land & Water National Science Challenge focused on erosion and sediment modelling, including climate change impacts. We delivered a very well-received workshop for Horizons on Manaaki Whenua's SedNetNZ sediment modelling capabilities to support the implementation of the *National Policy Statement on Freshwater Management* (2020).

In work for regional councils we evaluated soil quality indicators for state of the environment reporting and explored integrating Te Ao Māori into the management of soil contaminants. We also published new research on soil cadmium in agricultural systems and its accumulation in animals, on microbial communities in pasture soils, and on the effects of maize cropping on soil hydraulics.

Our scientists continue to work on the evidence base for regenerative agriculture practices, including the scoping and development of future projects to measure and verify regenerative outcomes compared with conventional farming. We are also providing behind-the-scenes science expertise to a whole-farm-scale study in North Canterbury being run by Ngāi Tahu Farming Limited and Ngāi Tūāhuriri in partnership with MPI. Te Whenua Hou, Te Whenua Whitiora (The New Land, The New Horizon), announced in mid-2022, is a 7-year project comparing a conventional and a regenerative dairy farm side by side.

Our Advanced Remote Sensing Aotearoa Endeavour research programme ran a series of webinars in May 2022 to showcase some of the recent developments in remote sensing technologies, including landslide modelling, and how these are applied to answer questions for policy-makers, councils and landowners.

Innovation stories

Making "un-poplar" decisions: a framework for better tree choices in our hill country

Around 20% of AoNZ (5.2 million ha) is classed as "hill country" – much of it marginal pastoral agricultural land with low productive potential. Often steep and treeless, hill country is prone to soil erosion and rapid surface runoff after rainfall. Land managers in hill country generally resort to strategic tree planting to stabilise soils in places prone to shallow soil slips, earthflows, and gully formation. Poplar and willow are most often chosen, at densities that range from 20 to 200 trees per hectare. Choice of tree has been largely pragmatic – both poplar and willow can be planted as unrooted poles that can survive grazing immediately – with decision-making based on tree performance rather than on wider ecological, economic, and cultural outcomes.

In new research, supported by Manaaki Whenua's Endeavour research programme Smarter

Targeting of Erosion Control (STEC), we assisted PhD candidate Thomas Mackay-Smith and colleagues at Massey University to update a widely used framework for decision-making on tree choice, originally developed for agroforestry systems worldwide in the early 1990s.

The updated framework adopts a broader "silvopastoral" outlook, in which trees are fully integrated into a pastoral system rather than just being used as a tool for soil stabilisation. It includes interactions between trees and livestock, and between the grazing livestock, soil, and pasture. New environmental considerations include biodiversity interactions, greenhouse gas implications, the longevity of the tree, and costs and ease of tree establishment. The framework also accommodates cultural outcomes such as animal welfare, cultural values of tree species, and aesthetic values such as ease of shaping.

Little work has been done on kānuka in a silvopastoral context, but the framework shows that kānuka has many benefits compared with poplar. For example, evergreen kānuka potentially provides more shelter for animals and warmth in winter, causes less pasture smothering from leaf fall, is much longer-lived, is known to support native bird populations, is culturally important to Māori, and is also a potential source of extra farm income from honey and essential oils. Kānuka has been studied rather than mānuka because it forms a larger tree when growing isolated in hill country. The framework also highlights surprising knowledge gaps for poplar – a much-researched tree in agroforestry – in terms of biodiversity interactions, livestock shelter, greenhouse gas implications and water and nutrient gains or losses.

Dr Scott Graham in a lucerne crop at Ashley Dene. Image: Brad White.

The role of trees in AoNZ's pastoral hill country has been contentious for many decades. However, as society explores new ways to combat the effects of rising CO_2, trees will become increasingly important as part of nature-based solutions in our hill country landscapes, and an assessment framework for choosing what tree to use where, and why, is a good starting point.

Getting to the root causes of soil erosion using high-res remote sensing

Soil erosion processes are notably active in AoNZ: our steep slopes, generally weak sedimentary rocks, and high annual rainfall totals including frequent large rainfall events, underscored by a history of vegetation clearance for agriculture, mean that around 192 million tonnes of soil on agricultural land are lost to erosion every year.

Large rainfall events in AoNZ commonly trigger hundreds to thousands of shallow landslides, especially in more marginal pastoral hill country, causing significant damage to land and infrastructure as well as contributing large quantities of sediment to aquatic environments. These landslide inventories are used to determine which land is most susceptible to shallow landsliding to support targeting of erosion control measures.

Within the STEC research programme, scientists at Manaaki Whenua have been using new remote sensing techniques to fill these data gaps, mapping over 100,000 landside scars from high-resolution satellite or aerial imagery across the North Island. The latest mapping uses very high resolution (0.5 m) satellite imagery from storm events. These landslide inventories

form the basis for machine learning models that predict where future landslides may occur based on landscape factors such as topography, land cover and rock type. Regional-scale modelling of shallow landslide susceptibility for Hawke's Bay and Horizons is now complete.

As part of his PhD work within the STEC programme, Manaaki Whenua's Raphael Spiekermann used semiautomated mapping with high-resolution aerial imagery and slope information from Light Detection and Ranging (LiDAR) data to record some 40,000 shallow landslides in the Wairarapa. Use of LiDAR-based data significantly improved the ability to correctly identify landslide versus non-landslide locations. The current acquisition of LiDAR elevation data across much of AoNZ will enable improved targeted erosion control with higher-resolution landslide susceptibility modelling.

In linked work published recently in the *Journal of Environmental Management,* Manaaki Whenua's Mr Spiekermann, Dr Hugh Smith, and colleagues at Massey University have used LiDAR to delineate individual tree crowns on two pastoral hill country farms near Masterton. This is the first classification of individual trees at landscape scale in AoNZ using freely accessible data, which achieved an overall accuracy of 92.6%.

Tree roots bind soil and help mitigate soil erosion, but some species are better at it than others. Poplars and willows are commonly used in pastoral hill country to mitigate landslide erosion on hillslopes. By identifying the locations and types of trees present or planned in the landscape, the researchers can estimate the reduction in future landslide erosion achieved.

Managing lucerne to fix soil nitrogen

Lucerne is a widely used grazing fodder crop, and, like other legumes, is able to fix nitrogen (N) in the soil. Well-managed lucerne is highly productive and the plant also has deep roots, which allow water extraction from well below 2-m depth and extract N from the soil.

Lucerne has been used extensively as forage for dryland sheep and beef farms in AoNZ, but few measurements of leaching losses from lucerne have been made, leaving a knowledge gap about whether its use in intensive, irrigated systems could reduce N leaching via extraction of water and nutrients at depth. This knowledge is important because the irrigated land area of AoNZ has increased by more than 90% over the past 15 years, to nearly 800,000 hectares, primarily to support dairy farming expansion. The intensification of land use associated with irrigation has been most pronounced in the Canterbury region, where shallow, stony soils are prone to nitrate leaching losses. Nitrate leaching for the region is estimated to have doubled between 1990 and 2011.

As part of the MBIE Endeavour programme Reducing Nitrogen Losses from Farms, Manaaki Whenua's Dr Scott Graham and colleagues aimed to quantify losses of N through leaching and crop harvest for lucerne on stony alluvial soils in two paddocks under different irrigation, effluent, and grazing management: one non-irrigated and one irrigated with water and effluent.

The study ran for three full growing seasons. It used six large lysimeters at the Ashley Dene Research Station, Lincoln University, for the soil drainage and leaching aspects of the study. Effluent and water inputs from the pivot irrigator were carefully monitored. Using stable isotopic analysis of the N in lucerne biomass, the researchers were able to differentiate between N fixed by the lucerne from soil N, effluent or animal dung and urine sources.

The study showed that the amount of N leached from irrigated and effluent-treated lucerne each year was from 1.5 to nearly 15 times greater than that from non-irrigated lucerne. N fixed by the lucerne was much less prone to leaching than N from the grazing animals and from the effluent. The progressive change from cut and-carry to grazing of lucerne also resulted in three times more N leached. Surprisingly, a summer rain event that led to soil drainage outside the normal winter leaching season at the irrigated site contributed more to N leaching than the typical winter leaching losses.

This work has important implications for farm management. First, planting lucerne is not an effective strategy for mitigating N leaching losses. The researchers also recommend irrigation practices that maintain a soil water deficit would limit additional soil drainage and leaching as a result of irrigation, particularly for summer rainfall events that contribute to high leaching losses.

Restoring biodiversity, beating invasive species

AoNZ's indigenous biodiversity evolved in isolation and much is globally unique. We curate national and Pacific collections of biodiversity on land (plants, invertebrates, fungi, and microorganisms), and our research helps users understand and value its richness, observe changes and risks from exotic species, and find new uses for biological materials. Our research provides understanding of how ecosystems function, the threats they face, and how they can be restored. The potential for Māori whānau, hapū, and iwi to generate economic returns from indigenous plants continues to be a strong area of interest. We contribute to national biosecurity through providing capability and confidence in assessing biological threats and using control tools – especially at landscape scales – for weeds, pests, predators, and diseases.

Selected highlights

Endeavour funding was secured for a project co-led by Kaihautū Dr Phil Lyver: 'Te Weu o te Kaitiaki – (The Roots of the Guardian) Indigenous regeneration pathways'. This project uses a te ao Māori worldview and whakapapa frameworks alongside the integration of value and ecological networks to re-imagine biocultural solutions for forest management which restore ecological systems, reinforce identity, reconnect people to place, enhance community well-being, and deliver sustainable economic growth for communities.

Two Endeavour Smart Idea projects were also funded: one, led by Dr Patrick Garvey, to harness the power of behaviour manipulation to reduce the impacts of cat predators on native species; the second, led by Dr Manpreet Dhami, to investigate the potential of fungi and bacteria that live in flowers to attract pollinating bees to increase their pollination of valuable crops.

As part of the More Birds in the Bush Endeavour research programme, Dr Jo Carpenter published results of a study showing how rats are affected by low food availability in cool, high altitude beech forests – a key contribution to understanding rat dynamics especially given a warming climate.

Senior research technician Rowan Buxton measuring wilding pines at Molesworth Station. Image: Brad White.

The Allan Herbarium and associated databases are central to the work of other government agencies – for example, Tier 1 National Heritage Monitoring System – the country's national biodiversity monitoring programme. This year the Allan Herbarium hosted three interns from the Department of Conservation who contributed towards the accessioning of over 2400 vascular plant collections (including ferns) and over 200 cryptogams (bryophytes and lichens). We also hosted biosystematics students from the University of Auckland at our Fungarium.

Bennett's wallabies in the South Island and dama wallabies in the North Island are spreading and increasing in numbers. MPI leads a National Wallaby Eradication Programme; Manaaki Whenua is contributing to the programme science, including in wallaby detection, genomics, spatial ecology, probability mapping of wallaby presence, improvement of bait stations, and testing of lures and baits.

The second volume of the *Te Reo o Te Repo* cultural wetland handbook series published by Manaaki Whenua was launched at the INTECOL Wetlands International Conference in October 2021. The handbook provides Māori values, knowledge, and perspectives from across AoNZ and explains the cultural significance of repo that can help define priorities for wetland restoration.

MfE contracted Manaaki Whenua to develop a national pasture exclusion assessment tool to identify wetlands in pastoral landscapes that do not meet the definition of 'natural wetland' under the *National Policy Statement – Freshwater Management* (NPS-FM) and associated regulations. Working with a core group of wetland ecologists from around New Zealand, Dr Bev Clarkson, Field Technician Scott Bartlam, and Karen Denyer of the National Wetland Trust developed an approach that was tested in field trials and stakeholder workshops.

New populations of old man's beard sawfly (*Monophadnus spinolae*) and the recently released eriophyid bud mite (*Aceria vitalbae*), two biocontrol agents for old man's beard (*Clematis vitalba*), one of New Zealand's worst invasive weeds, have been successfully established in Canterbury. The mites in particular are doing well and have spread far from their original release sites.

In work funded by MFAT, we are indexing taro virus with the Centre for Pacific Crops and Trees in Fiji, to check and clear their taro collection ahead of distribution to Pacific countries. Ensuring access to drought- and salt-resistant lines of a key food crop will boost food security in a region increasingly affected by climate change.

Ngāti Kuri have established a formal commitment from the Auckland Botanic Gardens to receive 500 critically endangered, cutting-grown rātā moehau per year over the next 5 years. This contributes to Ngāti Kuri's overall vision of 1,000 rātā moehau back into the wild within 5 years. Ngāti Kuri are leading the research, and Manaaki Whenua are providing technical support in a partnership arrangement.

A yellow Māhoenui giant wētā (Deinacrida mahoenui). *Image: Samuel Purdie.*

Postdoctoral Fellow Dr Natalie Forsdick completed research on the conservation genomics of the Māhoenui Giant Wētā (*Deinacrida mahoenui*), comparing a source population at Māhoenui Scientific Reserve with a translocated population on Mahurangi Island. Analysis showed very low levels of genetic differentiation between the two populations, proving to DOC that the translocation strategy they used has ensured no significant loss of genetic variation.

Dr Eva Biggs and colleagues completed a Vision Mātauranga Capability Fund project in which they worked towards Te Awahohonu Forest Trust's aspirations to reconnect with their natural heritage. One of their specific aspirations was to rediscover āwheto in their native forest and to gain knowledge on preservation of healthy āwheto populations. The project connected āwheto formation to healthy moth populations and red beech forest. The moths don't appear to have any introduced predators and deer seem to help maintain the foliage clearings needed for the moth to fly and lay eggs. This project strengthened our relationship with the Trust and provided foundations for future work together.

A 5-year Better Border Biosecurity (B3) project, using latest DNA sequencing technology to significantly improve MPI's ability to identify unknown potential biosecurity threats, came to an end in June 2022. Led by Manaaki Whenua's Dr Peter Johnston, this project addressed the critical issue of misleading species identifications from inaccurate DNA sequence data. Johnston and his team matched molecular data on invasive species to authentically identified specimens in Manaaki Whenua-managed authoritative collections of pests and living cultures.

Manaaki Whenua and Predator Free Rakiura signed a significant research partnership agreement worth a joint $2.8 million over 4 years to work together towards ridding Rakiura/Stewart Island of all major predators – possums, rats, feral cats and hedgehogs. A predator eradication project of this combined size and complexity has never been attempted before. It will be the biggest island predator eradication ever attempted globally and will also be a world-first project on an inhabited island. The research partnership will drive deep insights into achieving freedom from predators, a critical part of which is understanding the social aspects of resourcing, achieving and maintaining freedom from predators from the perspective of the local community and iwi. It will be a major step towards the goal of a predator-free AoNZ.

Innovation stories

Winning against Wildings – an update

Introduced conifers are the backbone of commercial forestry in AoNZ, worth around $5 billion a year. However, invasion of land by wilding conifers is arguably AoNZ's most serious and intractable weed problem.

Before 2016 wildings were estimated to be invading the equivalent of nine high country stations, or about 90,000 hectares, each year. Wildings are now thought to occur on at least 1.8 million hectares nationwide, and without control could invade a third of our total land area within 35 years.

Wildings have profound impacts on our national biological heritage, ecosystem services, economy, and cultural values. As a result, land managers, government agencies, and community trusts collectively spend over $14 million each year managing the problem.

As part of a nationwide response, a team of Manaaki Whenua scientists, led by Dr Duane Peltzer, undertook a wide-ranging MBIE-funded Endeavour programme, Winning against Wildings. The programme was a major collaborative effort with Scion, BioProtection Aotearoa, and the University of Canterbury, and it strengthened partnerships with the National Wilding Conifer Control Programme, the New Zealand Wilding Pine Network, and on-the-ground practitioners. The overall goal of the 5-year research programme, which began in late 2016, has been to ensure the long-term success of the National Wilding Conifer Management Strategy, which ambitiously aims to control or contain wildings nationally by 2030.

New knowledge, evidence, tools and processes developed through our research have generated a wide range of benefits with multiple pathways of uptake – including conferences, webinars and close links with operations and the forestry industry. These multiple approaches ensured our findings, tools, and innovations are widely implemented.

Highlights of the programme:

- We have quantified spread risk among wilding conifer species, and discovered that their dispersal distance is further than previously known. Spread risk is also driven by variation in seeds within individual trees rather than there being a few 'risky' trees that drive invasion.
- New remote-sensing methods have been developed to detect and map wilding invasions at large spatial scales, including the use of unmanned aerial vehicles (drones) and algorithms that can measure land-use change. These approaches are being used by managers to better plan control efforts, and to help ensure wilding spread is contained.
- Low-dose herbicides to control dense wilding invasion have been developed and tested operationally, reducing the chemicals used in management while effectively controlling over 95% of wilding trees.
- Ernslaw One, the largest Douglas fir grower in AoNZ, is establishing industry trials of Douglas fir that produce fewer seed cones to test their suitability for forestry use across a wide range of environments and thereby significantly reduce spread risk in the future.

Many of the improvements in wilding control tools we have developed are now an essential part of the good practice guides widely used by managers and contractors to help make control efforts cheaper, safer, and more effective.

Wilding conifers have major impacts on biodiversity, both above and below ground, and can leave persistent legacies in vegetation and soils following management. Social and economic research shows a growing interest in and concern from the public about these negative effects of wildings, and this has, in part, supported successful ongoing investments in national wilding control efforts.

Overall, the Winning against Wildings programme has developed a better understanding of the causes and consequences of wilding invasion. Improved control methods, innovations, and approaches have been developed, as has novel integration with social, cultural, and economic dimensions. During this time the National Wilding Conifer Control Programme has accelerated management from less than 300,000 hectares to over 1.5 million hectares nationally, estimated to have protected at least 3 million hectares of vulnerable landscapes.

Longer-term, these findings will be used to support longer-term investment in wilding control needed to stop and prevent future invasions. To fully implement and realise the benefits of wilding management, the next phase of effort (to 2026) will require stopping new invasions and reinvasions, and scaling up wilding management into new areas and regions if the ambitious national goal of stopping or containing wilding spread by 2030 is to be achieved.

How destructive could myrtle rust be to our trees?

Aotearoa New Zealand has 37 native Myrtaceae species, including pōhutukawa and rātā, mānuka and kānuka, ramarama and swamp maire, of which 25 are endemic. But there are many other non-native myrtle species in AoNZ, including eucalypts, feijoa, bottlebrushes, lilly pilly, and monkey apple.

Being able to quantify how important Myrtaceae are in AoNZ is important because some Myrtaceae species continue to be threatened by myrtle rust, an invasive disease caused by the fungal pathogen (*Austropuccinia psidii*), that found its way here from its native South America in 2017.

This is just what Manaaki Whenua ecologist Dr Insu Jo has set out to do. With the help of researchers including Drs Peter Bellingham, James McCarthy, Tomas Easdale, Maj Padamsee, Susan Wiser, and Sarah Richardson, the team analysed data from a nationwide forest and shrubland inventory collected from 2009 to 2014.

"Myrtaceae occurred in 74% of the plots we looked at," says Dr Jo. "And we found its importance value, determined by abundance and species richness, was the second highest after Nothofagaceae, also known as the southern beeches."

The results of the study, published in the *Journal of Vegetation Science*, also discussed the potential role of Myrtaceae as a relatively stable carbon store in local woody ecosystems. The study compared functional plant traits such as wood density with other co-occurring woody families and the significance of Myrtaceae woody climbers, of which six of the eight known Myrtaceae climbing species in the world are endemic to AoNZ.

Researchers are only beginning to understand the differences in susceptibility at a species or even individual level – like with Covid-19, some individuals are more hard-hit than others.

"We cannot definitively predict how myrtle rust will impact forest composition and ecosystem processes yet," says Dr Jo. "It's important to remember there is no functional equivalent, especially in terms of carbon storage, if they are lost. There will potentially be large and deleterious outcomes in forest ecosystems if taxon-specific pathogens, such as *A. psidii*, spread and significantly reduce the species."

In other work linked to myrtle rust, Dr James McCarthy and colleagues have been assessing the extent of the disease in the Taranaki area as part of the Beyond Myrtle Rust MBIE programme, using dataloggers to measure thousands of individual leaves of myrtle species. Work is also in the early stages looking for mycoparasites that might use myrtle rust spores as a food source.

Natural enemy for invasive African tulip tree arrives in the Kingdom of Tonga

The African tulip tree (*Spathodea campanulata*) is considered one of the 100 worst alien invasive species in the world and one of the top 30 terrestrial invasive plants. Introduced to many Pacific islands as an ornamental plant, the trees pose a huge threat to island biodiversity across the region. Native to tropical Africa, this fast-growing evergreen tree infests rainforests, out-competes native vegetation and impacts agricultural production.

Despite ongoing Covid-19 travel restrictions to the Kingdom of Tonga, in May 2022 our weed biocontrol team shipped a courier package containing African tulip tree cuttings infested with gall mites (*Colomerus spathodeae*) to collaborators in Tonga.

The shipment will ramp up weed-busting work in Tonga by introducing the gall mites to help reduce the spread and density of the invasive tree.

Our Pacific Natural Enemies – Natural Solutions (NENS) coordinator Mr Temo Talie says this shipment is an important milestone for Tonga. "The gall mites are a specialist natural enemy of the African tulip tree and form leaf galls known as erinea, which stunt new growth and reduce the invasive plant's competitive ability," says Mr Talie.

After the gall mites were brought to AoNZ from Ghana, via South Africa, in 2016, they were mass-reared in our containment facility in Auckland before being transferred to a containment facility in Lincoln to prepare the mites for the shipment to Tonga.

The mites had to be hand-transferred onto new plants to ensure the new population was free of any contaminants and pests, says Entomology Technician Arnaud Cartier, who looked after the mites in Lincoln.

The gall mites have been extensively tested to ensure no other plants are at risk and have been approved for release in Tonga. "The gall mites will be reared by Ministry of Agriculture staff on Tongatapu, and then released in all parts of Tonga where they are needed," says Viliami Hakaumotu, Tonga's National invasive species co-ordinator.

Work to control the African tulip tree is one of many projects

being supported by the Global Environment Facility and AoNZ's Ministry of Foreign Affairs (MFAT) to better manage invasive species in the Pacific. Manaaki Whenua, the Secretariat of the Pacific Regional Environmental Programme (SPREP), and the New Zealand Department of Conservation have joined forces to support Pacific Island countries and territories (PICTs) to take stronger action against invasive species, and thereby build resilience to climate change.

Using genomics data to unlock precision pest control

Pest control of invasive mammalian species – rats, mice, stoats, possums, and the rest – is a key priority for AoNZ to prevent further decline of our iconic, endangered native species, and to support the Predator Free 2050 initiative. One limitation of current vertebrate toxins for pest control is that they are relatively broad spectrum. Although risks to non-target species are carefully mitigated when these toxins are used, there remains a critical need to expand our toxin toolbox by developing new, highly pest-specific toxins.

Toxins work by altering normal chemical pathways in animal or plant cells, disrupting the cellular proteins or processes critical for life. Toxins can be species-specific at a molecular level through having different absorption and processing properties between species – this is why chocolate, which contains a chemical called theobromine, is poisonous to dogs at relatively small doses; dogs can't metabolise theobromine effectively, whereas in people it acts as a mild stimulant. As part of early research into species-specific toxins at Manaaki Whenua, Dr Erica Hendrikse used *in silico* (computer-based) modelling to identify potential molecular targets in a range of mammal species that could show promise in the eventual development of species-specific toxins.

Dr Hendrikse's work took advantage of recent advances in the sequencing of the genomes of several key mammalian pest species – stoat, ship rat and possum. The complete stoat genome, with over 2.4 billion DNA bases and more than 20,000 identified proteincoding genes, was deciphered and published in 2020 by an international collaboration led by Manaaki Whenua's Dr Andrew Veale. As a key approach for the project, Dr Hendrikse developed methods very similar to the ways antibiotic screening is done in the pharmaceutical industry. Screening and comparing "protein target libraries" of various species' genomes enable proteins to be pinpointed that are critical for life and differ between species.

The initial focus was on the G protein-coupled receptor protein family, as these are commonly used as therapeutic targets for human medicine, are already studied extensively, and are relatively well understood. Once a promising genetic sequence is identified, high-performance computing is then used to enable it to be modelled in 3D, to visualise how it compares to similar protein structures, and to understand what chemical actions it controls. This underpinning work helps to ensure that any eventual toxins are as humane as possible.

An important question arises: how different do proteins in different

Gall mite Colomerus spathodeae *damage on an African tulip tree.*

> The interesting part of this work is that we are bringing together many different areas of science.
>
> *Erica Hendrikse*

genomes have to be, to enable a toxin to eradicate a pest but leave a non-target animal unscathed? Animals can respond differently to toxins or medicines when their proteins vary by as little as one amino acid. However, to be confident that any potential toxins are as specific as possible, Dr Hendrikse is particularly interested in protein targets that are noticeably different between species. More difference makes it more likely that a toxin would have little or no effect on non-target species but would be lethal to target species, even at low doses.

For Dr Hendrikse, this research is an exciting voyage of discovery. "The interesting part of this work is that we are bringing together many different areas of science, from human drug discovery to genomics and conservation biology. This is an innovative approach to finding potential new pest control toxins. We are taking steps towards new ways of undertaking effective pest management, which will encourage our native species to recover and thrive."

New Zealand's Biological Heritage National Science Challenge

A system-wide collaboration to address the challenges of protecting our nation's unique biodiversity

National Science Challenges take a collaborative approach to solving some of New Zealand's biggest societal issues. They are mission-led, collaborative and connected across sectors to create impact from research and provide new approaches to tackling national science priorities.

Manaaki Whenua is proud to host New Zealand's Biological Heritage National Science Challenge (BioHeritage Challenge), one of New Zealand's 11 National Science Challenges (NSCs). We also contribute to Our Land & Water; Deep South; Resilience to Nature's Challenges; Science for Technological Innovation; Building Better Buildings, Towns and Cities; and Sustainable Seas. Working with the NSCs allows us to increase the impact of our research across our four ambitions through effective collaboration and adding value – solving national-scale problems for the benefit of Aotearoa.

New Zealand's Biological Heritage National Science Challenge – Ngā Koiora Tuku Iho

The mission of the BioHeritage Challenge is to reverse the decline of our biological heritage by protecting and managing biodiversity, improving biosecurity and enhancing resilience to harmful organisms.

To do this, they facilitate national collaborative approaches and have a strong commitment to partnerships, including honouring Te Tiriti o Waitangi and working with local communities. Working across the science system enables better outcomes for Aotearoa New Zealand's precious environment and taonga species.

BioHeritage is strategically focused on three impact areas:

- Whakamana – Empower
- Tiaki – Protect
- Whakahou – Restore

In addition to their seven original research programmes, the BioHeritage Challenge also leads Ngā Rākau Taketake (NRT) – a 4-year research platform finding new solutions for the management of kauri dieback and myrtle rust.

Recent BioHeritage Challenge successes that Manaaki Whenua are proud to include:

- *How To Talk About Co-Governance:* A report commissioned from The Workshop that provides helpful tools and language to enable tangata whenua and tangata Tiriti to work together to build the health of our natural environment.
- A trans-Tasman collaboration to understand how *Austropuccinia psidii*, the fungal pathogen that causes myrtle rust, avoids detection by plant defence mechanisms and successfully invades plant tissues to gain nutrients from living cells.
- An evaluation of the social acceptability of RNAi and gene editing technologies for pest control in Aotearoa.
- Farming with Native Biodiversity: A pilot project that is connecting farmers with ecologists to make it easier to improve and manage native biodiversity on farms. The project is led by NZ Landcare Trust with support from Silver Fern Farms, the Living Water Partnership (Fonterra and the Department of Conservation) and the BioHeritage Challenge.
- A review of the effects of climate change on species and ecosystems in Aotearoa.
- *Being Manuhiri:* An illustrated guide for guests and tourists within Aotearoa to better and more confidently engage with mana whenua and the land to which they are travelling.
- A NRT team at Massey University helped build what appears to be the first chromosome-level *Phytophthora* genome assembly in the world for *Phytophthora agathidicida*, the pathogen that causes kauri dieback. They collaborated with researchers at Scion, Plant & Food Research, Te Herenga Waka – Victoria University of Wellington and the University of Oregon.
- *Helping understand our biosecurity system better:* Partnering with the University of Canterbury's Biosecurity Innovations cluster to support three Master's students investigating the role of intuition in biosecurity decision making, and biosecurity risk communication – particularly with respect to impacts on native ecosystems.

Partnering for impact: our support for the BioHeritage NSC

As host to the BioHeritage Challenge, Manaaki Whenua provides premises and administrative support such as IT, human resources, legal and finance. We also align significant amounts of our research effort, which contributes to the collective success of the Challenge mission. In 2021/22 alone this aligned research amounted to $13.9M.

BioHeritage Challenge parties

Including Manaaki Whenua as host, 18 organisations formally partner to create the BioHeritage Challenge. They are: AgResearch, Auckland University of Technology, Cawthron Institute, DOC, ESR, GNS Science, Lincoln University, Massey University, MPI, NIWA, Plant & Food Research, Scion, University of Auckland, University of Canterbury, University of Otago, University of Waikato, Te Herenga Waka – Victoria University of Wellington.

Action on climate change

Climate change is the major challenge of our generation and is of specific concern to Pacific island nations. Over two decades we have redirected our research to focus on understanding AoNZ's emissions balance, supporting mitigation, and enabling adaptation and resilience to climate change. Our research has supported AoNZ's international emissions reporting, and has provided an understanding of carbon stocks in our indigenous forests and in the soil. We have designed and supported pathways for carbon sequestration and for businesses and communities to take meaningful climate action. Our Toitū Envirocare subsidiary has enabled hundreds of organisations to plan and achieve certification of their emissions management. Increasingly, Toitū members are offsetting their emissions to become carbon-zero.

Selected highlights

Our national soil carbon benchmarking and monitoring work continues to make good progress. As of June 2022, 275 of 500 on-farm sites have been sampled across five broad land-use classes.

Writing in the journal *Trends in Ecology & Evolution*, Senior Researcher Dr Kate Orwin and colleagues have developed fresh concepts about how plant species diversity may be designed into pastoral systems to increase their resistance and resilience to climate change and reduce environmental impacts. The paper emphasises ecological integrity in developing ideal species mixes for pasture, and suggests that more diverse pasture mixes may have advantages in overcoming environmental changes.

Field studies at Manaaki Whenua have also supported the use of more diverse pastures, including plantain, for reducing nitrous oxide emissions and nitrogen leaching, while also demonstrating important trade-offs with other greenhouse gases.

A History of Open Temperature and Rainfall with Uncertainty in New Zealand (HOTRUNZ), developed by Principal Scientist Dr Janet Wilmshurst and Dr Thomas Etherington, with Professor George Perry from the University of Auckland, is a new open access dataset that provides a 1910–2019 monthly time series of temperature and rainfall estimates across New Zealand at 1km resolution. This represents the best available option to compare long-term ecological datasets with climate data to better understand plant distributions, plant and animal phenology, wildfire histories and hydrology. The nearest alternative is NIWA's Virtual Climate Station Network data, that while daily has a 5-km resolution that is inappropriate in mountainous contexts, and is a proprietary dataset that must be purchased on a per-project basis. HOTRUNZ is also unique globally in being the only dataset of this kind that provides associated uncertainties to facilitate better use of this kind of data and hence more robust science.

Innovation stories

Swapping time for space to track the impact of climate change on soil microbes

To test the effects of climate change on species at any scale is difficult. Scientists can't manufacture realistic global warming in a test tube or in a lab over a few hours, or a few days. As a result, a big challenge for climate change researchers has always been how to best record potential shifts in species response over timeframes that are truly representative of gradually warming temperatures.

Working with soil microbes, Drs Manpreet Dhami, Gabriel Moinet, and John Hunt wondered what would happen if they turned the problem on its head and swapped geological time for space.

Because microbes are vital to the decomposition of organic material, and the subsequent release of carbon into the atmosphere, the ability to measure the physiological response of microbes to warmer temperatures will help to solve the puzzle of whether soils will lose or gain carbon under warming temperatures.

The researchers decided a 'conceptual trick' was needed. Instead of heading to the lab to try to replicate the effects of climate change on microbes, they looked for a geothermal feature that could represent a continuum of warming temperatures. A steam-heated depression that enabled sampling along a transect from the hottest areas closest to it all the way to the cool areas further out was identified in a field near Taupō, a volcanic area in AoNZ's North Island.

"The gradient mimics what would happen to the soil in different climate warming scenarios over very long periods of time," says Dr Moinet, now an Assistant Professor based at the University of Wageningen in the Netherlands. "This allowed us to sample the microbes along the transect, to see if, and how, they adapted and measure what, if any, physiological differences there were in response to changing temperatures."

As well as having having access to a unique geothermal environment the researchers built a mobile molecular lab that was towed to Taupō. The field lab was set up complete with pipettes, sterilised bench, and DNA extraction tubes to collect and process samples.

Drs Moinet and Dhami say that these findings bring them a little bit closer to fully understanding the role soil plays in climate change. "We were able to show that while communities of microbes in the soil do adapt in response to temperature, the physiological response to temperature in warm adapted microbes (thermophiles) and other microbes (mesophiles) was the same. If this is confirmed at other sites and other conditions, then predicting the microbial feedback to climate change can be done from short-term studies after all," says Dr Dhami.

Senior Researcher Dr Manpreet Dhami collecting field samples for research into manipulation of pollinator behaviour via floral microbes. Image: John Hunt.

Future drought could drain primary sector profit

Research published in August 2021 by the Deep South Challenge and Manaaki Whenua, with the support of Motu Economic and Public Policy Research, has found that more intense future drought is likely to lead to drops in farm profit. Comparing trends in 70,000 farm tax returns with temperature and soil moisture data, scientists were able to understand the historical relationship between local weather and farm profits in both the dairy and sheep+beef industries, and apply it to future scenarios. Manaaki Whenua research co-lead Dr Kendon Bell says that uncontrolled climate change is likely to bring somewhat more severe and far more frequent drought.

Under a high climate change scenario – the pathway representing little climate action and high economic growth – sheep+beef farmers, vulnerable to high temperatures and soil moisture loss, could see a profit loss of up to 54% by the end of the century, subject to a high degree of uncertainty. Analysing potential changes in soil moisture, both dairy and sheep+beef show a decrease in profit by 2100 (an average of 20% for dairy and 7% for sheep+beef). A more moderate climate change scenario suggests – unsurprisingly – more moderate losses given soil moisture changes alone, but losses nonetheless.

Dr Bell notes one use of these results is to better understand how climate change might encourage farmers and growers to implement adaptation measures, or even to change what they farm and where. Due to large capital investments, it's difficult for farmers to change the way they use their land, and the slow pace of climate change will be unlikely to force land-use change in the near future. Yet this research suggests that land-use change should at least be on the cards in some places.

"In New Zealand, very little research has been done about the implications of climate change for society using approaches that measure the historical relationship between weather conditions and economic and social outcomes – this research is among the first to do so. Rural communities may bear a large share of the burden of reducing emissions, and we have tried to understand, using real financial data, the size of the additional burden that climate change might impose."

He huringa āhuarangi, he huringa ao: a changing climate, a changing world

In October 2021, Ngā Pae o te Māramatanga and Manaaki Whenua released a report offering new guidance for Te Ao Māori on climate change adaptation and mitigation. *He huringa āhuarangi, he huringa ao: a changing climate, a changing world* was produced by a multidisciplinary Māori research team working across many research institutions and led by Manaaki Whenua's Dr Shaun Awatere.

Using a novel kaupapa Māori risk assessment approach to climate change, the report synthesises the latest climate change research through a Māori lens, and identifies the potential impacts, implications, mitigation and adaptation strategies for whānau, hapū, iwi, and Māori business. It follows the recent release of an Intergovernmental Panel on Climate Change report forewarning that global temperature is expected to reach or exceed 1.5°C of warming over the next 20 years.

He huringa āhuarangi, he huringa ao finds that Māori well-being across all four key domains – environment, Māori enterprise, healthy people and Maori culture – will be moderately impacted by 2050. By 2100, the risks to ecosystems are likely to show severe impact, compromising many aspects of Māori well-being. The authors write: "Climate change not only threatens the tangible components of Māori well-being, but also the spiritual components and, most important, the well-being of future generations."

The report sets out how the production and ecology of freshwater, terrestrial and coastal-marine ecosystems and biodiversity in AoNZ will be challenged by projected warming temperatures and reductions in rainfall. Vulnerable flora and fauna may face habitat loss and in some cases extinction. Any decline in the quantity and quality of keystone species like pāua, kina and koura, will adversely impact Māori customary practice, cultural identity, social cohesion, and well-being. Cultural infrastructure, especially in exposed areas (e.g. river valleys and coastal areas), will be particularly vulnerable to climate change impacts, and some marae and papakainga may have to be moved, along with urupā in low lying and coastal areas prone to flooding and erosion. While some hapū and iwi are developing their own climate change adaptation and mitigation plans, the report provides Māori-focused guidance on areas often overlooked in mainstream reports. As the authors note: "Evidence suggests climate-related adverse health impacts are expected to become more severe and be borne disproportionately by groups like Māori who already suffer health inequities".

Toitū Envirocare: Scaling to meet New Zealand's growing demand

Climate change continues to be one of the most critical global issues. Despite Covid-19, Toitū has continued to see strong interest and action from New Zealanders, the business sector and Government to measure and reduce the impact we have on the environment.

This year we have continued to experience significant growth in our customer numbers and revenue. Our total impact grew significantly, seeing us complete 487 carbon certifications, a 44% increase year on year. The total volume of emissions certified or verified during the year was 47.5 million tonnes CO_2e, and our clients cancelled 207k tonnes of high-quality offsets.

Our people

Our team numbers continue to increase in line with our growth. Current headcount is 66 (up 43% on FY21) and recruitment is ongoing. We have recently moved our office in Auckland to accommodate our team and to provide much improved facilities. Staff at the new office report increased employee morale and engagement after just one month. As well as being located in the three main centres, we now have people based all over the country including Queenstown, Dunedin, Cambridge, Rotorua, and the Kapiti Coast.

Operational and product development

The past year has seen rapid development in international best practice in GHG measurement, reduction and neutrality. The IPCC issued its sixth set of assessment reports about the state of climate science, mitigation and adaptation. The Glasgow COP saw numerous new international commitments leading to stronger expectations about climate ambition. We are reviewing our offerings to ensure they align with best practice. In the past year we've transitioned our carbon organisation certifications to the latest GHG accounting standard ISO 14064-1:2018, and have also re-labelled the Toitū carbonzero programme to Toitū net-carbonzero. Climate positive was launched in late 2021 as the third tier of our carbon certification programme, enabling clients to progress from net carbonzero. We intend to put more focus on this product over the coming year.

We have seen an increased demand from business for consultancy support outside of the core carbon products we offer, and strong demand for verification-only services. We are updating our small business offering (Carbon Assess) to meet changing Scope 3 measurement requirements and there has been significant growth in our agricultural client base.

Under the Financial Sector Amendment Act it will now be mandatory for certain organisations to produce climate statements that meet XRB (External Reporting Board) disclosure Standards. Toitū has been working closely with the XRB to understand these new standards and support our clients to comply with and report against them.

Operational improvement has been a key focus over 2021/22 with Client Delivery introducing new ways to service our clients, including a new customer service help desk to speed up our response time and a new telephony facility.

Education and engagement

Sharing knowledge continues to be a key focus for Toitū.

We undertook a strong webinar delivery programme to inform and educate clients and the wider community in a year where in-person events were often not possible. Toitū also had an active voice at over 21 external speaking opportunities, including industry events, webinars, and clients' senior leadership teams. To better understand the needs of AoNZ business, a large-scale independent research project was commissioned to inform how Toitū can tailor products and services to support AoNZ business achieve a carbon zero future. Toitū has actively partnered on insights and expertise, with an ANZ Bank partnership promoting carbon assessment and sustainability to their SME customers. Our teams have also been involved in monitoring, assessing, and contributing to many sector and government consultations and standards.

The coming 12 months

With the support of the Toitū and Manaaki Whenua Boards, we have started a 3-year transformation programme to simplify, streamline and digitise our systems and processes, and to work more closely with other sustainability organisations to deliver our products and services. With business interest continuing to grow, this will enable us to stay relevant in a digital environment, work with more businesses, and significantly grow our impact to ensure AoNZ achieves net zero by 2050 at the latest.

TOITŪ ENVIROCARE

People and environment

Since 1996 Manaaki Whenua has built social, cultural, and economic research capability to understand people's decision-making in matters of the natural environment. We now have one of the largest dedicated groups in the Southern Hemisphere. The audience for results from this research is diverse – including central and local government, Māori organisations, primary industry, businesses, NGOs, and communities – because all parts of society affect natural resource management. Our research spans rural, conservation, and urban landscapes, and the full range of ecosystem services viewed from both Western science and indigenous knowledge systems. It supports improved natural resource decision-making in AoNZ and in the Pacific. This work is integrated with our work in all impact areas where people need improved tools for decision-making, policy, governance, regulation, planning, and strategy development.

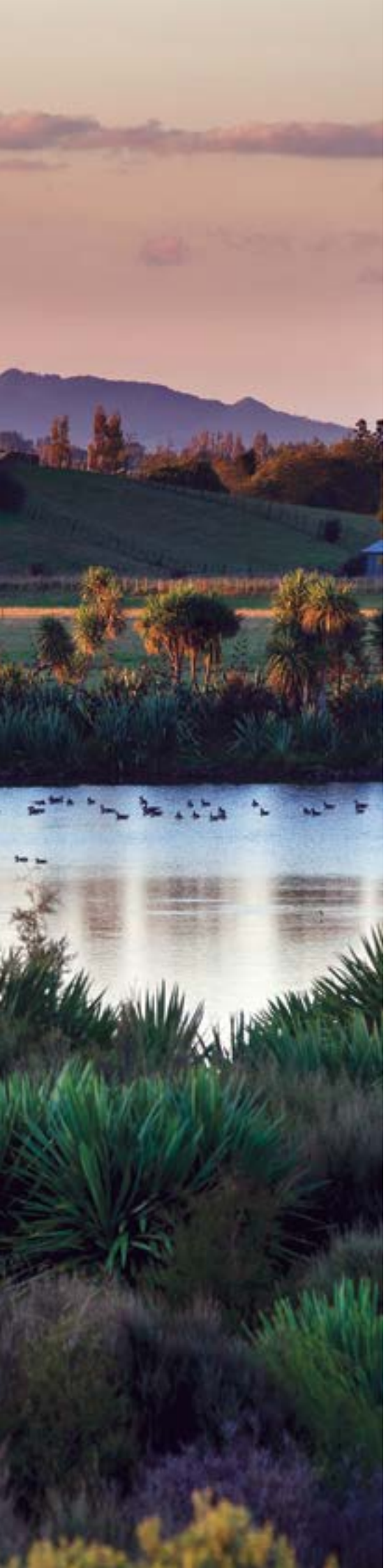
Selected highlights

Work is beginning on a new MBIE research programme Moving the Middle: empowering land managers to act in complex rural landscapes, led by Dr Suzie Greenhalgh and Dr Fraser Morgan. Many land managers are overwhelmed by the complex issues they face, and are not achieving the scale of action necessary to improve environmental performance. This social research programme aims to identify and test the system changes needed to enable land managers to act on the environmental, economic, and social challenges they face, including disruptors such as Covid-19 and climate change.

Data and associated infographics from the annual New Zealand Colony Loss Survey, which in 2021 involved 49% of all New Zealand's beekeepers, were much cited by speakers at the 2022 APINZ conference. Our survey statistics form the basis of a large number of interventions now promoted by the apiculture industry. We have the highest response rates in the world by a very wide margin (in Europe, the average response rate is 5.5%). We started doing the survey because beekeepers and MPI were worried about high rates of colony losses over winter, which have been steadily increasing from 2015 (8.4%) to 2021 (13.6%).

We reached 4,000 views of the research website i3, a guide to integrated research concepts and techniques. The site now has 535 users across 27 countries.

Waiwhakareke Natural Heritage Park in Hamilton.



Innovation stories

Building Te Ao Māori thinking into science knowledge systems

Indigenous knowledge systems and approaches hold a significant share in the well-being of the planet. Researchers say if we are to achieve our vision for AoNZ to improve the health of te taiao (the environment) and our people, we need to change the way people interact with the environment from a position of extractive resource use to one of reciprocal exchange.

New research from Manaaki Whenua has explored how better incorporating a Te Ao Māori (Māori worldview) thinking offers a pathway forward to achieving sustainable livelihoods that enable both the natural world and humans to prosper.

Led by Kaihautū Dr Nikki Harcourt, kairangahau from our Manaaki Taiao rōpū have explored how adapting the framework 'He Waka Taurua – the double-hulled canoe' for collaborative partnership can co-produce outcomes based on science and Indigenous knowledge. "He Waka Taurua is a metaphorical framework that elevates indigenous worldviews, values, and practices, alongside western science, and knowledge," explains Dr Harcourt. "It explicitly identifies a Te Ao Māori worldview and associated values as a distinct and complete knowledge system, separate from a western science worldview. This is represented by the two hulls, Waka Māori and Waka Tauiwi, and the hoe (paddles), which represent the tools, actions, and approaches relevant to each worldview. These worldviews are kept separate from each other, whilst the papanoho (deck) between the canoes represents a

> He Waka Taurua is a metaphorical framework that elevates indigenous worldviews, values, and practices, alongside western science, and knowledge.
>
> *Nikki Harcourt*

shared or 'negotiated space', where engagement and innovation can occur," she adds. Researchers drew on a case study on Whakatāwai Station in Waiapu Valley on the East Coast to demonstrate how the He Waka Taurua framework can be operationalised for the codevelopment of knowledge between a Māori agribusiness and Māori researchers.

"Whakatāwai Station, before European colonisation, was an area of land thriving under a Te Ao Māori knowledge system and framework. It had many different crops under cultivation and was a thriving catchment with high biodiversity of plant and animal species and an intimate connection of people to their land and the natural world," explains Dr Harcourt. But by the late 1970s large areas of land had been cleared for pastoral farming and Te Ao Māori thinking had been marginalised in favour of Te Ao Pākehā (the Eurocentric worldview). Land clearance led to the destabilisation of soils through deforestation, and an increase in erosion and sedimentation of the waterways, loss of biodiversity of plant and animal species, and creation of an exotic grassland. These changes had a profound impact on the Māori communities' cultural values and their enactment. At the station, blanket grazing is now a land-use deemed unsustainable

Kaihautū Nikki Harcourt and kairangahau Jade Hyslop, Waiwhakareke Natural Heritage Park, Hamilton.

due to it being at further risk of erosion from climate change. Whakatāwai Station's journey and current predicament are testament to the negative consequences that arise from marginalising Māori perspectives and management approaches in ecosystem management in favour of Eurocentric ones. However, using the He Waka Taurua framework to guide the partnership approach between kairangahau and Whakatāwai Station shareholders we were able to coproduce decision-making outcomes, based on both science and indigenous knowledge," says Dr Harcourt. "This was done by taking a true co-development approach and operating at the research interface where indigenous and non-indigenous knowledge systems share knowledge and perspectives. From this we used a kaupapa Māori approach to draw on relevant and meaningful knowledge, grounded in local experiences, and in parallel with quantitative data gathering to transform this pastoral grazing unit into a system that better aligned with Māori values and aspirations," she adds.

Predator modelling applied to study of Covid-19 health equity

The Covid-19 pandemic has been disruptive of many science activities over the past 2 years. Fieldwork, conferences, hui, workshops – much work has had to be rescheduled or moved online. However, scientists are lateral thinkers. The pandemic has also brought new and wide-ranging opportunities to apply knowledge in different ways. Our social researchers have adapted their understanding of decision-making in environmental management to predict likely compliance with public health directives, and our economists have assessed the impacts on businesses of government policies aimed at reducing the spread of Covid-19.

Government policy often requires people to think and act differently, but achieving meaningful behaviour change in practice is difficult. In several recent pieces of work to understand compliance with health measures during Covid-19, Dr Geoff Kaine and other social scientists at Manaaki Whenua have undertaken surveys of the public and applied the findings using the i3 compliance framework. i3 is a tool that analyses how strongly people are involved with, or care about, policy outcomes and related policy measures such as regulations, to predict whether they will comply with the measures. It also measures what they believe about policy outcomes and policy measures. The involvement component of the i3 framework shows whether someone is willing,

or not, to do something (for example, get vaccinated), and the belief component explains why they are willing, or not. The researchers have applied i3 to several different aspects of people's behaviour in reaction to public health measures: willingness to be vaccinated, compliance with mask wearing, use of the contact tracing app, willingness to be tested for Covid-19, and self-isolation.

The finding that people's willingness, for instance to be vaccinated, depends on involvement (motivation) as well as attitude has implications for the design of policy measures, for instance to promote high vaccination rates. It is important to distinguish between those with a lack of interest in getting vaccinated and those who strongly oppose it and therefore deliberately choose not to be vaccinated, and to tailor incentive and enforcement strategies appropriately.

The findings of each survey also have important implications for the design of promotional programmes intended to encourage the participation of the community in mass vaccination programmes. The findings also highlight the difficulty of communicating effectively through mass media with those who have little interest (low involvement) in preventing the spread of Covid-19.

Building social licence to operate

Social licence to operate (SLO) is an essential ingredient in successful applied research, and is sought after by groups and organisations wishing to bring about environmental change. For example, if AoNZ's ambitious predator-free goals are to be realised, SLO will need to be built around the introduction of new pest control technologies.

SLO is much more than good PR and promises: it involves the cumulative building of credibility and trust over time with affected communities of interest. Social licence is not a single specific permission granted by communities to an organisation, but is better thought of as multiple licences achieved across various groups at different times. It is subject to change as opinions and perceptions change, and needs to be continually managed rather than obtained.

Three of Manaaki Whenua's social researchers, Dr Dean Stronge, Robyn Kannemeyer, and Dr Peter Edwards, have developed a practical framework (see diagram), informed by both Western and indigenous views of engagement, which is now being used to guide organisations that wish to gain and maintain a credible and effective social licence. There is no one-size-fits-all approach, so the framework is intended only as a guide and is adjusted depending on the needs and understanding of the organisation or the issue in question.

There are four key phases to building social licence:

1. socialising the concept of SLO with the organisation
2. hearing the views of stakeholders, and understanding that their expectations are essential in building and maintaining SLO
3. integrating or co-developing the views and expectations of stakeholders into an organisation's processes and procedures so that they foster SLO and promote participative and learning opportunities
4. reflecting: working towards SLO is a dynamic and evolving process, so learning opportunities are important and need to be fed back into the process in a continuous reflecting step.

As an example of this framework in action, our researchers were asked to advise Predator Free (PF) Southland on a pathway that offered a greater potential to gain and maintain a social licence to eradicate possums and suppress mustelids in the Awarua region. The PF Awarua landscape extends from Sandy Point to Fortrose, covering approximately 69,000 hectares and including Bluff and Omaui, two communities with different experiences of previous predator control initiatives.
The recommendations that arose included engagement with the Awarua community early and often; transparency in sharing and communicating information; use of multiple communication channels; and thinking ahead about the legacy PF Southland and the community want to leave for future generations. Other vital factors in building successful SLO for PF Awarua include:

- the appointment of exceptional leaders and continuity of personnel
- an engagement plan that is adaptable and flexible to cater for different values, beliefs, and world views
- engagement and communication with some landowners and communities tailored specifically to those groups or individuals.

Building social licence is also an integral part of a new research project in conjunction with the Our Land & Water National Science Challenge. The project aims to explore new ways to connect producers, consumers, and citizens to constructively discuss, negotiate, share and communicate good farming practices. It will also consider where this should happen. Some spaces and places are likely to be better suited to building meaningful relationships than others, such as the peri-urban zones just outside cities. Research partners Open Farms, Thriving Southland and Quorum Sense will help develop, identify and test new practices and initiatives to strengthen relationships between producers and consumers, locally, regionally, and nationally.

During our work on SLO it has become clear that it has many synergies with kaupapa Māori research, which also requires a social licence to engage with individuals, communities, and organisations, and includes building credibility and reciprocity when establishing relationships, empowering communities to build capacity, or leaving something tangible for the community when the project is completed. This is an area that is now being investigated further at Manaaki Whenua.

Modelling the nation's Covid-19 response

Recognising the need for robust ways to measure the effectiveness of contact tracing in reducing the spread of Covid-19, a team of researchers, including Manaaki Whenua's Dr Rachelle Binny and Dr Audrey Lustig, applied their wildlife disease modelling knowledge to develop a model to investigate the importance of contact tracing, quarantine, and isolation in reducing transmission. "We used an age-structured branching process model for Covid-19 transmission in AoNZ, in the presence of contact tracing and case isolation," says mathematical modeller Dr Binny.

"Our results show that a high-quality, rapid contact tracing system, combined with strong support for people in quarantine or isolation, can be highly effective in reducing the spread of Covid-19.
"If case isolation or quarantine are imperfect, or some contacts aren't traced or are traced more slowly, then the reduction is only around 40%, meaning that stronger social distancing measures would be needed to control an outbreak."
Predicting the elimination of evolving Covid-19 variants.

A second research paper involving Dr Binny, 'Predicting elimination of evolving virus variants', models the recent emergence of multiple SARSCoV-2 variants and the risk these pose to global efforts to control the Covid-19 pandemic. In the study, researchers created a simple model of disease spread, which includes the evolution of new variants and varying vaccine effectiveness for these new strains. They found that viruses that mutate into multiple new variants need fast vaccine delivery in order to be contained. The researchers concluded that rapid vaccine updates to target new strains are more effective than slow updates, and that containing spread through non-pharmaceutical interventions is vital while these vaccines are delivered.

The study also suggested that a continuous vaccination roll-out programme, where updated vaccines are given to unvaccinated individuals, rather than revaccinating high-priority individuals, may slightly increase the probability of elimination. However, the researchers note that this prediction warrants further investigation using population-structured models to assess the risk this would pose to vulnerable individuals such as frontline workers or those at higher risk of severe disease.

Prepare to arrive as guests: being manuhiri in the production of knowledge

New research led by Senior Researcher Dr Alison Greenaway has focused on how non-indigenous scientists embrace the geographical, cultural, and social places they find themselves as manuhiri (guests). The researchers discuss the need for non-Indigenous researchers 'to prepare to arrive as guests' in a co-production of knowledge process and to adopt methodological sensitivities for such work. In this discussion, nine signs emerged to help primarily non-indigenous researchers and practitioners navigate the co-production of knowledge and practices shaping environmental outcomes.

1. Alternative worlds are becoming visible and possible
2. Power asymmetries are being made visible
3. Invitations from indigenous peoples are accepted, and challenges are being responded to
4. Indigenous ways to represent non-indigenous people are at the centre
5. Stumbling, failures, and mistakes are acknowledged and redressed
6. Care is taken when moving insights from one context to another
7. Shared leadership is remaking institutional spaces
8. Shared values are explored for points of connection
9. Relationship building is prioritised.

As Dr Greenaway explains, this work supports those in the research system to move towards an unknown and as yet unknowable knowledge destination, solution or outcome. "It may also help groups move beyond the paralysis generated when non-indigenous partners become cognisant of the enormity of devastation their Indigenous partners are working through," she notes. The research also supports environment and recreation groups who are navigating a shift from linear, siloed environmental management to collective management. "As co-management of (and with) places becomes more typical, community groups such as tramping, pest control, and mountain biking groups find they are changing how they relate with places, tangata whenua, and Crown agencies involved with these places. In some parts of AoNZ this is a journey of learning to be manuhiri," she explains. Co-management of places is being enabled through Te Tiriti o Waitangi settlements establishing co-governance agreements, the Resource Management Act (1991), related memorandums of understanding, or special legislation supporting collaborative decision making driven by tangata whenua. Behind all these initiatives is an increase in capacity for more relational ways of caring for the environment and generated momentum for co-produced environmental and cultural practices. "Co-produced knowledge opens alternative worlds and develops new social contracts," Dr Greenaway says, as she and colleagues attempt to work with an ethic of reciprocity. "We respond to invitations from Indigenous scholars, kairangahau Māori colleagues and those intentionally creating spaces in organisations, budgets and funding processes, and review practices, for Indigenous knowledge and practices." The social knowledge has been crafted into a discussion guide *(Arriving with Care)* and related resources *(Being Manuhiri)* to support environmental researchers and practitioners to arrive with care in the places they are exploring. This work contributes to the conversation in AoNZ about how we can know we are building enduring trustful Tiriti o Waitangi-based partnerships.

Senior Researcher Dr Norm Mason running a pest control seminar.

How we work
Te āhua o tā tātou mahi

Our goal at Manaaki Whenua is to create an environment that allows the right people to come together and create high impact research that meets AoNZ's needs. That means supporting our own people, but also supporting a high level of collaboration and integration across the research sector and the wider community that relies on and uses our research and solutions.

The official opening of Te Rauhītanga (The Gathering Place) at our Lincoln site in May 2022. Image: Kim Triegaardt.

Putting people at the centre

Our overarching priority is development of our people and culture, which also puts our people at the centre of everything we do. We are also committed to ensuring our financial resilience, developing impact processes for our science, and continually improving our support systems and infrastructure.

A great place to work – being an employer of choice

Our goal of being an employer of choice for the world's best talent is focused on creating an environment of support and opportunity for our people.

Our culture of empowerment comes from diverse talents, great leadership, and communication. We bring together the best teams from within and beyond our organisations and provide our staff with opportunities for career and leadership development skills enhancement, external interaction in our sector.

Flexibility is a key component of our way of working, enabling working arrangements to meet people's diverse circumstances and encouraged collaboration in different ways. During Covid-19 lockdowns in 2021/22 we continued to refine our flexible working policy.

Soils Database Engineer Shirley Vickers experiments with a VR headset at our Lincoln site. Image: Cissy Pan.

Employee experience staff survey results

We achieved an 82% response rate to this year's Employee Experience Survey. Our engagement index was 76% (and 86% in Toitū Envirocare). These engagement scores help us understand the overall experience for our people at Manaaki Whenua.

- This organisation is a place where everyone can succeed to their full potential no matter who they are (e.g. all genders, races, cultural backgrounds, etc.) – 74%
- I feel included at this organisation – 76%
- Diverse perspectives are valued at this organisation – 72%
- I feel comfortable being myself at work/with my colleagues – 83%

Providing for health, safety and well-being

Our goal is that everyone is 100% committed to health, safety, and well-being. We continuously seek to mitigate risks inherent in our work in laboratories, on our sites, and in our fieldwork in remote locations.

We have continued to support the health and well-being of our employees through our Manaaki Tangata well-being programme, providing a monthly focus on different well-being themes. Harassment and bullying prevention Manaaki Whenua has a zero tolerance for bullying and harassment of any kind.

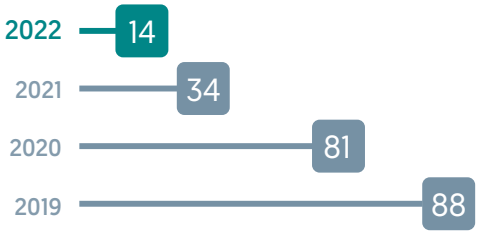
We regularly review processes in place to ensure we are providing a safe work environment for all people working for and with Manaaki Whenua.

Manaaki Whenua achieved external certification against the AS/NZS 4801 health and safety standards in 2018. Further external audits in 2019 and 2020 highlighted the progress that has been made in our health and safety practices. We achieved re-certification in our 2021 audit against the new ISO 45001 standards.

We have stepped up our worker engagement during 2021/22 with the creation of a Field Expertise Group, which meets quarterly to help progress fieldwork safety improvements. In addition, a new Field Safety Advisor was appointed in early 2022 to provide specialist Health & Safety advice for our soils researchers.

HEALTH AND SAFETY

Near misses



Lost-time injuries

HSNO Act and Biosecurity Act compliance has been maintained during 2021/22, with all our Transitional and Containment Facilities maintaining their registrations following their MPI verification audits.

Creating an equitable culture

Manaaki Whenua and its employees are committed to taking proactive steps to achieve a working environment for all workers that is free from bias and discrimination in employment and pay practices, and in which all can achieve their full potential.

We have developed a Gender Pay Gap action plan focusing on activity to address the under-representation of women in leadership roles. This is linked to our commitment to Kia Toipoto – a Public Service Action Plan to reduce and ultimately eliminate gender and ethnic pay inequity.

Our vertical pay gap – the difference between salaries for men and women across the organisation – fell from 16.7% in June 2020 to 14.8% in August 2021, and to 14% in June 2022. Our Māori staff have a median pay gap in their favour of 11.6% compared with non-Māori.

Building a diverse and inclusive work culture

We are committed to the development of our bicultural capability. Building on our diversity of thinking enables us to better understand the needs of our stakeholders and people and respond effectively to them.

Our ability to engage Māori in every part of our research is a key to our success. Building an understanding of and empathy for Māori culture is a key part of our Diversity and Inclusion Strategy, as well as being central to our Kia Māia bicultural competency programme.

Our Diversity and Inclusion group of staff has run many initiatives and provided resources during 2021/22. As an organisation, in 2020/21 we have celebrated Māori Language Week, Pride Month, Matariki, Sign Language Week, Pink Shirt Day (anti-bullying in the workplace), Tuvalu Language Week, neurodiversity, and mental health awareness.

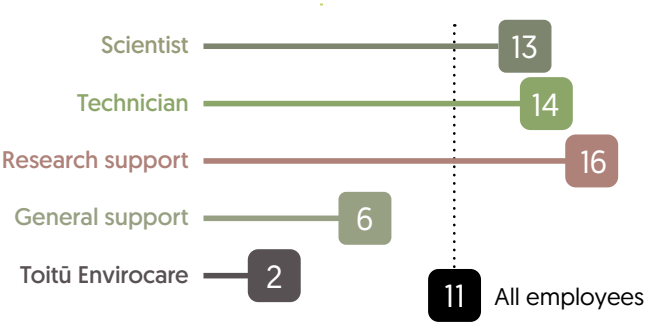
STAFF OVERVIEW

Overall engagement (%)

Overall gender distribution*

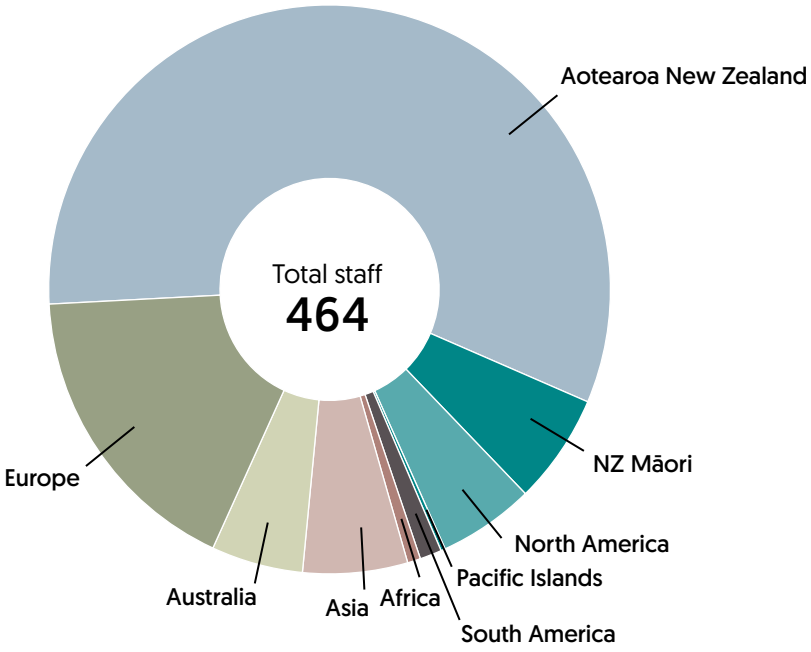
* None of our staff identified as genders other than male or female.

Average years' tenure

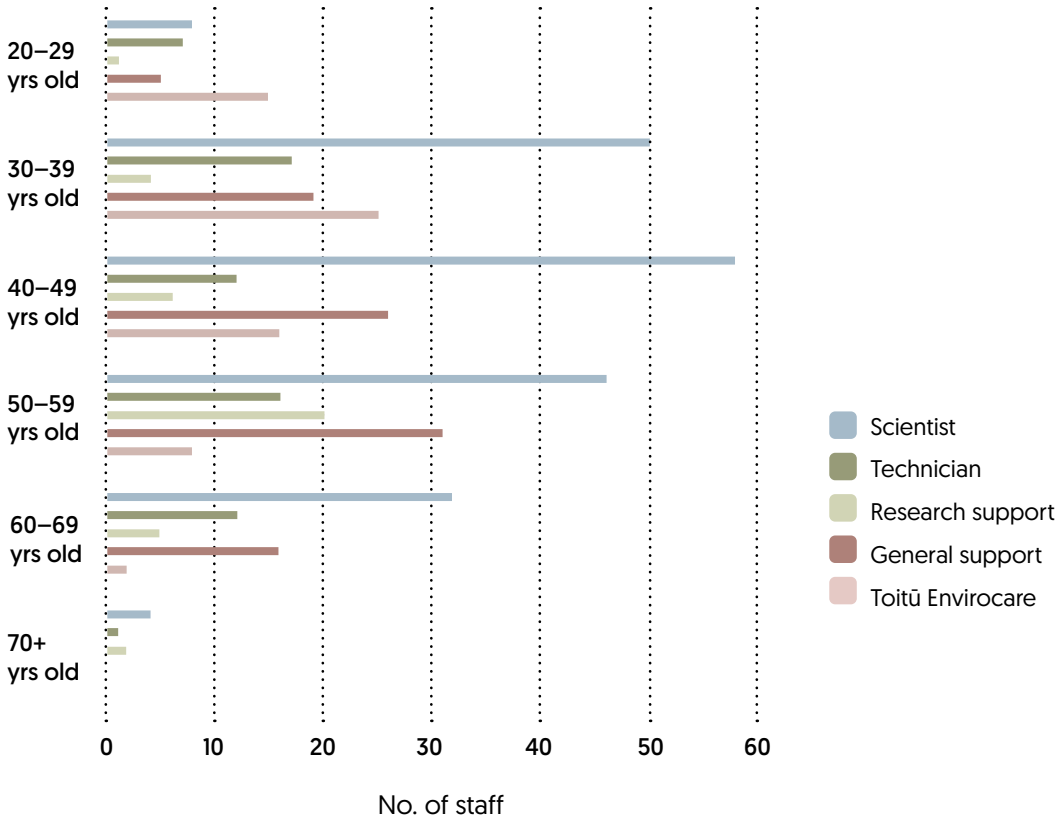


Annual turnover (%)

Origin



Age distribution



Our infrastructure

Our goal is that our collections and databases, property, equipment, and IT infrastructure support excellent research; and that our sites provide great working environments, support our partnerships, and are a base of interaction with New Zealanders.

Selected highlights

Our Te Rauhītanga project at the Lincoln site was completed and the new building officially opened in early May 2022 by Hon Dr Megan Woods, Minister for Research, Science & Innovation. The new spaces are a physical manifestation of our corporate strategy, deliberately designed to ensure integration among and interaction between staff and visitors, with many collaborative spaces and meeting points complemented by enabling technology.

The liquid nitrogen system for the ICMP collection at our Tamaki site was significantly upgraded in March 2022. Three new liquid nitrogen storage tanks were installed, extending our existing storage space from 3,400 to 23,000 samples per tank. This was the biggest upgrade since we began using liquid nitrogen for the storage of fungi and bacteria cultures in 1993.

Building security system upgrades were completed at the Lincoln and Hamilton sites, and improvements were made to Auckland site security. Other building upgrades include CO_2 monitoring in shared spaces at all sites, a new uninterrupted power supply in the Palmerston North instrument lab, a dust extraction unit installed at the Hamilton grinding room, carpark lighting at Lincoln and an upgrade to the Auckland staff café and kitchen.

Our nationwide printer fleet was modernised and upgraded as part of a move from Ricoh to Canon as a service provider. This move included implementation of a full cloud print solution (Uniflow Online). We also initiated an organisation-wide IT security maturity assessment in June/July 2021, aligned to the NIST (National Institute of Standards and Technology) Framework. This framework has also been adopted by several other CRIs.

National New Zealand Flax Collection – Te Kohinga Harakeke o Aotearoa – curator Katarina Tawiri (right) and contractor Aroha Jones with kete made from each of the 52 harakeke cultivars in the collection. Image: Kim Triegaardt.

Our impact processes

We identify groups of partners, and we formalise partnerships to bring together complementary skills, align planning, and build trust within and beyond the science sector, into government and industry.
Our emphasis is strongly on integration – across organisations, disciplines, and issues.

We have continued to support the Impact Planning and Evaluation Network (iPEN), a joint initiative between the seven CRIs that aims to create greater impact for research. Over the past year iPEN has developed resources and methods, related in part to our own work in i3 (see page 46) to hone the impact creation cycle and to develop a community of best practice.

Partnering nationally and internationally for greater impact

Our pathway to science impact depends on working with local, regional, and national government, the AoNZ science sector (including universities and the National Science Challenges), the primary sector, and Māori entities. As in previous years, this year we have developed new partnerships across linkages in the science value chain.

Partnership with Māori

Manaaki Whenua has developed enduring partnerships with selected iwi, groups of iwi, Māori trusts/incorporations, and Māori organisations (see also page 10). These partnerships support and contribute to our partners' aspirations. We engage regularly with these groups in the spirit of partnership, as expressed in the principles of the Treaty of Waitangi.

We seek to understand and respond proactively to the needs of our Māori partners, including novel approaches (e.g. through secondments and new commercial models). We increasingly co-design our science and research programmes with our Māori partners. We build on and add value to the platforms, tools, and technologies of our Māori partners to grow joint intellectual property that is beneficial to AoNZ. Our people have the skills and characteristics to engage well, deliver value, and support our Māori partners.

National partnerships

Local and regional sector partnerships
Manaaki Whenua has provided leadership in partnership with the regional and unitary council sector's Te Uru Kahika for a cross science institute alliance to increase the translation of science to improve implementation, increase scalability, prioritise research, improve capability and capacity to meet national, regional and subregional issues where a collective and collaborative response is needed.
Ministry for the Environment (MfE)
MfE and Manaaki Whenua signed a Partnership Agreement in 2019 which outlined a framework for working together and an engagement plan. Broad priorities were set (Capability Development, Land Use Adaptation and Resource Management System) We contribute to several MfE Advisory Groups and Working Groups such as the Science and Matauranga Advisory Panel (Dr Shaun Awatere and Garth Harmsworth). Manaaki Whenua is a member of MfE's Science provider panel.

Secondments have also proved to be a successful way to share expertise. Recent examples include Dr Anne-Gaelle Ausseil (leading the land domain reporting and latterly via MfE to the Prime Minister's Chief Science Advisor) and Dr Nina Koele (environmental reporting).

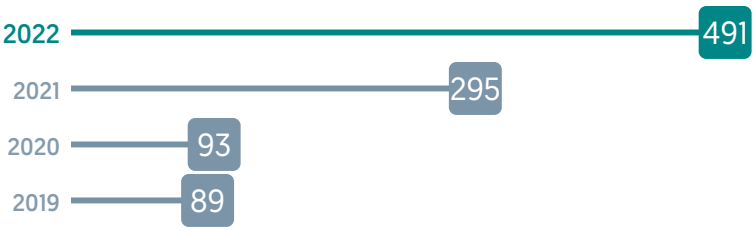
Ministry of Foreign Affairs and Trade (MFAT)
Our key relationship for work in the Pacific is MFAT, which has reached out to a number of CRIs to discuss a partnership that will sit outside a single contracting approach. Both the agriculture and climate sectors of MFAT are looking at specific partnerships to drive improved response in the pacific for social well-being under climate change. Discussions with Manaaki Whenua as one of the partners in climate and agriculture for research are advancing to identify the research needed and research alignment to address climate change within pacific countries for a more sustainable and resilient environment. Historically our main focus in the Pacific has been weeds, seeds, and soil, with some economic and social research. With the change in approach to funding and contracting and in-country development, it is anticipated a greater need across multiple portfolios will be required.

Department of Conservation (DOC)
A collaborative relationship agreement was signed in April 2021; the goals of this instrument are to achieve more relevant targeted conservation research and increase capability, work with iwi and share data.

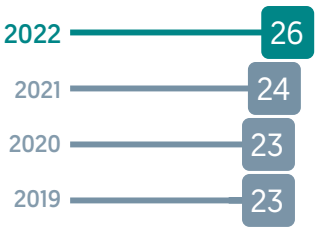
We have established agreed priority areas for development of research: in 2022 these are social and cultural

VISION MĀTAURANGA PROJECTS

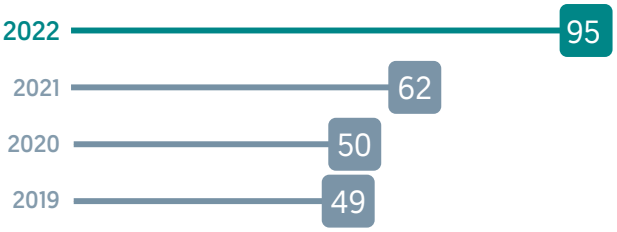
Research specifically relevant to Māori



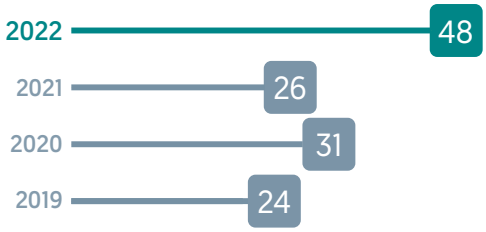
Kaupapa Māori



Research involving Māori

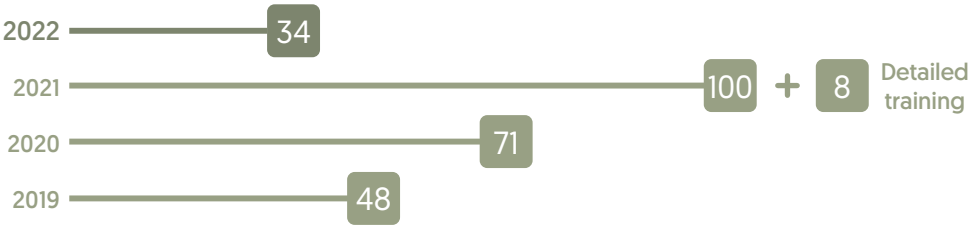


Māori-centred research

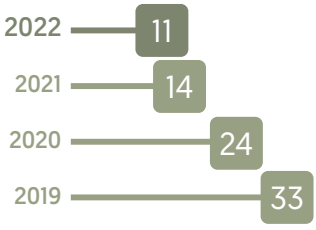


NUMBER OF WORKSHOPS

Treaty workshops



Cultural awareness workshops



Since 2019/20 some of our bicultural training activities have been affected by Covid-19. In 2021/22 these workshops included te reo Māori and tikanga, and some were held weekly.

research, climate change adaptation and carbon sequestration, and new technologies for conservation. Each of these areas is progressed through portfolio leaders and their counterparts at DOC, with support from relationship managers. Oversight of priorities and other areas of collaboration, in annual progress meetings between DOC's Deputy Director Generals and Manaaki Whenua's senior leadership team, ensures strategic alignment and review.

Primary sector partnerships

We are involved in several significant multi-agency primary sector initiatives, including working with MPI. Two examples are given below.

He Waka Eke Noa is a public-private primary sector climate action workplan. Detailed planning is occurring in farm planning, emissions reporting, on-farm sequestration, emissions pricing, Māori agribusiness and delivery (partner extension). Our contributions include work on the inclusion of soil carbon in a farm-level pricing system, analysis of barriers and incentives for Emissions Trading Scheme participation for planted native forests, and work on what drives a landowner in their land-use decision-making to choose afforestation of natives, for example carbon price level, grants in assisting planting, information and support for land management.

The NZ Agricultural Greenhouse Gas Research Centre (NZAGRC) is a partnership of nine organisations hosted by AgResearch. Manaaki Whenua's main research interests in NZAGRC are nitrous oxide mitigation, in which we play a small role, and soil carbon. There was significant funding in the last budget to accelerate the NZAGRC's research programmes, and we are working with collaborators at the University of Waikato to scope out future activities in this space.

International partnerships

Science is also an international endeavour. We reach out to and share expertise, staff, and data with many organisations across the globe. During COVID, our international interactions were continued remotely or in person where permitted, mostly between individual researchers. Organisational collaborations will be strengthened once again as travel restrictions ease.

Outside Thinking and Brilliant Writing

Outside Thinking and Brilliant Writing is designed to give researchers time to develop new thinking and novel ideas through collaborating both internally and externally, to provide significant mentoring to early-career scientists in writing and critical thinking, and to gain fresh inputs and to challenge our thinking. In 2021/22 we funded one initiative with $150k, to link our understanding of soil microbial ecology to soil formation, to conceptualise how chemical/physical processes interact with biology as dominant soil forming process at different soil depths.

The Science Den

The Science Den is an initiative to support the development of innovative and challenging ideas. The scheme is all about the ideas themselves, not running projects or doing the actual research, because truly innovative research isn't possible without really good ideas in the first place. No ideas are out

JOURNAL PUBLICATIONS

Average journal citation score of MWLR articles[1]

341 Papers published[2]

[1] Scimago journal ranking.

[2] Web of Science 2011–2022, for financial year 2021/22. Over 50% (196) of these 341 papers were collaborations with international institutes.

SCIENCE DEN

of scope. Risk-taking is encouraged, and failure is celebrated alongside success if we learn from it and try again. During 2021/22 we funded the development of three ideas:

- Controlling deer numbers with human odour.
- Developing a Neutral Landscape model using gaming.
- Developing a blood test to predict the toxicity of bait poison to birds.

Is our research being used by other scientists?

Our science adds to global knowledge and understanding of the natural world. Scientific knowledge is advanced by researchers building on each other's knowledge. A measure of this process is scientists citing other scientists' work in their publications in journals. The journals themselves are ranked by the level of citation of the articles they publish. Both are measures of scientific excellence.

In accordance with the Platform Plan, Manaaki Whenua aspires to be in the top 15% of research institutes globally for citation impact of publications, thereby maintaining and building on our internationally and domestically recognised excellence in science.

According to the InCites database, a tool based on the Clarivate Web of Science, New Zealand has a citation impact of 1.43, ranked as the 17th most-cited country in the world for papers published in 2017-2021.

For our 341 publications from 2021/22 we currently have a citation impact of 1.61, placing us behind Auckland University of Technology, on a par with the University of Auckland and ESR, and ahead of all the other CRIs and universities. Benchmarking against other CRIs, we produce the most papers per FTE and have the lowest cost per paper. These differences reflect, in part, that other institutes undertake more commercial research not leading to publications than we do. However, the data indicate our efficient use of funds to generate scientific advances.

We have two disciplines (Mycology and Soil Science) within the top 10% of all organisations globally. A further four disciplines (Evolutionary Biology, Entomology, Environmental Sciences, and Ecology) are within the top 30%. A relatively low citation impact for Zoology and Plant Sciences is due in part to many of these papers being 'New Zealand-specific' or published in AoNZ journals, thereby not attracting many citations internationally.

Our average Scimago journal ranking (citations per document over 2 years) is currently 5.2, up from 4.0 in 2020/21.

ONLINE ENGAGEMENT

LinkOnline seminars

Live session attendees		Later views		Total audience		
2,227	and	2,029	=	4,256	across	12 seminars

Manaaki Whenua social media

Facebook likes[1]

9,679

11% INCREASE in audience (all social media channels)

NZ Garden Bird Survey

Facebook Group members[1]

9,289

Instagram likes[1]

1,221

[1] Sprout Social media management tool.

Is our research valued and trusted by all AoNZ?

As we face complex challenges like climate change, biodiversity loss, and land-use intensification, Manaaki Whenua has a responsibility to support the conversation and understanding of these problems with robust, science-backed information. Engaging Government, industry, Māori, other scientists, and the AoNZ public with our research supports new partnerships for impact, helps develop social licence, educates, and helps shape our approach to these problems as we understand and incorporate the values of New Zealanders into our research.

Our Brand and Communications team leads the execution of this strategic goal area, supporting the wider organisation to engage through marketing, communication, and digital platforms.

Across all Manaaki Whenua social media channels (Facebook, Twitter, Instagram, LinkedIn, YouTube), our audience grew to 34,337, an increase of 3,467 (11.1%). The biggest increases were seen on YouTube (492 new subscribers, an increase of 63.5%) and Facebook (21.5%).

We continued to build on the success of our online seminars. Over the past year, we have held 12 Link Online webinars seen by more than 4,200 people. The most popular for the year was held in June 2022 – More Birds in the Bush – which had 612 registrations, reflecting how interested our stakeholders are in our biodiversity work.

We held the Biosecurity Bonanza webinar series virtually in May 2022, promoting the latest research from our weed biocontrol and predator control teams. Total registration numbers were up by 27% from 2021. Our virtual event hosted 961 people across the country, with 2,692 registrations across nine webinars that were watched over 2,100 times either live or via the recording. Several of the research stories were also covered in the national media.

During 2021/22 the Beyond Myrtle Rust MBIE research programme hosted well-attended webinars every month, with around 850 registered invitees and an average attendance of around 150 people including scientists, land managers, nursery owners and government. Presenters included researchers from the US and Brazil.

We also held our first webinar series with our remote sensing team to showcase our capability in this area. The mini-series hosted 712 people across the country, with 1,581 registrations across four webinars.

In June 2022 we had an actual, rather than a virtual, presence at E Tipu: The Boma Agri Summit, AoNZ's biggest food and fibre sector summit. We profiled the work of our some of our Kaihautū Māori Research Impact Leaders on a framework they developed for land-use decisions that allow the dual elevation of both te ao Māori and Western science knowledge systems to achieve sustainable and enduring livelihoods.

Senior Researcher Dr Ronny Groenteman in the field near Lake Tekapo, working on biocontrol of the invasive weed horehound. Image: Kim Triegaardt.

Our financial resilience

To fulfil our role as a CRI, we need financial strength to build and maintain critical research capability for AoNZ, to fund research infrastructure (buildings and technology), and to invest in the research ideas and opportunities agreed with our partners. Our financial resilience is therefore crucial to achieving our ambition.

CRIs are stand-alone businesses responsible for their own financial resilience. All our work is done on contract to clients and we are not bulk-funded. We operate on tight margins and we aim to be financially self-sufficient and sustainable. We target an average 6% return on equity to enable us to reinvest in our infrastructure. The shareholding Ministers have not required a dividend to be paid if we can show a valid investment of those funds in our assets. CRIs are responsible for funding their own capital developments (sites and equipment) in addition to staff costs.

Our financial performance for 2021/22 is outlined in Part 2 of this Annual Report.

Kākā, a large olive-brown parrot endemic to Aotearoa. Image: Neil Fitzgerald.

Our commitment to sustainable development

Our contribution to the future of AoNZ is underpinned by a sustainable business model that balances social, economic, and environmental impacts. As a Crown Research Institute, we are expected to be self-sufficient and financially sustainable. With the permission of our shareholding Ministers, our surplus is reinvested in our science and infrastructure.

In 2020 we identified the UN Sustainable Development Goals (SDGs) most relevant to Manaaki Whenua's research impacts and to how we operate as an organisation. From within and outside Manaaki Whenua, 38 people contributed to selecting 12 of the 17 SDGs. We then used those 12 goals as the framework for a new Sustainability Policy, launched to the organisation in mid-2021. On pages 64-65 we summarise how the 12 goals fit with our research and operational activities.

The UN has recently further developed its guidance around SDGs through the creation of SDG Impact Standards, a set of voluntary internal management standards designed to help organisations to embed sustainability and the SDGs into their management systems and decision-making practices. They are management practice standards similar to ISO standards, allowing meaningful and measurable progress to be made towards sustainable development.
We are now exploring these Impact Standards to enable further progress to be made in reporting of our organisational sustainability, including how the standards enhance the ISO certifications that we already hold across many aspects of our activities.

Sustainable procurement
As a Crown Research Institute, we access several All of Government (AoG) and syndicated contracts. Several of these have sustainable procurement practices, as required by the Government's broad outcomes, which are built into them. Our own Procurement Policy notes we 'Require sustainably produced goods and services wherever possible having regard to economic, environmental and social impacts over their life cycle'. We work to ISO 20400 standards for sustainable procurement.

Taking action to combat climate change
Given the focus of our business on the sustainable use of natural resources, it is especially important that we manage our operational activities to minimise any adverse impacts on the environment and our communities. The scope of these activities include moving our car fleet to electric vehicles, sustainable travel procurement and making progress towards sustainable energy use in our buildings

We have been certified to the ISO 14001 standard since 1998, meaning that we maintain systems to document and manage our environmental impacts. We have been certified carbon-neutral since 2011, meaning that we measure and manage our greenhouse gas emissions and pay to offset those emissions that we have not been able to eliminate. We maintain carbonzero certification through our subsidiary, Toitū Envirocare, which purchases certified carbon credits on our behalf, and with whom we have worked to explore how the UN's Sustainable Development Goals can be used for reporting on our sustainability.

This year we have taken delivery of an additional two full electric vehicles into our fleet, making a total of four (two in Lincoln, one in Auckland, and one in Hamilton). EV charging infrastructure is in place in Lincoln and Auckland and soon to be installed in Hamilton. Dunedin will follow later this year.

Photovoltaic solar panels are fully installed and operational at Lincoln, sufficient to provide base load power to our new Godley building on sunny days.

Our building energy use increased in 2021/22 directly relating to increased air flows and lengthier mechanical systems operation to help combat the spread of Covid-19 and improve air quality throughout our buildings.

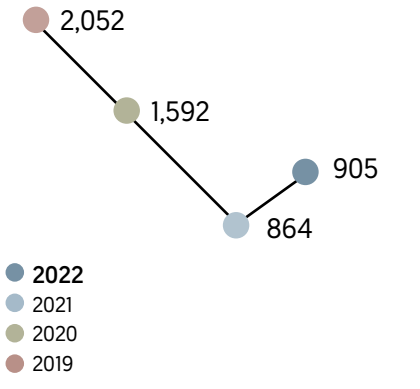
Carbon zero certification

2011–present
ISO 14001 certification
1998–present

TOITŪ CARBON ZERO ISO 14064-1 ORGANISATION

Total emissions (tCO_2-e)

* tCO_2-e = tonnes carbon dioxide equivalent.



Partly because of Covid, in 2020 and 2021 our carbon emissions were reduced.

Our research outcomes and the UN Sustainable Development Goals

Our research outcomes align with the UN Sustainable Development Goals as shown in the table below.

	UN SDG	Our goal statement
	**15. Life on land (and in water, from SDG14)** Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.	**We will** empower stakeholders to: • conserve, restore, and protect land-based ecosystems, soils and their services • reverse the decline of indigenous biodiversity and natural habitats • reduce the impact of invasive species • develop the sustainable use of land resources • develop equitable policies through partnership.
	**2. Zero hunger** End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.	**We will** inform the development of food production systems that enhance soil, land, water, and ecosystem services, and ensure climate change adaptability, while working especially with Māori in Aotearoa New Zealand and indigenous peoples in Pacific nations.
	**6. Clean water and sanitation** Ensure availability and sustainable management of water and sanitation for all.	**We will** guide the use of land in ways that improve freshwater quality, enhance water-use efficiency, protect, and restore water-based ecosystem services, and support integrated catchment-based governance and management.
	**11. Sustainable cities and communities** Make cities and human settlements inclusive, safe, resilient and sustainable.	**We will** inform the development of integrated policies and planning that enhance resource-use efficiency, ecosystem services, climate change mitigation and adaptation, resilience to natural disasters, and inclusive governance processes, while decoupling waste from growth.
	**13. Climate action** Take urgent action to combat climate change and impacts.	**We will** empower organisations, sectors and the nation to measure, manage, reduce, and mitigate their greenhouse gas emissions; understand climate risk and increase resilience; create opportunities, and develop policies and plans that integrate social, economic, cultural, and environmental dimensions.
	**16. Peace, justice and strong organisations** Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.	**We will** support the development of responsive, inclusive, participatory, and representative decision-making and governance by our stakeholders and the Treaty Partner, Māori.

Our corporate activities and the UN Sustainable Development Goals

The table below shows how our corporate activities align with the UN Sustainable Development Goals.

	UN SDG	Our goal statement
	3. Good Health and Well-being	**We will** empower our people to commit themselves 100% to health, safety and well-being while executing our own responsibilities as their employer.
	5. Gender Equality	**We will** ensure gender equity in participation, leadership opportunities, conditions and reward in all aspects of our work, using enabling technologies where appropriate.
	8. Decent Work and Economic Growth	**We will** achieve sustainable economic performance that supports innovation, entrepreneurship, job creation, staff development, fulfilling roles, and advancement opportunities with fair remuneration.
	10. Reduced Inequality	**We will** enhance the inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion, or economic, or other status and sustain income growth for our lower earners.
	12. Responsible Consumption and Production	**We will** measure and manage our own consumption and outputs to sustain and restore natural resources, reduce waste and emissions and foster a circular bio-economy, while through our procurement and services encourage other to adopt sustainable practices.
	13. Climate action	**We will** measure, reduce, and mitigate our greenhouse gas emissions, understand climate risk to our business, and increase our resilience.
	17. Partnerships to achieve the Goals	**We will** partner nationally and globally to build capacity, enhance knowledge and data sharing and access to science and technology, and enhance the Global Partnership for Sustainable Development.

Non-financial KPIs

Here we provide an overview of our non-financial performance metrics. Our full audited financial statements and other performance information are detailed in Part 2 of our Annual Report.

KPI		FY19	FY20	FY21	FY22
How we work	1. Employee engagement index	88%	81%	75%	76%
	2. Employee turnover	6.9%	4.5%	7.05%	8.33%
	3. Health & safety (near misses)	46	31	34	14
	4. Health & safety (lost-time injuries)	2	1	5	3
	5. Average tenure (years)	11	8	8.48	11
Science working with mātauranga Māori	1. Research with no specific Māori component	570	490	233	64
	2. Research relevant to Māori	89	93	295	491
	3. Research involving Māori	49	50	62	95
	4. Māori-centred research	24	31	26	48
	5. Kaupapa Māori	23	23	24	26
Our sustainability	1. Tonnes CO_2 per $m revenue*	27.11	18.95	9.77	9.46
	2. Total tonnes CO_2-e*	2051.63	1591.78	864.47	905.03
Our impact processes	1. Impact of scientific publications (mean citation score)	3.9	4.2	4.0	5.2
	2. Facebook likes	8758	9206	9182	9679
	3. Participants in Garden Bird Survey	3082	7800	6632	6234
	4. Interactions per social media post	126	143	119	187

*This table shows provisional amounts for 2021/22. Full audited amounts are shown in Part 2 of the Annual Report.

Index of innovation stories

Innovation stories can be found on the Manaaki Whenua – Landcare Research
landcareresearch.co.nz/publications/innovation-stories

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Becky Lloyd	Chief Executive, Toitū Envirocare
Daniel Patrick	Director, NZ Biological Heritage National Science Challenge
Prof Shaun Ogilvie	Kaihautū Ngātahi, NZ Biological Heritage National Science Challenge

*to 29 July 2022.
**to 9 September 2022.

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Science working for New Zealand

The Crown Research Institutes (CRIs) proudly work, individually and collectively, to create a more prosperous, sustainable and innovative New Zealand

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