Value of Crown Research Institutes in Aotearoa New Zealand's science system today

A Report for Science New Zealand

7 September 2021

Science New Zealand

agresearch
āta mātai, mātai whetū

E/S/R
Science for Communities

GNS SCIENCE
TE PŪ AO

Manaaki Whenua
Landcare Research

NIWA
Taihoro Nukurangi

Plant & Food™ Research
Rangahau Ahumāra Kai

SCION
FORESTS • PRODUCTS • INNOVATION

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INTRODUCTION TO THIS DOCUMENT

Overview

Thirty years ago, Parliament reshaped the way in which the national science research and innovation system worked. It split the policy, purchase and provider functions into different agencies, and melded government research elements from several agencies and departments into 10 Crown Research Institutes.

The Crown Research Institutes Act 1992 set out the CRI mission: to undertake, promote and disseminate research that benefits Aotearoa New Zealand. In doing so, the CRIs must pursue excellence, be ethical and socially responsible, good employers and financially viable.

Thirty years on, the mission remains the same – but how it is achieved has changed considerably. Good organisations have a clear mission and are dynamic in execution. The 30-year story of CRIs is one of change consistent with a focus on the science-based challenges and opportunities for Aotearoa New Zealand.

This document provides some insight into how the CRIs of today are delivering on their mission to benefit Aotearoa New Zealand. The examples come from areas that have long been critical to the nation's economic, environmental, social and cultural wealth and wellbeing.

What has changed is the scale of the ambition; the framing of the questions; and how new knowledge is generated, synthesised with existing knowledge and applied to greatest effect.

That has meant re-thinking the relationships between science disciplines, and of researchers with sectors, society, policy makers, and with other types of researchers.

Organisational relationships have changed markedly. The initial 10 CRIs operated very separately. The current seven are a more cohesive group, acknowledging they are bound by a common mission and ownership. They leverage the capabilities of each other to amplify the impact in their areas of core purpose. This is not limited to the formal lead or contributing roles each has in an area.

Today, too, there are deeper and broader connections globally as well as nationally with researchers, policymakers and sectors. This enables Aotearoa New Zealand to be more effective in shaping global thinking and practice on major science-based challenges, and increases access to the best ideas from offshore.

A fundamental shift is in the relationships with Māori and mātauranga Māori. While still a work in progress, the CRI engagement is substantially changed from the transactional approach of 30 years ago. There is commitment to deep, rich engagement, building

the capability of their staff and organisations and helping strengthen Māori and Crown capabilities.

Crown Research Institutions: a distinctive role

The government first made a commitment to put science research and innovation at the service of the people of Aotearoa New Zealand in 1849. CRIs continue that commitment in ways relevant to new times, challenges and opportunities.

Today's system has many more actors, each with their own role, purpose, culture and drivers: universities, charitable trusts, industry funded bodies, private sector companies, Ministry or departmental research capability, and various other Crown-owned or substantially Crown-funded entities and arrangements.

The CRIs remain distinctive through their mandate:

- to be relevant and responsive to Aotearoa New Zealand's unique economic, environmental, social and cultural requirements;
- to work on the issues of the day and especially those which others cannot or will not;
- to take the research through to impact that makes a difference for Aotearoa New Zealand;
- to look beyond the present to the future challenges and opportunities for the nation;
- to help the nation be prepared for natural, public health or other emergencies, and to be immediately available to help the nation at those times, and when government directs.

Success measures have changed

CRIs and shareholders have a more nuanced understanding of what success looks like than in 1992.

CRIs initially had to get onto a commercial footing within an open, competitive funding market. Financial targets set by the shareholder were above the required rate of return of those in the same market, such as government departments or universities. Not all survived: the Board of one CRI closed it after two years.

The shareholder has at times required CRIs to favour start-ups and spin-outs as ways of commercialising research. The difference between State Owned Enterprises (SOE) which are required to match or exceed returns from their market comparators, and the requirement upon CRIs to be (as the CRI Act requires) 'financially viable', was blurred. Dividends were expected, used in part to fund other Crown activity such as the Venture Investment Fund.

Today, the CRIs see success through how they enable their sectors and stakeholders achieve objectives which benefit Aotearoa New Zealand; and how they have ensured human talent and critical infrastructure is maintained and improved to sustain that success.

The shareholder acknowledges the importance of the social dividend - the environmental, social, and cultural gains as much as the economic, made possible by CRIs.

Relevant research

CRI science research is embedded in most of the country's exports, whether measured on volume or value. The value component of a largely volume-based export trade thirty years ago has increased substantially. The gold kiwifruit, for example, is worth two-thirds of the export value although only one-third of the plantings.

Productivity gains can also be seen in technologies and processes across the sectors which CRIs serve.

Relevance, excellence and value for money is indicated by the trust placed in CRIs by business. Of each $4 that businesses commission on external R&D, $3 is spent with CRIs. CRIs regularly top the OECD rankings for government-owned research entities commissioned by business.

Engagement with other researchers

CRIs have increased their engagement in the national and global research communities. This benefits research staff, the CRIs global connectivity, and the effectiveness of Aotearoa New Zealand's contributions to global science-led challenges and policies.

CRIs are the most connected science research organisations in the motu. They are regionally distributed, with more than 20 of their 54 sites shared with other CRIs, universities, public and private sector research organisations.

CRIs co-supervise 320-450 PhD students at any one time, and upwards of 100 at Masters level.

They are attracted by the quality of the research being undertaken, the business-like environment, and the opportunity to work on questions that matter with people who want to make a practical difference.

CRI-university science collaboration is extensive and both formal and informal. It shows in jointly authored papers, collaborative bids, co-supervision, and mentoring, and in joint graduate schools or specialised programmes.

CRIs are co-located with, or close to, each university. Over 30 CRI staff hold joint appointments (25 as full appointments). There are 13 joint graduate schools or specialised programmes with universities, and CRIs participate in 8 of the 10 CoREs (Centres of Research Excellence).

The number of refereed publications from the CRIs has risen steadily, with the output of refereed publications per CRI researcher now in the middle group among OECD countries. Importantly, the quality is high: citation rates are above the OECD average and match or exceed those of local universities.

Most outputs however are in the form of commissioned reports, conference presentations and other forms of knowledge transfer. This is the work that end users can take up.

Use-inspired science

Today's CRIs are built around the concept of use-inspired science: research whose framing and direction is driven by the potential use to which the knowledge will be put. It reaches into basic or discovery research, as well as engaging with the end users. It requires people able to work across the spectrum. The objective is knowledge that is useful, usable and used.

CRIs are now more deeply engaged with end users. Deeper understanding builds mutual respect, sharper research objectives and greater uptake or adoption.

Such proximity between CRI and end users requires more than ever that CRIs research is not only relevant, but rigorous and independent. CRI structures robustly support these 3 key criteria, to ensure trust by clients and society.

Government-owned capability

As with most advanced economies, most researchers in Aotearoa New Zealand are in the private sector. Aotearoa New Zealand has a relatively large number in government-owned research labs rather than universities. This distribution resembles other countries with resource-based economies, such as Australia and Canada.

It is consistent with the strong relationship between government policy and the primary and environmental sectors. Much research in and around these sectors is public good research, underpinning e.g. regulation, market access, exploration, land use, environmental concerns. While the private sector may wish to influence these areas, typically it has less interest in funding such research than does the government.

It also ensures the government has greater ability to both set the research agenda and ensure that there is continuity of scientific capability. It is easier to do so when it owns the principal provider in the sector and can set its strategic long-term direction, rather than be wholly reliant upon third-party organisations in academia or the private sector, with their different imperatives.

Most stakeholders seek payoff in the near to medium-term from research they fund. Long term research, including that which may provide long-term competitive advantage is riskier. This is where CRIs take a lead. CRIs have an important role in generating knowledge which can open new opportunities in existing sectors or create new sectors.

Stewarding national assets

The company model for CRIs was chosen in 1992 to incentivise efficiency and relevance, using financial viability as an indicator.

As stewards of critical capability, CRIs determine what meets current needs and what enables future opportunities for Aotearoa New Zealand – and so what needs to change in terms of science, other skill sets, equipment, facilities, and external linkages.

This has enabled Aotearoa New Zealand to acquire significant assets, such as high-performance computers, which are then available to other users.

Recruiting and retaining talent in internationally competitive fields is equally important to the country's future. CRIs have to be dynamic to meet or be ahead of challenges and opportunities. This requires careful management and development of staff skills and disciplines, from research through to its application and impact.

Change is managed within the parameters of what the Crown or others are prepared to support at any point. The net profit of each CRI has varied by the business cycle of the sectors its serves, its own business cycle and investment programme, and global and national economic cycles.

Encouraging and rewarding innovation

CRIs differ from many other research organisations in how research and its application is staffed. It is a team-based structure, and increasingly the team can be multi-organisational as well as multi-disciplinary. Who gets to work on a project is determined by expertise and availability.

The wider organisation, rather than an individual or research team, is responsible for taking the work through to impact. This contrasts with academics who are free to determine their own agenda, availability, research clients and end point.

Internal reward systems recognise this approach. CRIs regularly consult with staff on remuneration systems and find a variety of methods of rewarding good performance are preferred to individuals being rewarded for IP.

A project may have the prospect of commercially valuable intellectual property or may be focussed on 'public good' outputs (which, however, may still generate valuable IP).

The IP ownership is determined by the type of work, and who and how it is commissioned.

IP arising from government funded research is vested in a CRI, on the principle that a CRI is likely to make better use of it than a government department. When research is co-funded by the government and a third party, the third party may gain some IP rights, depending on how much background IP already existed. When IP is created under a commercial contract between a CRI and a client, the client owns it.

For the CRI, the key principle is: who can maximise the value to Aotearoa New Zealand from the IP.

The same principle underlies the release of data collected by CRIs. CRI data is released as soon as possible.

For some CRIs, royalty streams are now important sources of revenue. In other cases, a CRI might work alongside a commercial partner to exploit a new technology. CRIs are active in the proof-of-concept space, and all are now part of the commercialisation co-operatives which enable best practice to take new ideas to market.

In all cases the 'national interest' test is applied before a commercialisation route is chosen.

Databases and collections

The CRIs maintain and curate the officially designated nationally significant databases and collections. These are vital to creating new knowledge, or understandings.

CRIs have also developed other databases and collections to meet the nation's evolving needs. Many of these are internationally significant and underpin Aotearoa New Zealand's contribution to global issues such as climate change, natural hazards, or public health.

Many of these collections – especially of biological materials – have significance for Māori. They contain taonga from the rohe of iwi and hapū. The uses of these taonga must be considered against the rights of those peoples. CRIs are aware of obligations referred to in the Waitangi Tribunal claim WAI-262, relating to the use of indigenous flora and fauna and indigenous intellectual property.

Creating efficient, relevant, effective organisations

The introduction of commercial-like structures and processes was one of the most visible changes made in 1992. It brought new efficiencies to the science activities of government-owned entities, and enabled innovations in relationships with the sectors.

Accountability was intended to rest with the Boards; however, the nature of the government bidding process limited the ability of CRIs to make commitments of significant size or duration with partners. When this changed, CRIs were able to apply their knowledge of sectors, science and global markets to partner with, challenge and lead their sectors.

While CRIs must still operate within the competitive funding market, they now work cooperatively wherever possible. This includes extensive multi-disciplinary, multi-organisational activity across support services, such as ICT, as well as the science.

Tying them together is the shared mission: to benefit Aotearoa New Zealand through research that is useful, usable, and used.

CRIs have constantly evolved with the science system and government's policy settings. They remain committed to ongoing improvement as they look to reinforce their collaborative focus and accelerate their impact.

Scope

This Report provides a view of the CRIs as they are today. It uses eight focus areas to illustrate how CRIs perform their mission to deliver benefit to Aotearoa New Zealand from excellent, relevant science research.

The eight areas are:

1. Emergency response
2. Biosecurity and Public Health
3. Biodiversity
4. Water resources
5. Climate change
6. Energy
7. Food and Fibre, and Manufacturing
8. Land use.

The Report:

— Outlines the collective role of the CRIs in the science system.
— Describes how CRIs are aligned and connected to deliver the focus areas identified above including: Mapping the role of each CRI supporting each focus area (lead and specialised); complementary science capabilities and resources deployed; end users of scientific research and how the knowledge is applied; outcomes for Aotearoa New Zealand.
— Identifies some areas of opportunity for improved coverage, alignment and effectiveness in the delivery of outcomes.

The report does not include detail on current state funding across the CRIs.

Note: See Appendix 1 and 2 for documents, information and stakeholders engaged to inform this current state report.

1. https://www.beehive.govt.nz/sites/default/files/CRITaskforceFinalreport.pdf
2. https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/national-science-challenges/
3. https://www.mbie.govt.nz/assets/436ecb3be9/strategic-science-investment-fund-investment-plan.pdf

BACKGROUND

ABOUT THE CRIs[4]

Each CRI has a Statement of Core Purpose set by Government in 2010. The Statements of Core Purpose set out the unique purpose of each CRI and the areas in which a CRI leads and those in which it contributes. It requires a CRI to work in partnership with government, industry or sectors, Māori and communities. A CRI develops its strategies with these stakeholders, and collaborates with clients, partners and researchers around the world to action them. Detail on capabilities and outcomes are described later in the document.

AgResearch

AgResearch plays a key role in delivering science, research, new ideas and technologies to support the agriculture sector of Aotearoa New Zealand.

Purpose:

- To enhance the value, productivity and profitability of Aotearoa New Zealand's pastoral, agri-food, agri-technology sector value chains.
- To contribute to economic growth and beneficial social and environmental outcomes for Aotearoa New Zealand.

Institute of Environmental Science and Research

Purpose:

- To deliver enhanced scientific and research services to the public health, food safety, security and justice systems, and to the environmental sector.
- To improve the safety and contribute to the economic, environmental and social wellbeing of people and communities in Aotearoa New Zealand.

Institute of Geological and Nuclear Science

GNS Science focuses on understanding the natural Earth's system processes to translate these into economic, environmental and social benefits for Aotearoa New Zealand.

Purpose:

To undertake research that:

- Drives innovation and economic growth in Aotearoa New Zealand's geologically-based energy and minerals industries;
- Develops industrial and environmental applications of nuclear science;
- Increases Aotearoa New Zealand's resilience to natural hazards; and
- Enhances understanding of geological and earth-system processes.

4. Crown Research Institutes. 'Ministry of Business Innovation and Employment', [website], https://www.mbie.govt.nz/science-and-technology/science-and-innovation/agencies-policies-and-budget-initiatives/research-organisations/cri/, (accessed 8 April 2021).

The CRIs have two shareholding ministers (the Minister of Research, Science and Innovation and the Minister of Finance). The Ministers appoint the Board of a CRI, which then appoints a Chief Executive.

The Shareholders' expectations are contained in a Statement of Core Purpose that defines each CRIs purpose, expected outcomes, scope of operation and operating principles. The Ministers also provide an Annual Letter of Expectation to each Board.

A Statement of Corporate Intent (SCI) is agreed with the Ministers, setting out the strategy for delivering against the core purpose of the CRI over the following five years. The SCI is reviewable annually. Each CRI also presents an Annual Report in line with Companies Act and CRI Act requirements, to Parliament.

Manaaki Whenua Landcare Research

Manaaki Whenua

Purpose:

- To drive innovation in Aotearoa New Zealand's management of terrestrial biodiversity and land resources in order to both protect and enhance the terrestrial environment and grow Aotearoa New Zealand's prosperity.
- It aims to ensure that all New Zealanders have the understanding, tools and confidence to truly live in harmony with this land. Their vision is Kia tupu matomato a Tane, a Rongo, a Haumia-Tiketike (let it be that the land and all its fruits should flourish).

NIWA Taihoro Nukurangi

National Institute of Water and Atmospheric Research

Purpose:

- To enhance the economic value and sustainable management of Aotearoa New Zealand's aquatic resources and environments.
- To provide understanding of climate and the atmosphere, and increase resilience to weather and climate hazards to improve the safety and wellbeing of New Zealanders.

Plant & Food Research Rangahau Ahumāra Kai

Plant & Food Research

Purpose:

- To enhance the value and productivity of Aotearoa New Zealand's horticultural, arable, seafood and food & beverage industries.
- To contribute to economic growth and the environmental and social prosperity of Aotearoa New Zealand.

SCION FORESTS • PRODUCTS • INNOVATION

Scion

Purpose:

- To drive innovation and growth from Aotearoa New Zealand's forestry, wood product, wood derived materials, and other biomaterial sectors;
- To create economic value and contribute to beneficial environmental and social outcomes for Aotearoa New Zealand.

Note: See Appendix 3 for further detail on each of the CRIs.

ABOUT THE CROWN RESEARCH INSTITUTES

CRI SCIENCE SYSTEM

agresearch
āta mātai, mātai whetū

E/S/R
Science for Communities

GNS SCIENCE
TE PŪ AO

Manaaki Whenua
Landcare Research

NIWA
Taihoro Nukurangi

Plant & Food™ Research
Rangahau Ahumāra Kai

SCION™
FORESTS ▪ PRODUCTS ▪ INNOVATION

$805.76M
Total operating revenue

$401.79M
Total revenue from MBIE
(Includes the Strategic Science Investment Fund, MBIE contestable funding and COVID19 funding)

$365.94M
Total revenue from contract research
(Includes commercial contracts from public and private sectors)

CRIs are, collectively, the largest providers of science research to Aotearoa New Zealand's public and private sectors. When business commissions external research, it is primarily done with CRIs. In the OECD Aotearoa New Zealand has the highest percentage of research funded by industry and conducted at government institutions (principally CRIs and Callaghan Innovation) - nearly five times the OECD average and double that of the EU.

3,756 FTE

Full Time Equivalents

(Includes research teams, research support and other staff)

40

Nationally significant databases and collections

(Includes the 27 officially designated NSDC)

54 SITES (PLUS 9 FARMS)

Operational sites including international

(21 are co-located with 1 or more CRI, Callaghan Innovation, universities and/or private sector organisations)

6,000

Projects p.a.

(Approx.)

Source: (OECD MSTI database).https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB
CRI Data: CRI Annual Reports for financial year ending 30 June 2020.

ROLE OF THE CRIs IN THE SCIENCE SYSTEM

CRIs provide science, research, innovation and related services for the long term benefit of Aotearoa New Zealand.

The CRIs are mandated by their Act to benefit Aotearoa New Zealand by providing scientific research and by transferring the knowledge and technologies to their sectors.

Scientific research is core but not the end point of the CRI purpose.

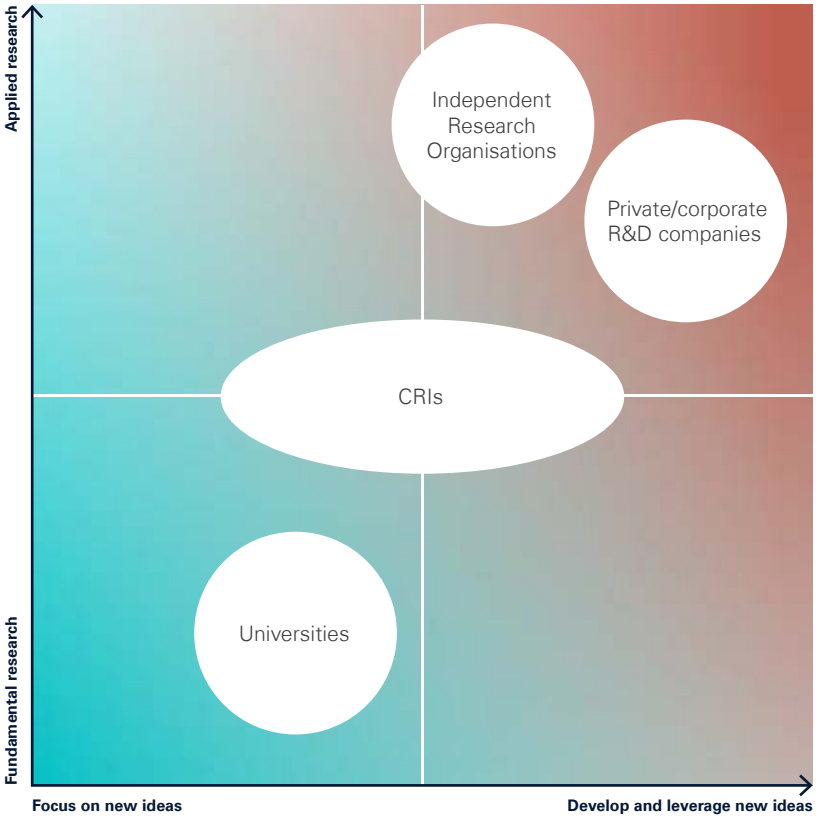
CRIs develop close partnerships with public, private and community users to guide the direction of their science, research and innovation. This ensures a focus on excellent, relevant and timely ideas and solutions, whether incremental or step change.

Close partnerships also enable CRIs to anticipate issues, challenge existing science, policies or practices and to present new opportunities.

The CRIs were set up from existing Government owned bodies. Their new role included to support, sustain, challenge and develop existing sectors and contribute to the development of new sectors.

While each CRI has a unique core purpose, collectively their aim is to deliver science and research for public good and the improvement of New Zealand Inc. They achieve this by addressing Aotearoa New Zealand's most pressing issues, driving innovation, contributing to social wellbeing, economic growth, and maintaining capability critical to this country. They work with other research and commercialisation partners nationally and globally as a natural part of this mission.

The mission-led focus of the CRIs leads to a natural alignment of science research and innovation with end users who apply their research. Fundamental research is undertaken only in so far as it contributes to the overall mission.



Develop and leverage new ideas

The mission-led nature of CRIs leads to more predetermination of the 'next users' of work, which allows CRIs to build stronger partnership with their sectors and end users. This type of science and research is essential to Aotearoa New Zealand sectors, organisations, people and communities.

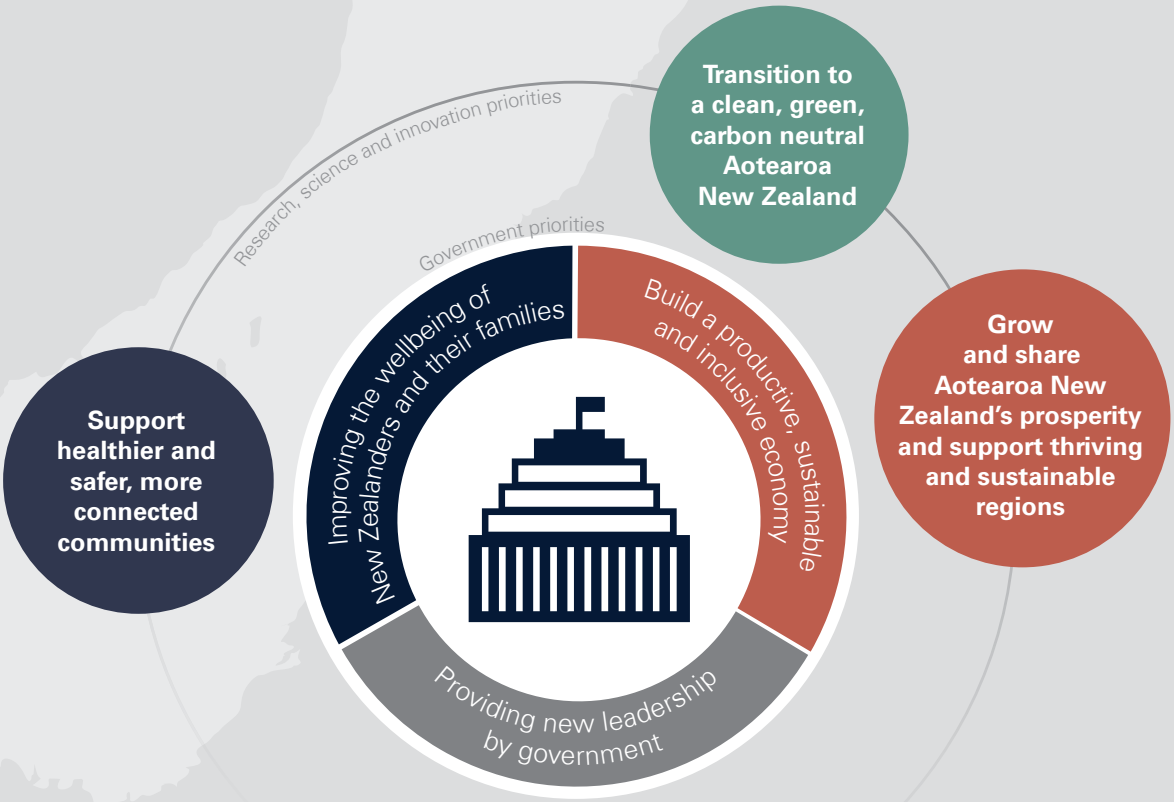
Note: the diagram is indicative of the core purpose of each type of organisation, considering science capabilities and overall focus. In practice, there is overlap due to complementary activity.

GOVERNMENT PRIORITIES

As the CRIs have a mandate from government to deliver mission-led science for the benefit of Aotearoa New Zealand, it is important that they work towards government's priorities. The diagram below summarises the current government priorities for Aotearoa New Zealand and how they link to the Ministry of Business Innovation and Employment's Research Science and Innovation Strategy (RSI) priorities. Partnership with Māori, co-development and innovation with Māori and honouring Te Tiriti o Waitangi obligations are a key focus for government and intrinsic to the RSI strategy, science system and the CRIs.

The RSI priorities (below) are a synthesis of relevant policies. They represent broad thematic areas rather than specific goals for mission-led science organisations.

The next two pages provide an overview of what and how the CRIs currently collectively deliver within Aotearoa New Zealand's science system, using the eight focus areas. This shows the linkage between the CRIs focus, government priorities and the needs of NZ Inc more widely.



NEW ZEALAND PAN-CRI SCIENCE ON A PAGE

Government Science Priorities

Support healthier and safer, more connected communities

Transition to a clean, green, carbon neutral Aotearoa New Zealand

Focus Areas

1 EMERGENCY RESPONSE

Enhance Aotearoa New Zealand's preparation, response, recovery, and management of emergencies.

Key Areas of CRI Expertise

- Public health emergencies
- Security and justice sector
- National and environmental threats

2 BIOSECURITY AND PUBLIC HEALTH

Reduce the entry and establishment of new plants, pests, and diseases in Aotearoa New Zealand, and increase the nation's public health preparedness against future threats.

Key Areas of CRI Expertise

- Public health
- Detection and identification
- Response and eradication
- Monitoring and control

3 BIODIVERSITY

Reverse the decline, maintain, protect, and restore Aotearoa New Zealand's unique biodiversity.

Key Areas of CRI Expertise

- Identification and characterisation
- Management and conservation

4 WATER RESOURCES

Enhance the safety, management, sustainability, value, and maintenance of Aotearoa New Zealand's drinking, recreational, and other water resources.

Key Areas of CRI Expertise

- Freshwater
- Groundwater
- Wastewater
- Coast and oceans

Foundational Enablers

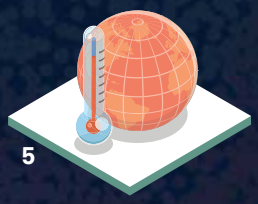
- **Connection with international research, science and innovation for the benefit of Aotearoa New Zealand**
- **Partnership, co-development and innovation with Māori and honouring Te Tiriti o Waitangi**
- **Partnership between CRIs and their sectors**
- **Societal dimension of impact and response to environmental challenges, economic development and risk**

CRI Enabling Capabilities

- Science staff
- Laboratories and research facilities
- Collections, libraries and databases

Below is an overview showing how the CRIs collectively contribute to the Aotearoa New Zealand science system. The following sections provide further detail. While the Priorities and Focus Areas are identified separately, it is important to note that they are interlinked and impact each other.

Grow and share Aotearoa New Zealand's prosperity and support thriving and sustainable regions



CLIMATE CHANGE

Enhance Aotearoa New Zealand's resilience to climate risks and support transition to a zero-carbon future.

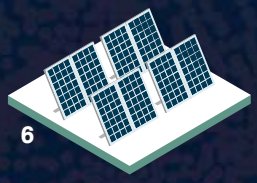
Understanding change

Assessing risk

Supporting adaptation

Reducing emissions

Clean Energy



ENERGY

Enhance the availability of clean energy for Aotearoa New Zealand's societal welfare, economic competitiveness, and support the transition to a zero-carbon future.

Energy storage

Energy resources and production

Energy utilisation

FOOD AND FIBRE AND MANUFACTURING

Enhance the economic, environmental, social and cultural sustainability, value, innovation and growth of Aotearoa New Zealand's food and fibre sectors – and of associated manufacturing.

Pastoral

Horticulture

Seafood, fisheries, aquaculture

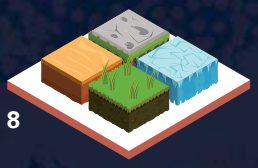
Food and beverage

Bio-based products

Forestry

Advanced manufacturing

Packaging



LAND USE

Ensure that Aotearoa New Zealand's land is valued, protected managed and used effectively.

Land health

Land management

Land use prioritisation

Farms, nurseries, glasshouses and pilot facilities

Marine research vessels

High performance computing

Sensor networks, data science and AI

ENABLING CAPABILITIES

The CRIs have a range of enabling capabilities which support the delivery of their core science, research and innovation for Aotearoa New Zealand. These capabilities are enduring and often unique to the CRIs. Investment in enabling science capabilities such as specialist infrastructure, digital assets, information, and human capital and knowledge are fundamental to the performance of small advanced economies. These economies nurture globally competitive companies that trade distinctive goods and services. The success of these companies relies on an ecosystem of innovation and improvement that often requires scientific research which goes beyond their in-house R&D capability. Therefore the importance of investment in enabling capabilities should not be overlooked as a critical aspect of the Aotearoa New Zealand economy and wellbeing of its people.[5]

5. New Zealand Productivity Commission (2021). *New Zealand firms: Reaching for the frontier. Final report.* Available at www.productivity.govt.nz/inquiries/frontier-firms/

Some of the CRIs' core enabling capabilities are summarised below.

Science staff

The CRIs invest in deep and enduring capabilities across their areas of expertise. This knowledge cannot be replicated or replaced easily and requires time to develop. CRIs' staff (close to 4,000 FTEs) provide the bulk of Aotearoa New Zealand's science and research capacity in their respective areas, and are core enablers of activity across the science system. Their deep subject knowledge is fundamentally unique to the CRIs, hard to replicate and valuable for Aotearoa New Zealand.

Laboratories and research facilities

Laboratories and research facilities enable the application of the CRIs capability and theory into products, knowledge and services for Aotearoa New Zealand. This infrastructure is shared with the science system across CRIs, Callaghan Innovation, universities and private sector organisations. They provide testing, screening and detection services for which CRIs are responsible; environments for developing and proving innovative ideas and exploring underlying fundamental science relevant to the core purpose of the CRI. Examples include: AgResearch's Large Animal Containment Unit, GNS's Geomechanics Lab, Plant & Food's Seafood Research Facility, NIWA's Marine Research Centre, Scion's Pilot Scale Mechanical Pulping Plant, NIWA's Lauder Atmospheric Research Facility.

Collections, libraries and databases

The CRIs' maintain and develop extensive collections, libraries and databases that are used across government, private organisations and internationally. They hold unique information about a particular focus area. For example, the National Vegetation Survey Databank maintained by Manaaki Whenua is a nationally recognised archive used by local government, research organisations, universities and private research organisations. These resources have been developed over many years and enable research projects as well as the science services provided by CRIs to their partners. The information can be used to determine needs, strategies and success in specific objectives such as restoration efforts, biosecurity, understanding environmental change effects, assessing and quantifying damage. They can be the basis for decision making for policy and regulatory change.

Farms, nurseries, glasshouses and pilot facilities

The CRIs own and maintain farms, nurseries, glasshouses and pilot facilities. Examples are Scion's GMO Field Trial and glasshouse facilities and the Marine Products and Extracts processing pilot plant operated by an alliance of AgResearch, Plant & Food Research, Scion and Callaghan Innovation. These assets are also used by other organisations across the science and innovation system.

Marine research vessels

The CRIs operate Aotearoa New Zealand's key marine research vessels. These vessels are used for world-class environmental monitoring and research. Some of them are national research facilities owned by the CRIs. They are equipped to enable the exploration and understanding of the ocean, the worlds most poorly understood resource. NIWA owns most of these Marine Vessels such as RV Tangaroa which is Aotearoa New Zealand's only ice strengthened and dynamically positioned deep-water research vessel.

High performance computing

High performance computing assets are now essential in realising the potential of data-driven science, research and innovation. NIWA, AgResearch and Manaaki Whenua have HPC capability customised to their areas of science and sectors.

The computing power enables CRIs to carry out fast processing / big data analysis for their own use and for other users of their research. This enables CRIs to work at the forefront of Aotearoa New Zealand's science challenges requiring this capability. These include modelling the impact of climate change, analysing genetic information, understanding the system driving our ocean and building science algorithms and artificial intelligence networks. The CRIs make this computing power available to other users for the benefit of Aotearoa New Zealand.

Sensor networks, data science and AI

Sensor networks, 'internet of things', data science, artificial intelligence and other technologies are core enabling capabilities for CRIs. They allow CRIs to gather data and provide fit- for-purpose solutions for end users, enhance the speed, precision and effectiveness of the science they provide and can result in new technologies, products and services for public and private sectors, including communities. The CRI focus is on advancing the technology in order to achieve benefits to Aotearoa New Zealand. Examples include application of sensor networks to monitor air quality for communities and monitoring soil quality on farms to optimize productivity in the growing cycle. Other examples are ESR's EpiSurv – Notifiable Disease Surveillance System, Plant & Food Research's Consumer Sensory facilities and GNS's GeoNet monitoring and associated GeoNet databases and digital assets.

SENSOR NETWORKS, DATA SCIENCE AND AI
CASE STUDY

Plant & Food Research's development in sensor technologies and artificial intelligence demonstrates how a CRI uses advanced technology solutions to contribute to social, economic, and environmental benefits.

Plant & Food Research is using their knowledge of insects' super sensitive smell receptors, sensor technology, and insight into potential real-world uses to create a new product: an artificial insect smell sensor that can be programmed into a computer and has the potential to be used across personal devices. This type of technology will enable doctors to test a patient's breath to determine if they have a disease, give warnings about expired food, test produce freshness to direct the timing of shipments, and find single insect stowaways in shipping containers and thus protecting Aotearoa New Zealand's borders.

Not only does this innovation provide economic, social and environmental benefits, it also places Aotearoa New Zealand as a world leader in this type of technology.

MĀORI ENGAGEMENT ACROSS THE CRIs

Ensuring meaningful engagement between Māori and CRIs is a priority underpinned by the Crown-Māori relationship. CRIs value the traditions of both science and mātauranga Māori in adding to knowledge generation and its application in Aotearoa New Zealand.

Individually and collectively, CRIs have links with numerous Māori entities: iwi, hapū, Māori businesses, land-owning incorporations, etc. These include long-established extensive networks and engagement with Māori communities on local Māori needs.

How CRIs enter into and participate in such relationships has transformed in recent years. Relationships are developed more in line with a Māori world-view comprising kaitiakitanga, manaakitanga and tino rangatiratanga. It corrects the historical approach of science for Māori rather than science with Māori.

A co-creation approach recognises the importance of wellbeing, social capital, and cultural wealth concepts. This holistic approach makes different demands on science than the non-Māori approaches to, for example, natural resource development. CRIs embrace this approach.

CRI science practice is increasingly integrating different disciplines to reflect the nature of contemporary issues where social and cultural issues are inherent. This is particularly seen regarding the whenua, indigenous flora and fauna, climate change, food sustainability, water and predator-control.

CRIs seek to make it easier for Māori to engage, including for Māori to initiate engagement and drive the process. An important channel is the long-standing group of Māori senior managers, Te Ara Pūtaiao, led by the General Managers in each CRI.

CRIs acknowledge that there is a difference between scientific researchers who are Māori and Māori researchers who are trained in te ao Māori methods. CRIs seek to encourage and develop both.

Collectively, about 3% of staff in CRIs are Māori, with Māori comprising about 2% of the science staff (these figures vary across CRIs and disciplines). To reach parity with the Māori proportion of the population would require an additional 540 staff members.

CRIs are concerned that too few Māori enter tertiary study, and that fewer still attain science, technology, engineering or mathematics-based qualifications. Māori choose STEM subjects at a lower ratio than do non-Māori. This constrains capacity within Māoridom and the CRIs.

CRIs provide scholarships, summer schools and internships, promote opportunities at CRIs and highlight research relevance to Māori aspirations.

Each CRI Board has at least one director identifying as Māori (around 1 in 7 or 14%). Each CRI has a Māori General Manager and a Māori-focused role in the Senior Leadership Team, reporting to the Chief Executive.

The responsibility for greater cultural competency rests throughout the organisation, and so CRIs have been building processes and personal development opportunities to ensure it is embedded in the internal culture of the CRI. This includes co-creation and co-development processes, and widening and deepening the relationships with Māori at the institutional level.

The mission of CRIs brings a focus on understanding the needs of Māori in both the research and its application, and thus together developing successful outcomes.

Partnering with Māori in science and innovation unlocks the unique innovative potential in Māori knowledge (mātauranga), Māori people and resources, and further develops the closeness of relationship that is needed for authentic co-innovation and development of partnerships.

- Iwi and Māori businesses are keenly interested in the potential for generating economic, environmental, employment or cultural returns from whenua. Some are willing to accept a lower economic yield provided there is increased uri connection with their whenua, greater local employment options and better environmental outcomes because of the initiative.
- The One Billion Trees initiative enables integrated development options that include the planting of commercial trees and restoration of native tree populations for multiple benefits (biodiversity, carbon, natural products, etc).
- CRI capability, knowledge and application is relevant to Māori aspirations in areas such as freshwater and protection of taonga species (including mahinga kai and threatened birds); and mātauranga Māori is a critical pillar in that work.
- Various forms of MOU exist to identify indigenous knowledge and seek protection of that for its owners under agreed intellectual property rights and accessibility.
- CRIs invest in Māori-related projects from their SSIF (Strategic Science Investment Fund), but cannot fund the extent of available high-quality, high impact mātauranga-led projects. The system funding model prioritises "transformational" science; however land-use options and managing environmental change are often at the centre of Māori aspirations for the whenua and taiao.

CRI-Māori engagement is a critical element in each of the 8 focus areas presented in this Report, and examples are provided under those headings. The following pages present additional examples to illustrate the breadth of engagement, collaboration and partnership.

SPECIFIC EXAMPLES OF CRIs MĀORI FOCUS

agresearch
āta mātai, mātai whetū

AgResearch is implementing a strategy (Te Ara Tika) focused on supporting Te Taiao by bringing a unique Māori approach to their science and creating meaningful impact for Māori by: embracing mātauranga Māori, being impact focused and delivering to Māori land, businesses and communities, honouring the Treaty relationship, and co-designing and co-developing capabilities and aligning values in everyday work.

E/S/R
Science for Communities

ESR has a Māori impact programme which aims to grow and embed investment in Māori-led and mātauranga Māori science and research, partner with Māori to take a co-design approach in research, science and innovation.

GNS SCIENCE TE PŪ AO

Vision Mātauranga is at the core of **GNS Science's** strategic framework. GNS Science is strengthening existing and creating new relationships with iwi/ Māori, growing Vision Mātauranga across its Science Themes, supporting the development of iwi-led research, and collaborating with other CRIs to develop Māori research and innovation capability. It seeks strong, meaningful relationships to better understand Māori science needs and expectations. The aspiration is that Māori worldviews, priorities and needs are clearly visible and reflected in how it works as well as its strategic direction.

Manaaki Whenua
Landcare Research

Manaaki Whenua have embedded in their culture and strategy the requirement to build understanding between scientific and Māori world- views and to support Māori land development options that enhance community resilience and restore natural capital. This includes embedding Tiriti (Treaty) principles of partnership, participation and active protection of Māori interests through the organisation.

NIWA
Taihoro Nukurangi

NIWA is focused on increased partnership, collaboration, co-development, empowerment and work with whānau, hapū, iwi and Māori enterprises. This focus aims to sustainably develop resources and businesses in accordance with Vision Mātauranga and respecting government's obligations to Māori through Te Tiriti o Waitangi.

Plant & Food Research
Rangahau Ahumāra Kai

Plant & Food Research has a 10 year strategy, Tono, to build strong, long-term, trusted partnerships with Māori, and towards a Smart Green Future in partnership with Māori.

SCION
FORESTS • PRODUCTS • INNOVATION

Scion has committed to embedding Te Ao Māori into the business with investments in Māori partnerships, collaborations and investing in research programmes that directly support Māori aspirations.

Scion has mana whenua embedded into the organisation and have a full-time Hapū Operations role reporting directly to the Hapū, Scion and other companies on site.

CRIs are committed to deliver on these strategies by increasing collaboration with Māori, co-developing research programmes, and uplifting staff skills and understanding to embed this approach in daily operations.

Some examples of collaboration are listed below:

AgResearch has co-created and implemented an engagement framework with Māori stakeholders for researchers to align science with Māori agribusiness. One of AgResearch's key outcome areas is achieving vibrant Māori agribusiness.

ESR uses Māori-led science and research for the use of freshwater, using an approach that honours Te Tiriti o Waitangi. ESR have experience in kaupapa Māori research and core capabilities in Māori and iwi specific research for water resources to improve the safety of freshwater, drinking water and groundwater. ESR is investing in relationships with iwi to have a base for research and common objective engagement. This includes the wai mapuna initiative and regional tangata whenua engagement.

GNS has Māori partners in research and commercial initiatives centred on mutual interests in ngā taonga tuku iho – the treasures of our heritage. Māori collaboration covers coastal environments, processes and strong collaboration with iwi around Northland and the geocamps programme which is focused on immersion (with local iwi) for co-designing schooling about the coast and environment.

Manaaki Whenua - Examples of collaborations include a Māori soil sovereignty and health project; manuka/kanuka honey and ecosystem health; Kaupapa Māori ecosystem assessment; bicultural forest monitoring; and a co-developed biodiversity framework for iwi (wetland health assessment framework e.g. Ngāi Tūhoe).

NIWA has assets and resources in Te Kūwaha, National Centre for Māori Environmental Research, and key partnerships with Māori to develop plans and tools for adaptation and emissions reduction. NIWA recently completed a climate change vulnerability assessments for ten taonga species for Te Wai Māori Trust.

Plant & Food Research is embedding collaboration into its projects and upskilling staff on Te Ao Māori.

Scion is experienced in Māori co-innovation, with many successful programmes where this has occurred. Its Cultural Competencies framework is uplifting the skills of staff in Te Ao Māori. Scion is committed to strengthening mātauranga capability, including Mātauranga Researcher career pathways and the appointment of a Principal Researcher-Mātauranga.

ABOUT THE NEXT SECTION

Introduction

This section of the report provides more detail on the collective contribution of CRIs to the focus areas.

For each focus area, the section provides:

- An introduction to the focus area.
- The key scientific capabilities offered by CRIs.
- The roles of CRIs and key outcomes they seek.
- Enabling assets and resources.
- Cross-CRI collaborations.
- End users.
- Case studies that showcase the collective impact of CRIs.

Important considerations when reading this section

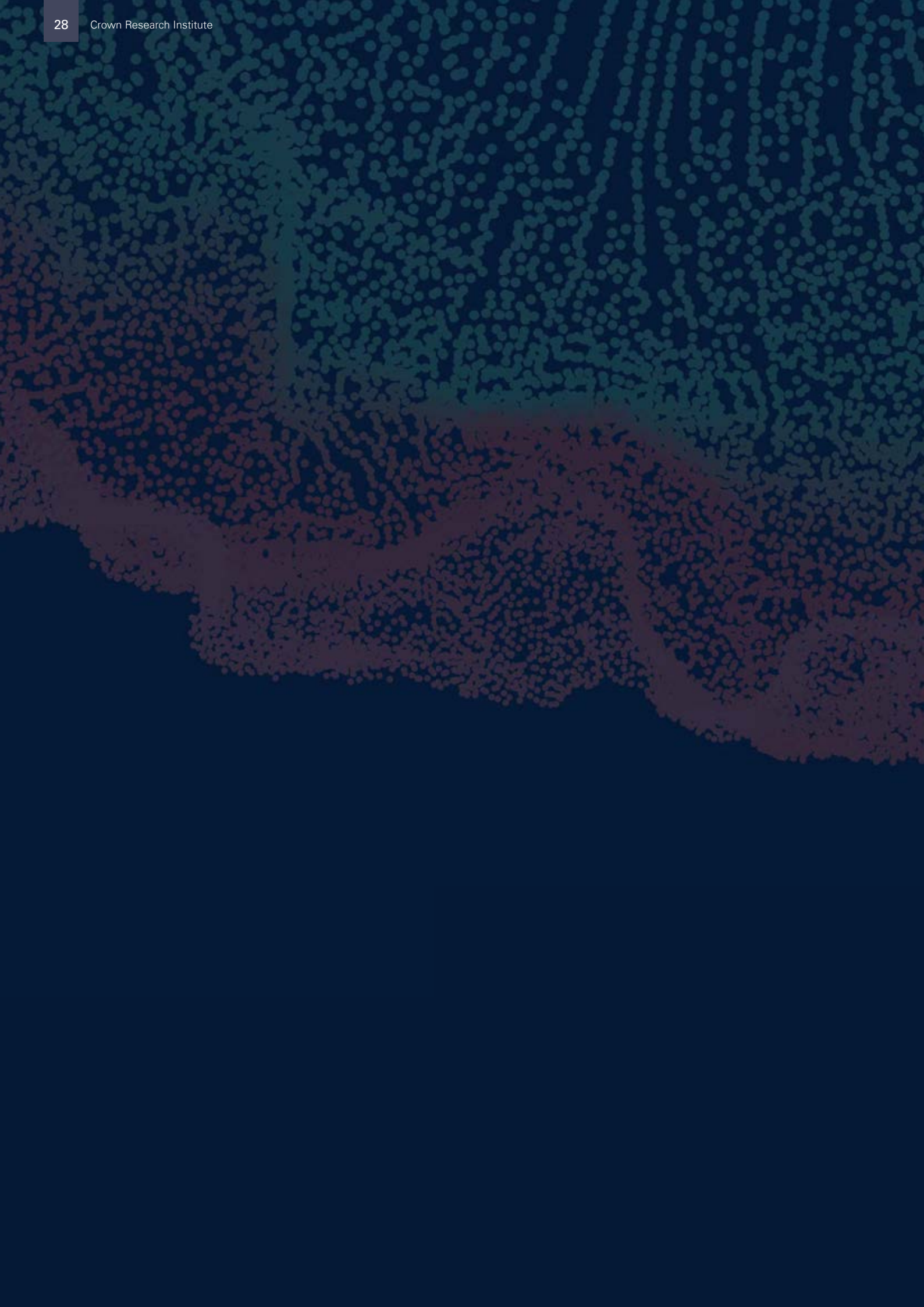
The information is not exhaustive. It is intended to provide an indicative overview of what CRIs do in each focus area. It does not cover all that CRIs do, and thus other capabilities.

There are lead and contributing capabilities in each focus area. These are assigned to each CRI by its Statement of Core Purpose. In practice, the CRIs leverage off each other for specific strengths in the science, its application or sector knowledge. In this way, progress can be accelerated.

This approach acknowledges areas of strength and also recognises that capabilities are dynamic and interlinked across the focus areas. For example, capabilities that help with 'biodiversity' outcomes can also assist areas such as 'biosecurity' and 'food and fibre, and manufacturing'.

Similarly, efforts and changes in climate change will directly effect water resources, food and fibre, manufacturing, biosecurity and land use.

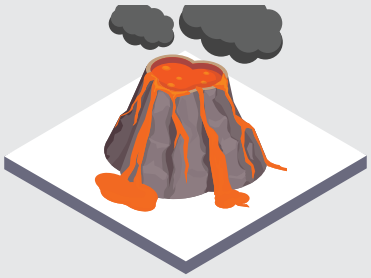
A CRI can play a key role in several focus areas, reflecting the expertise they have relative to the sectors they serve. This enables complementary capabilities across the CRIs to cover different aspects of the focus areas and better achieve the desired outcomes for that focus area.



FOCUS AREA 1

EMERGENCY RESPONSE

FOCUS AREA 1 – INTRODUCTION



EMERGENCY RESPONSE

Enhance Aotearoa New Zealand's preparation, response, recovery, and management of emergencies.

Emergencies, including natural disasters and public health emergencies, can cause significant damage that can be long lasting and cause multiple negative economic, environmental, social and cultural consequences. They are also hard to predict. So, for both reasons, efforts to identify risk, enhance preparedness, minimise harm or damage, and effectively respond to these emergencies is a key focus area for CRIs.

Security and Justice sectors are also an important aspect of emergency response. They provide the core capabilities and assets required to help mitigate impacts of emergencies and protect/support society, people and communities.

Emergencies are often unpredictable and require a collaborative response from all involved. Some of the work that can be done to reduce and minimise harm includes:

- Understanding threats and reducing risks.
- Understanding the potential effect of emergencies and mitigating these through appropriate policy, planning infrastructure, and response capabilities, such as a strong and effective security and justice system.
- Emergency management plans to enable the swift action and minimisation of damage across areas affected.
- Prediction techniques where applicable to minimise harm to people and environments.
- Protection efforts across areas of harm and understanding of the type of emergencies and the resources required to respond to them.
- Response techniques understood through deeper understanding of the risks and behaviours arising from different types of emergencies and security risks.

Some of the benefits of increasing capabilities and understanding in this area include:

Economic – reducing the cost of emergencies and enabling quick and effective response and recovery. Having an effective security and justice system can drive productive results for the economy and help guide and protect society.

Environmental – reducing the extent of damage to the environment and sensitive ecosystems. Enabling better recovery and restoration and improving resilience to damage.

Social – reducing the damage, loss and harm caused to communities and ensuring that people are kept safe and healthy.

Science and research are key to emergency response across these domains.

The CRIs provide essential science and research for Aotearoa New Zealand emergency response efforts in:

- Knowledge and capabilities in understanding the natural environment to mitigate the effects of natural disasters and environmental threats on Aotearoa New Zealand and other countries.
- Capabilities to manage threats such as new viruses and diseases that affect public health.
- Tools, technology, methods and processes to ensure the impact of these threats is lessened.
- Security and justice sector work, specifically working with key service providers in Aotearoa New Zealand to provide more efficient methods, tools and way of doing things.

The lead CRIs in emergency response are:

— GNS: focus on Aotearoa New Zealand's resilience to natural hazards through understanding of geological and earth system processes.
— ESR: focus on forensic services to the justice sector, and ensuring Aotearoa New Zealand has safer and healthier communities.
— Scion: focus on rural fire research; Aotearoa New Zealand's specialist provider of fire research expertise in rural and forest landscapes for wildfire response.

GNS SCIENCE	180 FTE
E/S/R Science for Communities	265 FTE
NIWA	50 FTE
SCION	12 FTE

The contributing CRIs in emergency response are:

— AgResearch
— NIWA.

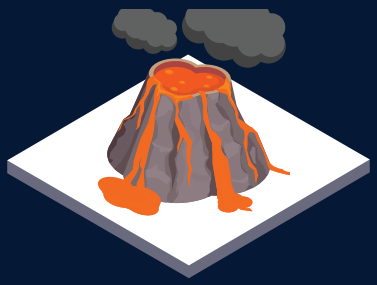
Key CRI capabilities in this focus area can be grouped as:

Natural and environmental threats – Increasing the understanding of climate and weather hazards, earth systems and processes and environmental feedback systems and applying this knowledge in event response and emergency management associated with natural hazards.

Public health emergencies – Enhancing the understanding and response to public health threats such as diseases and contaminant outbreaks. This includes monitoring of public health and social systems to solve complex problems and tailoring of responses, and increasing the safety of food products and exports.

Security and Justice sector – Increasing the integrity of the justice and border security systems, including forensic research and support services to keep New Zealanders safe by preventing, detecting and solving crime.

FOCUS AREA 1 – LEAD CAPABILITIES



EMERGENCY RESPONSE

Natural and environmental threats

NIWA

- Atmospheric/ocean measurements and remote sensing for climate, weather and ocean hazards
- Modelling and predictions of weather ocean and climate hazards
- Natural hazard risk assessment
- Operational environmental forecasting of weather and climate related hazards and their impacts

SCION

- Fire team
- Remote sensing
- Modelling and forecasting

GNS SCIENCE

- Land and marine geoscience including thermal, tectonic and surface (volcanoes and land slides) processes
- Geohazard models for early warnings and forecasts including communication
- Response, decisions and recovery plans including risk governance
- Maintaining and enhancing GeoNet

GNS Science	180 FTE
E/S/R Science for Communities	265 FTE
NIWA	50 FTE
SCION	12 FTE

Public health emergencies

- Analytical chemistry
- Genomics
- Clinical and environmental microbiology
- Disease identification, surveillance, advice response and monitoring
- Epidemiology
- Outbreak response
- Food safety risk identification, response and advice
- Social science systems
- Radiation science
- Data science and modelling

Security and justice sector

- Forensic service support and research for the justice sector
- Support for terrorist threat responses
- National drug harm insights
- National pharmaceutical assurance

FOCUS AREA 1 – KEY OUTCOMES

KEY OUTCOMES FOR AOTEAROA NEW ZEALAND'S EMERGENCY RESPONSE

GNS SCIENCE TE PŪ AO

Key outcomes for emergency response

Undertake research that drives innovation, increases Aotearoa New Zealand's resilience to natural hazards and enhances our understanding of geological and earth-system processes.

Key Performance Indicators

- Preparedness
- Build resilience
- Event response support
- The Earthquake Commission contract KPIs.

E/S/R Science for Communities

Key outcomes for emergency response

Provide advanced forensic services for the justice sector and ensure Aotearoa New Zealand has:

- Safer communities
- Healthier communities.

Key Performance Indicators

Safer communities KPI's:

- Police satisfaction with ESR's timeliness and quality of service.
- Fulfilment of contractual obligations under the service level agreement.
- Total number of cases where ESR provides Police with forensic evidence analysis.
- Percentage of homicide investigations finalised within 12 months.
- Percentage of sexual assault investigations finalised within 12 months.
- Number of research projects undertaken by ESR for the Evidence-Based Policing Centre (EBPC).

Healthier communities KPI's:

- Time-critical turnaround times are met.
- Ministry of Health's satisfaction with ESR's services.
- Ministry of Health's project brief milestones and deliverables are consistently met.

Technology KPI:

- Commercial reports per scientist FTE.

Science KPI:

- Impact of scientific publications.

NIWA Taihoro Nukurangi

Key outcomes for emergency response

Increase resilience to climate, weather and ocean hazards in Aotearoa New Zealand and the South Pacific.

Improve the management and mitigation of climate, weather and ocean hazards through:

- Measurement systems and networks for the detection of weather and ocean hazards.
- Prediction of climate, weather and ocean hazardous event.
- Operational forecasting of weather, climate and ocean hazard impacts.
- Natural hazard risk assessment to inform planning and response.

SCION
FORESTS ■ PRODUCTS ■ INNOVATION

Key outcomes for emergency response

Assist Fire and Emergency New Zealand in a wildfire response at Incident Command for significant wildfires (through specialist fire research expertise in rural and forest landscapes).

Key Performance Indicators

Forests and Landscapes

- 80% increase in forested area managed to enhance soil and water resources, biodiversity, landscape and resilience.
- Mitigate Aotearoa New Zealand's indigenous forests from abiotic threat of wildfire as evidenced by low area burned despite both a shift in climate and increased number of starts.

FOCUS AREA 1 – ENABLING CAPABILITIES

ENABLING CAPABILITIES EMERGENCY RESPONSE

The CRIs have the following enabling capabilities that support their lead scientific capabilities in the emergency response focus area.

Enabling capabilities

- Data science capabilities
- Social science capabilities
- National Geohazards Monitoring Centre
- GeoNet monitoring network and associated databases and digital assets
- Nationally significant collections (e.g. earthquake data)
- National laboratories
- IODP/ICDP (global geoscience)
- High performance computing
- NIWA & NEMA – resilience to hazards and risks (NIWA ship access)
- Understanding Zealandia (the continent) - this work is fundamental to other CRIs' work and to Aotearoa New Zealand

Enabling capabilities

- Data Science
- Rapid and high throughput Next Generation Sequencing
- Kaupapa Māori research
- Police Forensic DNA databank
- Microbiology Culture Collection
- Portable computing power
- Internet speed (REANNZ)
- Access to data other organisations have custodianship over
- Fit-for-purpose science infrastructure, including laboratory instrumentation
- Portable point of use devices
- EpiSurv (disease surveillance system)
- Portable computing power devices - for point of care (e.g. nitrogen detecting device)
- Quality accreditations of service
- Global relationships (community of laboratories)
- National reference laboratories
- Chemical Warfare Agent Laboratory Network membership

Enabling capabilities

- Research vessels – RV Tangaroa, RV Kaharoa, RV Ikatere
- Te Kūwaha, National Centre for Māori Environmental Research
- Sensor networks & IoT
- High performance supercomputing, data analytics and modelling
- Remote sensing, enterprise data products and services
- Databases e.g. climate, river flows

Enabling capabilities

- High resolution thermal infrared camera
- Specialist in-fire equipment designed to withstand 1000-1500 degrees C including several go-pro cameras and 3-D cameras
- Five in-fire turbulence towers (three @ 10 m and two @ 30 m) and associated sensors
- Five fire weather station towers and associated sensors
- Two Terra-torch ignition devices
- Supercomputing
- NZ BlueSky Framework to forecast fire spread and smoke plume transport and dispersion
- Prometheus fire spread model and expertise

- NZ Fire database
- Historical wildfire case studies
- Four wildfire fire-fighters
- Specialist skills in: Fire behaviour, Turbulence at the fire-front, Atmospheric science, Social science, Human factors, Fuels, Incident Command
- Datasets from research burns over 30 years ago
- Drones and drone pilots for both fuel mapping and fire-front observations and drone pilots with experience flying under incident command and during research burns
- High-spectral imaging
- Infrared and LiDAR
- Eight experienced in-field fire-researchers
- Transfer of knowledge web page
- The Fire Danger Rating System

FOCUS AREA 1 – CRI COLLABORATIONS

CRI COLLABORATIONS EMERGENCY RESPONSE

Below are examples of CRI collaborations in this area. Some CRIs contribute to this work – although it is not their core focus – through other expertise they bring.

GNS Science Te Pū Ao · NIWA Taihoro Nukurangi · Manaaki Whenua Landcare Research

RiskScape collaboration -– RiskScape is software designed by NIWA, GNS and the Earthquake Commission which uses their capabilities and knowledge of hazards to help users with decisions about planning and assessing ideas to limit potential damage.

GNS Science Te Pū Ao · NIWA Taihoro Nukurangi · SCION Forests • Products • Innovation · Manaaki Whenua Landcare Research

Resilience to Natures' challenges | Kia manawaroa - Ngā Ākina o Te Ao Tūroa – To enhance Aotearoa New Zealand's resilience to natural disasters.

NIWA Taihoro Nukurangi · GNS Science Te Pū Ao

Computing system collaboration.

Plant & Food Research Rangahau Ahumāra Kai · ESR Science for Communities

Rapid COVID-19 diagnostics test.


A3
A

FOCUS AREA 1 – KEY END USERS

KEY END USERS EMERGENCY RESPONSE

Key end users for each CRI are shown below. The list is illustrative, not exhaustive. Some organisations – such as large government departments – appear more than once, as CRIs provide different services for different groups within them. The end users vary in scale and specialisation, therefore different CRIs connections with end users generally do not overlap.

GNS SCIENCE TE PŪ AO

Government agencies: Ministry of Business, Innovation and Employment, Ministry for the Environment, Earthquake Commission, Ministry of Foreign Affairs and Trade, Department of Conservation, KiwiRail, National Emergency Management Agency, Civil Defence Emergency Management.

Industry bodies: Major infrastructure asset owners.

Māori trusts & companies: Iwi and hapū.

Other/private organisations: Environmental Resources Management.

E/S/R Science for Communities

Government agencies: New Zealand Police, New Zealand Customs Service, Ministry of Justice, NZ Aviation Security Service, New Zealand Defence Force, Ministry of Health, District Health Boards, Ministry for Primary Industries, Ministry for the Environment, Ministry of Foreign Affairs and Trade.

Regional council: Territorial Local Authorities.

Other/private organisations: Commercial – food cost, wastewater treatment plants, milk plants (Fonterra others), Hemp growing organisations, Taumata Arowai.

NIWA Taihoro Nukurangi

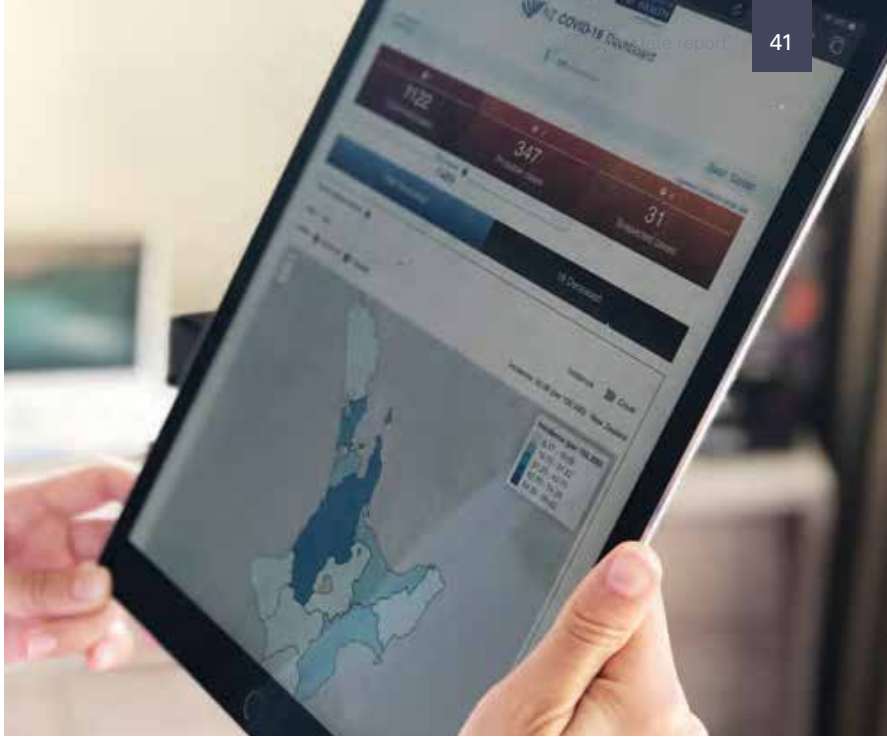
Government agencies: Ministry of Business, Innovation and Employment, Ministry for the Environment, Earthquake Commission, Department of Conservation, Ministry for Primary Industries, National Emergency Management Agency, The Treasury, Fire and Emergency New Zealand (FENZ).

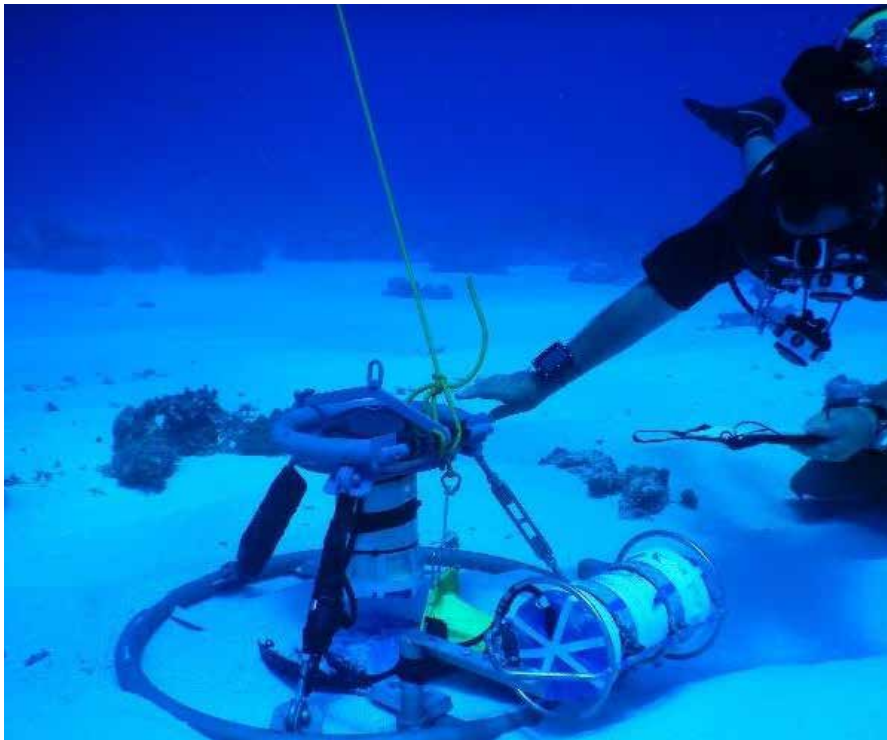
Regional council: Local government (regional and district councils).

Research organisations: National and international research organisations.

Māori trusts & companies: Iwi and hapū, Māori agencies/groups.

Other/private organisations: Energy sector, Food and Fibre production sector.



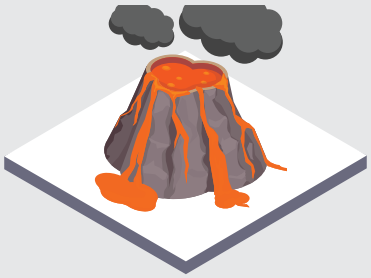


SCION
FORESTS ▪ PRODUCTS ▪ INNOVATION

Government agencies: Fire and Emergency New Zealand (FENZ), Forest Growers Research, New Zealand Defence Force, Department of Conservation, Federated Farmers, Ministry for Primary Industries.

Regional council: Regional council.

FOCUS AREA 1 – CASE STUDIES



EMERGENCY RESPONSE CASE STUDIES

GNS Science, NIWA

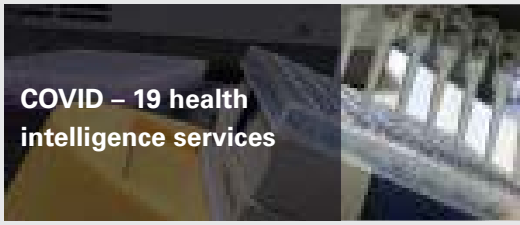
Understanding natural hazards and their consequences is essential in ensuring that appropriate decisions are made around mitigation, planning and response to emergencies.

RiskScape is software designed by NIWA, GNS Science and the Earthquake Commission. It uses their capabilities and knowledge of hazards to help users with decisions about planning and mitigating ideas to limit potential damage.

The software performs complex calculations quickly to create natural hazard scenarios through simple steps for users. The results can determine expected impact from hazards on exposed buildings, the degree of damage and economic loss, the expected human causalities and disruption to lifelines e.g. electricity, road and water networks. RiskScape is used widely in Aotearoa New Zealand and internationally e.g. in Samoa to identify flooding risks, inform emergency evacuation and plan flood response procedures.

The outcomes of this collaboration are:

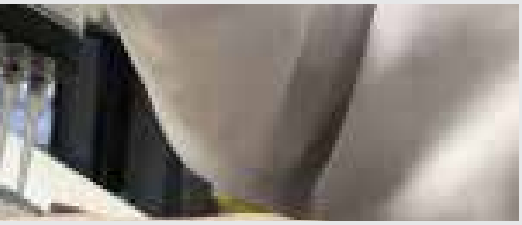
- Open access software which enables users to assess risk to buildings, infrastructure and people from natural hazards such as earthquakes, tsunamis, and floods - leading to better management and less damage caused by the hazard.
- Improved decision making around hazard management and mitigation to lessen the impact they may have on the economy, people and environment.
- Improved preparedness to limit the loss caused by these natural disaster events.



ESR

ESR is currently providing national and international health intelligence to the Ministry of Health and the wider health sector about the global pandemic, COVID-19. ESR is an essential part of responding to the pandemic. ESR was the first organisation in Aotearoa New Zealand to sequence genetic material, now the key tool in Aotearoa New Zealand's emergency response to the virus.

ESR have sequencing facilities in Auckland, Wellington and Christchurch for urgent sequencing of the virus to enable the tracking of C-19 across Aotearoa New Zealand. They also have a public dashboard which provides the number of COVID-19 cases over time and a map of the cases by district health board, age, sex and ethnicity. The dashboard also includes an outbreak tab for each of the outbreak clusters in Aotearoa New Zealand. It has become a 'go-to' tool for media, health professionals and the wider public.



The outcomes of this work have been:

- Tracking of the virus leading to informed response and decision making by government.
- Testing of the virus across Aotearoa New Zealand to guide decision making.
- Assisting overall response to the infectious disease through providing advice for the best-informed action to cause the least harm.
- Protecting New Zealanders from the infectious disease, through providing trusted information.

Never-before-seen insights into fire

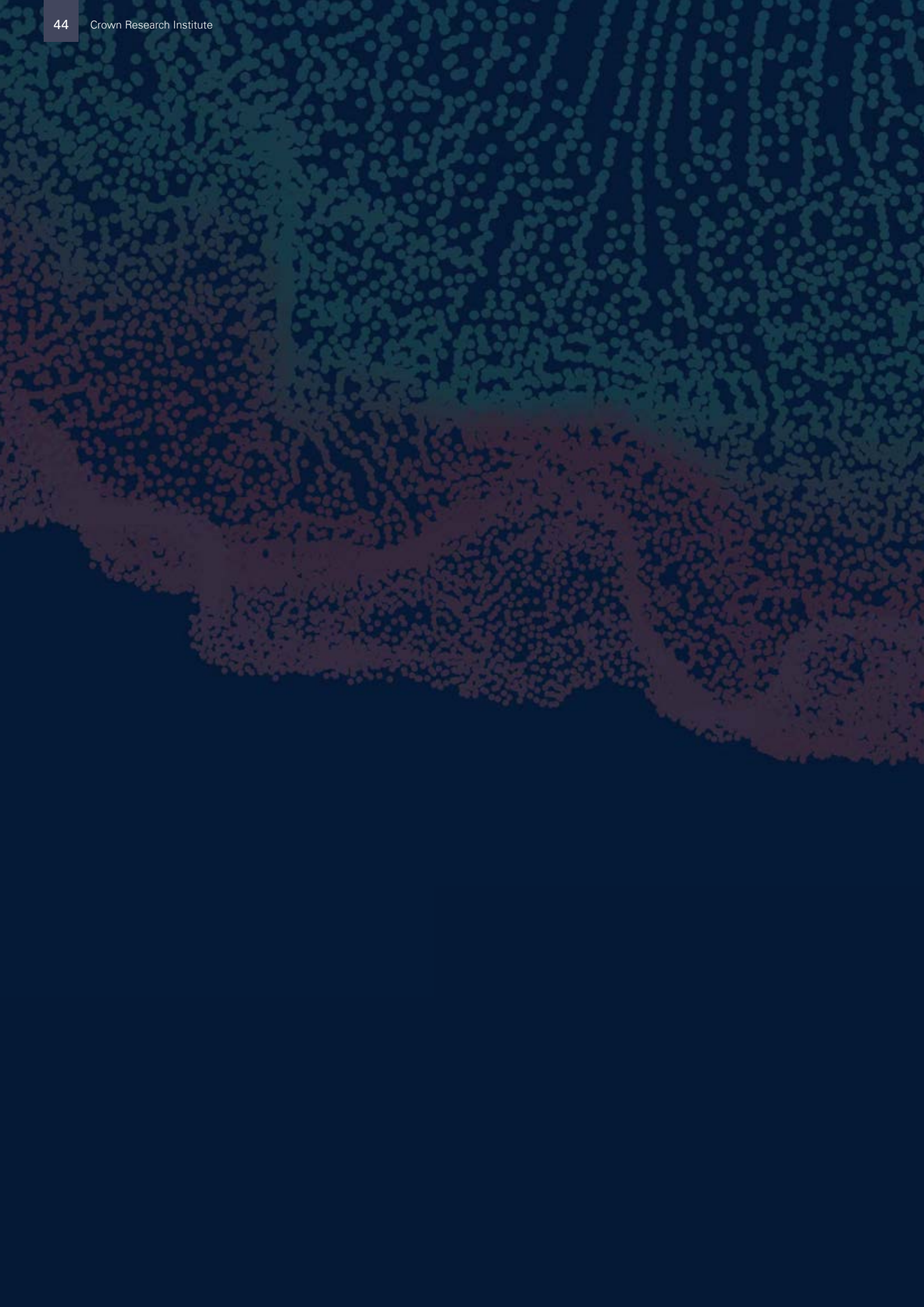
Scion

Fires are difficult to predict and respond to, they are fast moving and dangerous and cause detrimental social, environmental, cultural and economic effects. Scion's Fire Research Team has generated better understanding of fire behaviour so that responding to fire is both safer and more effective. Wildfires are likely to be an increasing threat and frequency as the climate warms, making these insights important now, and more so in the future.

During one project Scion carried out six experimental burns which resulted in new insights into fire behaviour, specifically fire spread base on convection. The learnings from Scion's research burns will contribute to firefighter and community safety by changing the way we predict and respond to wildfires. The burns are also an invaluable opportunity for firefighters to practice their skills and observe extreme fire behaviour while in a highly managed environment.

The outcomes of this research were to:

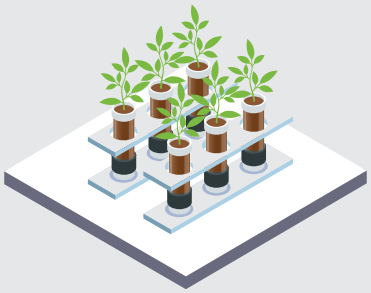
- Better understanding and insight into fire behaviour.
- Allow for safer and more effective responses to fires, minimising damage and cost to the economy.
- Set Aotearoa New Zealand up for the future which is likely coupled with increased risk of bush fires and therefore cost, damage and loss to the environment and society.



FOCUS AREA 2

BIOSECURITY AND PUBLIC HEALTH

FOCUS AREA 2 – INTRODUCTION



BIOSECURITY AND PUBLIC HEALTH

Reduce the entry and establishment of new plants, pests, and diseases in Aotearoa New Zealand, and increase the nation's public health preparedness against future threats.

Unwanted pests and diseases can damage Aotearoa New Zealand's economy, environment and way of life with breaches costing the economy billions of dollars. Biosecurity focuses on keeping harmful pests and diseases out of Aotearoa New Zealand, and eradication and management of them if they are found in New Zealand. Public health focuses on safeguarding the health of New Zealanders through monitoring, assessing and managing the threat and impact of disease outbreaks.[6]

There are several major risks associated with biosecurity and public health breaches:

Economic risks – biosecurity breaches can weaken the earning potential of commercial animals, plants and tourist areas through degradation, and introduce new costs by limiting access to export markets and requiring multi-million dollar control/eradication programmes.[6] Public health threats can affect the economy directly through reducing productivity of people, putting pressure on industries, and have widespread financial burden and hardship.

Environmental risks – biosecurity breaches can negatively effect ecosystems and native species through predation, disease and changing habitat, killing taonga species and creating risks to infrastructure and natural processes.[6]

Social risks – biosecurity threats can have negative social impact by causing travel restrictions, destroying wildlife areas, spoiling waterways and reducing animal, plant and fishing stocks.[6] Public health threats are social risks as they can directly affect population health, community and family health which flows on to creating pressure on society, the healthcare system and the whole economy.

The Aotearoa New Zealand biosecurity and public health systems include Government, industry, Māori and all New Zealanders. Public health protects and improves communities by preventing epidemics and spread of diseases. The foundation of the biosecurity system is risk management activities undertaken across inter-related areas; international, border and within Aotearoa New Zealand.

- International includes: International Plant and Animal Health, Trade Agreement and Bilateral Arrangements, Risk Assessment; and Import Health Standards.[7]
- Border includes: Border Intervention.[7]
- Within Aotearoa New Zealand includes: Surveillance, Readiness and Response, and Long-term Pest and Disease Management (national and regional scale management).[7]

The CRIs provide essential science and research for Aotearoa New Zealand biosecurity and public health efforts in:

- Collections and databases that provide understanding of Aotearoa New Zealand's ecosystem to make more informed decisions.

- Innovative methods, tools and techniques to better eradicate and respond to biosecurity and public health threats.
- Understanding impact of biosecurity threats to allow for better management at the border and within Aotearoa New Zealand.
- Reducing the damage and cost to the economy and public health of biosecurity threats.
- Protecting New Zealanders from the risk of epidemics and having tools to prepare for and respond to outbreaks.
- Developing tools and systems for food safety systems in local and traded foods.

The lead CRIs in biosecurity and societal security are:

- AgResearch: focus on biosecurity management of animals and plants through their outcome to develop fit-for-purpose plants and animals.
- Scion: focus on Aotearoa New Zealand's biosecurity resistance to pests and diseases across forests, landscapes and timber products.
- Manaaki Whenua: focus on Aotearoa New Zealand's management of terrestrial biosecurity.
- Plant & Food Research: focus on enhancing Aotearoa New Zealand's science-based plant and border biosecurity systems.
- NIWA: focus on management of invasive species to protect aquatic ecosystems.
- ESR: focus on enhanced science and research services for management of biosecurity threats to public health, food safety systems and societal impacts of public health threats.

agresearch *āta mātai, mātai whetū*	90 FTE
SCION	59 FTE
Manaaki Whenua Landcare Research	68 FTE
Plant & Food Research	40 FTE
NIWA	18 FTE
ESR Science for Communities	11 FTE

Key CRI capabilities in this focus area can be grouped as:

Public health – Safeguarding the health of New Zealanders through improvement in the management of biosecurity threats to public health. Includes enhancing the food-based economy through the management of food safety risks associated with traded foods.

Detection and identification – Understanding, assessing and detecting biosecurity risks, pests and diseases across Aotearoa New Zealand. Enhance the understanding of biosecurity management to reduce the entry and establishment of new plants, pests and diseases in Aotearoa New Zealand.

Monitoring and control – Monitoring and controlling of invasive species and their biological impacts. Using science and research to find new and improved biosecurity tools and approaches for biosecurity controls and welfare management of all species. This also includes valuing and using Te Ao Māori and Treaty-informed approaches to weed, pest and disease challenges and prediction and control of future potential pests.

Response and eradication – Response to biosecurity outbreaks and pest, plant and disease eradication methods. This includes finding new methods and tools for eradication methods that consider the entire welfare system being affected. This also includes quick responses to biosecurity outbreaks and ways to eradicate the threat in the most efficient way.

A major science collaboration for biosecurity is called **Better Border Biosecurity** which is a multi-partner, cooperative science program that researches ways to reduce the entry and establishment of new plants, pests and diseases in Aotearoa New Zealand. Scion, Manaaki Whenua, AgResearch and Plant & Food Research are part of this science collaboration.

6. Ministry for Primary Industries. 'About biosecurity in New Zealand' [website], https://www.mpi.govt.nz/biosecurity/about-biosecurity-in-new-zealand/why-we-want-to-keep-pests-and-diseases-out-of-nz/, (accessed 30 March 2021)
7. Biosecurity 2025, 'Direction Statement for New Zealand biosecurity system', New Zealand, Ministry for Primary Industries, 2016 Nov, 34 p. Report No.:978-1-77665-9

FOCUS AREA 2 – LEAD CAPABILITIES

BIOSECURITY AND PUBLIC HEALTH

Public health

ESR Science for Communities

- Management of biosecurity threats to public health
- Food, clinical and environmental microbiology
- Risk identification, assessment and mitigation
- Anti-microbial resistance
- Microbial genomics
- Public health intelligence
- Analytical chemistry
- Human genomics
- Environmental science

agresearch āta mātai, mātai whetū

- Food and bio-based products for food safety

Response and eradication

SCION

- Forest and tree protection including atmospheric science capability

agresearch āta mātai, mātai whetū

- Pesticide replacement

Plant & Food Research Rangahau Ahumāra Kai

- Surveillance, response, eradication

Manaaki Whenua Landcare Research

- Development of biological control agents, novel toxins and predator control technologies at local and landscape scales.

NIWA Taihoro Nukurangi

- Development of more effective technologies and strategies for established pests

agresearch	90 FTE
SCION	59 FTE
Manaaki Whenua Landcare Research	68 FTE
Plant & Food Research	40 FTE
NIWA	18 FTE
E/S/R Science for Communities	11 FTE

Detection and identification

NIWA
- Marine and freshwater – surveillance and identification of aquatic pests

SCION
- Understanding forest ecosystems

agresearch
- Animal nutrition and health
- Testing services for biosecurity and incursions and surveillance

Plant & Food Research
- Risk assessment
- Diagnostics including techniques and pathogenicity detection

Monitoring and control

Manaaki Whenua Landcare Research
- Wildlife management and conservation ecology
- Plant biosecurity and biodiversity
- Weed biological control
- Quantitative modelling
- Identification of invasive organisms and field monitoring

SCION
- Plant science – forest species

agresearch
- Forage science including plant protection and plant-microbe interactions

Plant & Food Research
- Risk management

NIWA
- Marine and freshwater – improved understanding of harmful organisms

FOCUS AREA 2 – KEY OUTCOMES

KEY OUTCOMES FOR AOTEAROA NEW ZEALAND'S BIOSECURITY AND PUBLIC HEALTH

agresearch
āta mātai, mātai whetū

Key biosecurity outcomes

Enhance Aotearoa New Zealand's biosecurity management of animals and plants and food through outcome in the focus area:

— Fit-for-purpose plants and animals.

Key Performance Indicators

Fit-for-purpose plants and animals:

— A set of measurable indicators to determine the wellbeing of the animal is developed in conjunction with industry and embedded across AgResearch research programmes by 2022.
— Development and scale-up of 3 state-of-the-art technologies that have been designed to accelerate adoption of genomic selection by industry by 2025.
— Development and field validation within Aotearoa New Zealand of 3 multiple end-point technologies that concurrently decrease auditable environmental impact and target value-add productivity gains by 2025.

SCION
FORESTS • PRODUCTS • INNOVATION

Key biosecurity outcomes

To increase Aotearoa New Zealand's biosecurity/resistance to pests and diseases by focussing on the priority areas:

— Forests and Landscape
— Forest to Timber products.

Key Performance Indicators

Forests and Landscapes:

— 80% increase in forested area managed to enhance soil and water resources, biodiversity, landscape and resilience.
— Protect Aotearoa New Zealand's indigenous forests from new pests (insect and pathogen).
— Biotic threat profiles forming due to climate change are mitigated as evidenced by thriving indigenous forests.

Forest to Timber products:

— An increase in net biomass gains from radiata pine of an average of 35m^2 per year with improved wood quality, uniformity and resilience to pests and pathogens.

Manaaki Whenua
Landcare Research

Key biosecurity outcomes

To drive innovation in Aotearoa New Zealand's management of terrestrial biosecurity.

— Improved biosecurity tools and approaches to reverse the decline of New Zealand's biodiversity.
— Enable faster and more effective predictions and responses to biosecurity threats.
— Increased resilience of natural ecosystems.
— Kia tiakina ngā taonga tuku iho (better protection of taonga species).
— Reduced impact of weeds.
— Enable a reverse in the decline of native species, habitats and ecosystems.
— Makuru ana ngā mahinga kai (enable gathering of food from abundant and flourishing areas).
— Kia tiakina ngā taonga tuku iho (better protection of taonga species).
— More effective and targeted conservation and restoration of native terrestrial species, habitats and ecosystems.
— Reduced impact of pests.
— Providing industry with the licence to operate in a TB-free NZ.

New Zealand is facing increasing biosecurity threats from marine pests. [Photo: Crispin Middleton, NIWA]

Plant & Food Research
Rangahau Ahumāra Kai

Key biosecurity outcomes

Enhance Aotearoa New Zealand's science-based plant border biosecurity systems by:

- Developing a better understanding of the risks Aotearoa New Zealand is facing using rigorous risk assessments and by deploying new diagnostics techniques.
- Responding to threats with new and improved tools for surveillance, incursion response, eradication.

NIWA
Taihoro Nukurangi

Key biosecurity outcomes

Strengthen the management of aquatic biosecurity.

Support the management, surveillance, eradication and control of marine and freshwater invasive species through:

- Improved knowledge of emerging harmful invasive aquatic organisms.
- Development of new technologies for the surveillance and identification of aquatic pests.
- More effective technologies and strategies for the eradication or control of established aquatic pests.

ESR
Science for Communities

Key public health outcomes

Deliver enhanced science and research services to the public health and food safety systems.

- Safer food.
- Technology.
- Science impact.

Key Performance Indicators

Safer food KPIs:

- Number of projects delivered for the New Zealand Food Safety Science & Research Centre (NZFSSRC).
- Number of projects delivered for MPI.
- Number of projects delivered for industry.

Technology KPI:

- Commercial reports per scientist FTE.

Science KPI:

- Impact of scientific publications.

FOCUS AREA 2 – ENABLING CAPABILITIES

ENABLING CAPABILITIES BIOSECURITY AND PUBLIC HEALTH

The CRIs have the following enabling capabilities that support their lead scientific capabilities in the biosecurity focus area.

agresearch
āta mātai, mātai whetū

Enabling capabilities

- Free Air Carbon Dioxide Enriched (FACE) site
- PC3 Laboratory
- Systems Biology Platform (genomics, proteomics, metabolomics)
- Large Animal Containment Unit and Research farms
- High performance computing
- Future focused polices
- Access to future workforce talent
- Social license to operate
- Insectary (insect breeding)

SCION
FORESTS • PRODUCTS • INNOVATION

Enabling capabilities

- PC3 Diagnostic Laboratory – entomology and pathology diagnostics
- Insect rearing and containment
- World recognised developer of Aerial spray modelling
- Remote sensing drones, LiDAR, Hyperspectral disease and thermal imaging
- Turbulence tower, Weather Stations, Boundary layer turbulence
- Dispersal models and modelling capabilities, Aerial swath expertise
- Wilding control expertise
- Chemical ecology
- Electroantennogram

Manaaki Whenua
Landcare Research

Enabling capabilities

- Nationally significant collections/ databases e.g., National Vegetation Survey Databank, NZ Anthropod Collection, Fungarium, the Allen Herbarium, International Collection of Microorganisms from Plants
- Māori engagement
- Social and biocultural perspectives
- Genetic identification
- Data science and spatial modelling

Plant & Food™ Research
Rangahau Ahumāra Kai

Enabling capabilities

- Germplasm and the associated data including the National Collections
- Inspect rearing facility, Disinfestation Unit and Fumigation facility
- PC2 and 3 laboratories for plant pathogens
- Research Orchard Network

NIWA
Taihoro Nukurangi

Enabling capabilities

- Research vessels – RV Ikatere
- Sensor networks & IoT
- High performance supercomputing, data analytics and modelling
- Remote sensing, enterprise data products and services
- National Marine Invertebrate Collection
- Databases e.g. environmental classifications
- Northland Marine Research Centre

E/S/R
Science for Communities

Enabling capabilities

- Data Science
- Rapid and high throughput Next Generation Sequencing
- Kaupapa Māori research
- EpiSurv (disease surveillance system)
- NZ Reference Culture Collection
- Portable computing power
- Internet speed (REANNZ)
- Access to data other organisations have custodianship over
- Fit-for-purpose science infrastructure

FOCUS AREA 2 – CRI COLLABORATIONS

CRI COLLABORATIONS BIOSECURITY AND PUBLIC HEALTH

Below are examples of CRI collaborations in this area. Some CRIs contribute to this work – although it is not their core focus – through other expertise they bring.

agresearch *āta mātai, mātai whetū*

Manaaki Whenua Landcare Research

SCION FORESTS • PRODUCTS • INNOVATION

Plant & Food™ Research Rangahau Ahumāra Kai

Better Border Biosecurity – a multi-partner, cooperative science collaboration that researches ways to reduce the entry and establishment of new plant pests and diseases in Aotearoa New Zealand.

agresearch *āta mātai, mātai whetū*

Manaaki Whenua Landcare Research

Plant & Food™ Research Rangahau Ahumāra Kai

Taranaki whenua ora – national engagement programme designed to promote land based primary industry career pathways.

CRIs to be engaged as part of the biosecurity 2025 direction

Biosecurity 2025 – Biosecurity 2025 is a partnership between people, organisations, Māori, and central, local and regional government. The aim of the programme is to make the Aotearoa New Zealand biosecurity system more resilient and future-focused to better protect our taonga and Aotearoa New Zealand for diseases and pests.

agresearch *āta mātai, mātai whetū*

Manaaki Whenua Landcare Research

Dairy effluent to grown crops.

agresearch *āta mātai, mātai whetū*

NIWA Taihoro Nukurangi

Plant & Food™ Research Rangahau Ahumāra Kai

SCION FORESTS • PRODUCTS • INNOVATION

Manaaki Whenua Landcare Research

Cross CRI resilient & regenerative agriculture partnership – including on-farm forestry for riparian protection, erosion prevention, carbon sequestration, emissions mitigation, identification and afforestation of marginal land.

All the CRIs for information and knowledge

State-owned enterprise collaboration (AsureQuality).

agresearch
āta mātai, mātai whetū

E/S/R
Science for Communities

High Performance Computing System.

Manaaki Whenua
Landcare Research

agresearch
āta mātai, mātai whetū

Plant & Food™ Research
Rangahau Ahumāra Kai

Animal and plant containment facility.

agresearch
āta mātai, mātai whetū

E/S/R
Science for Communities

Post COVID-19 task force.

E/S/R
Science for Communities

Manaaki Whenua
Landcare Research

Plant & Food™ Research
Rangahau Ahumāra Kai

SCION
FORESTS ▪ PRODUCTS ▪ INNOVATION

Genomics Aotearoa – a collaborative research platform for genomics and bioinformatics. The platform was established to ensure that Aotearoa New Zealand is internationally participating and leading in the fast-developing fields of genomics and bioinformatics.

Manaaki Whenua
Landcare Research

(Host)

E/S/R
Science for Communities

agresearch
āta mātai, mātai whetū

GNS SCIENCE TE PŪ AO

NIWA
Taihoro Nukurangi

Plant & Food™ Research
Rangahau Ahumāra Kai

SCION
FORESTS ▪ PRODUCTS ▪ INNOVATION

National Science Challenge: New Zealand's Biological Heritage | Ngā Koiora Tuku Iho: To protect and manage New Zealand's biodiversity, improve Aotearoa New Zealand's biosecurity, and enhance our resilience to harmful organisms.

FOCUS AREA 2 – KEY END USERS

KEY END USERS BIOSECURITY AND PUBLIC HEALTH

Key end users for each CRI are shown below. The list is illustrative, not exhaustive. Some organisations – such as large government departments – appear more than once, as CRIs provide different services for different groups within them. The end users vary in scale and specialisation, therefore different CRIs connections with end users generally do not overlap.

agresearch
āta mātai, mātai whetū

Government agencies: Ministry for Primary Industries, Department of Corrections.

Industry bodies: Industry bodies such as Dairy NZ.

Regional council: Regional councils.

Research organisations: NZ Food Safety Science & Research Centre, Our Land & Water, NZ Agricultural Greenhouse Gas Research Centre.

Māori trusts & companies: Includes iwi and hapū.

Other/private organisations: Seed companies, Better Border Biosecurity.

SCION
FORESTS • PRODUCTS • INNOVATION

Government agencies: Ministry for Primary Industries, Department of Corrections, WorkSafe NZ.

Industry bodies: Forest Owners Association.

Regional council: Regional councils e.g. Environmental Southland.

Research organisations: University of Waikato, University of Auckland, Lincoln University, Plant & Food Research, ArborGen (improved genetic tree producer), Manaaki Whenua.

Māori trusts & companies: Includes iwi and hapū, Ngāti Awa.

Other/private organisations: Primary industries e.g. Zespri, NZ Apples and Pears, Proseed, Royal Society Te Apārangi, Nurseries.

Manaaki Whenua
Landcare Research

Government agencies: Ministry of Business Innovation and Employment, Ministry for Primary Industries, Department of Corrections, Ministry of Foreign Affairs and Trade.

Regional council: Regional councils.

Māori trusts & companies: Includes iwi and hapū.

Other/private organisations: OSPRI, National Biocontrol collective, Community groups, Predator-Free 2050 Ltd, Pacific communities.

Plant & Food Research
Rangahau Ahumāra Kai

Government agencies: Ministry for Primary Industries, Environmental Protection Authority.

Industry bodies: NZ Apple and Pears, Horticulture NZ, NZ Onions, Potatoes NZ, NZ Avocado, NZ Wine, Foundation for Arable Research, NZ Beef and Lamb, Dairy NZ, Forest Owners Association.

Regional council: Regional councils.

Māori trusts & companies: Includes iwi and hapū.

Other/private organisations: Zespri, T&G Global, PGG Wrightson.

NIWA
Taihoro Nukurangi

Government agencies: Department of Corrections, Ministry for the Environment, Biosecurity NZ, Ministry for Primary Industries, Land Information New Zealand.

Industry bodies: Food manufacturers.

Regional council: Local government (regional and district councils).

Research organisations: National and International research organisations.

Māori trusts & companies: Iwi, hapū, agencies/groups.

Other/private organisations: Food and fibre production organisations.

E/S/R
Science for Communities

Government agencies: Ministry of Health, District Health Boards, Ministry of Foreign Affairs and Trade, Ministry for Primary Industries.

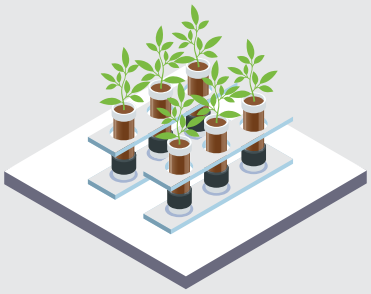
Industry bodies: Food manufacturers.

Regional council: Regional councils.

Research organisations: NIWA, GNS.

Māori trusts & companies: Includes iwi and hapū.

FOCUS AREA 2 – CASE STUDIES



BIOSECURITY AND PUBLIC HEALTH CASE STUDIES

Manaaki Whenua, AgResearch, Scion, Plant & Food Research

To protect Aotearoa New Zealand's highly valued native trees from the invasive fungus myrtle rust (MR), Manaaki Whenua, Plant & Food Research, AgResearch and Scion are collaborating to understand the short-term and long-term impacts of MR on native ecosystems. Myrtle rust was first found in Aotearoa New Zealand on May 2017 and in 2019 had been found in 12 mainland regions which cover most of the North Island and some of the South Island. The research aims to boost the resilience of Aotearoa New Zealand landscapes to this fungus and reduce its impacts.

Manaaki Whenua, AgResearch, Scion and Plant & Food Research bring a diverse range of research expertise to develop the approach for short-term and long-term management. The project has a key focus on engagement with iwi and hapū, ensuring the incorporation of Mātauranga Māori throughout the project. The proactive engagement and an open-source approach aims to optimise on-the-ground adoption by biosecurity and conservation managers, landowners, industry, Māori and communities.

The outcomes of the project were to:

- Protect ecosystems by learning and predicting what effects the fungus will have on different ecosystems before it becomes widespread.
- Work closely with iwi and landowners to understand disease impacts and create approaches/tools to mitigate impact.
- Draw on Mātauranga Māori throughout using traditional management and medicinal approaches for control and eradication efforts.
- Create effective long-term management plans for the fungus to reduce its impact and cost to the economy, environment and social aspects of Aotearoa New Zealand.

NIWA

Clarity in understanding the types of invasive species within Aotearoa New Zealand's ecosystems allows for better management, mitigation and eradication of the threat they pose. There is a good level of public awareness of campaigns like Predator Free NZ and terrestrial weed responses (e.g. pine control programme) but aquatic pests are relatively unknown resulting in delayed management options and less effective eradication responses for these invasive species. This can have increased negative effects on the ecosystems being affected and increase the damage and cost to Aotearoa New Zealand.

In 2020, NIWA updated their *Freshwater Invasive Species of New Zealand* document as an online accessible resource. The guide is aimed at agencies who manage aquatic invaders and users of freshwater bodies. The update included 9 fish species, 1 reptile, 11 invertebrate species, 3 algal species and 32 plant species.

The document includes the most invasive freshwater animals and plants found in Aotearoa New Zealand, how they got here, how they spread, an assessment of the threats they pose to Aotearoa New Zealand's freshwaters, and how they are managed under biosecurity legislation (including roles and responsibilities for management). The outcomes for upkeep with these types of collections is:

— Public awareness of the invasive species resulting in better management of the threat.
— Understanding of the invasive species leading to better management, tools, methods and approaches to lessen the impact they have on different ecosystems.

Detecting tree disease from space

Scion

Red needle cast is a disease that infects Pine trees and Douglas-fir needles. It can limit growth by up to 40%. The disease has been in Aotearoa New Zealand since the 2000s and tends to outbreak with prolonged wet / misty weather. Due to the effect the disease has on tree growth and the desire to restore Aotearoa New Zealand forests, it is important to understand the extent and spread of the disease in affected areas of Aotearoa New Zealand.

Scion researchers have developed a method to monitor red needle cast from satellite imagery. Their goal was to produce maps that accurately showed areas of possible red needle cast infection. Satellite imagery of three forest areas with known red needle cast infections were used to test out their approach. Scion scientists created a method to recognise red needle cast in satellite imagery by defining what unhealthy foliage looks like, i.e. clusters of pixels with the same specified characteristics.

The outcomes of this work are:

— The range and understanding of red needle cast monitoring will increase, including knowledge of outbreaks and the ability to monitor and respond to them.
— The understanding of infection will result in better long-term management and decision-making supporting restoration of the trees and forests.
— The negative impacts of the disease will be reduced and the spread of the disease will be better managed, reducing the cost of management if outbreaks occur.

FOCUS AREA 2 – CASE STUDIES

ESR

STRmix™ (www.strmix.com) is expert, innovative forensic software that can resolve previously unresolvable mixed DNA profiles. It was developed by ESR in collaboration with Forensic Science South Australia (FSSA).

STRmix™ removes the need for subjective interpretation of DNA evidence from a crime scene. It uses probabilistic modelling to determine how likely the genotypes present within a DNA profile are to occur.

Its introduction in New Zealand saw a 30 to 50 percent improvement in the DNA profiling success rate, with the rates getting better the more complicated the profile was.

After a partially KiwiNet funded R&D phase (2010) and first use in case work in New Zealand (2012), STRmix™ was released to market in 2014. It has now been used in more than 300,000 cases and transformed the way DNA evidence is interpreted worldwide.

It has been adopted by over 180 laboratories, including all state and territory labs in Australasia and labs in 13 other countries, including the UK, Ireland, Finland, Denmark, and Canada. In the USA, STRmix™ is used in 65 local, state, federal, and private labs, including those of the FBI and ATF (Federal Bureau of Alcohol, Tobacco, Firearms, and Explosives).

Two applications have been added to the STRmix software portfolio: FaSTR™ DNA and DBLR™.

— DBLR™ is used with STRmix™ to undertake superfast database searches, visualize the value of the DNA mixture evidence, and carry out mixture to mixture matches, allowing kinship analysis.
— FaSTR™ DNA rapidly analyses raw DNA data generated by genetic analysers and standard profiling kits and assigns a number of contributors (NoC) estimate.

STRmix™ is making a significant contribution to local and global justice, by increasing the usefulness of forensic DNA as a crime solving tool and therefore reducing the likelihood of wrongful implication of innocent individuals in criminal activities.

ESR

ESR is the lead agency for the WellKiwis study, part of the SHIVERS (Southern Hemisphere Influenza and Vaccine Effectiveness Research and Surveillance) project series. The Team is based at the National Centre for Biosecurity and Infectious Disease, where ESR leads the WHO National Influenza Centre.

The study is part of a large international collaboration which has received funding from the United States National Institutes of Health through the St Jude Children's Research Hospital in Memphis.

New Zealand is one of three international study sites. The multi-agency collaboration includes Lead Maternity Carers, Otago and Auckland universities, the Capital Coast and Hutt Valley District Health Boards and Regional Public Health.

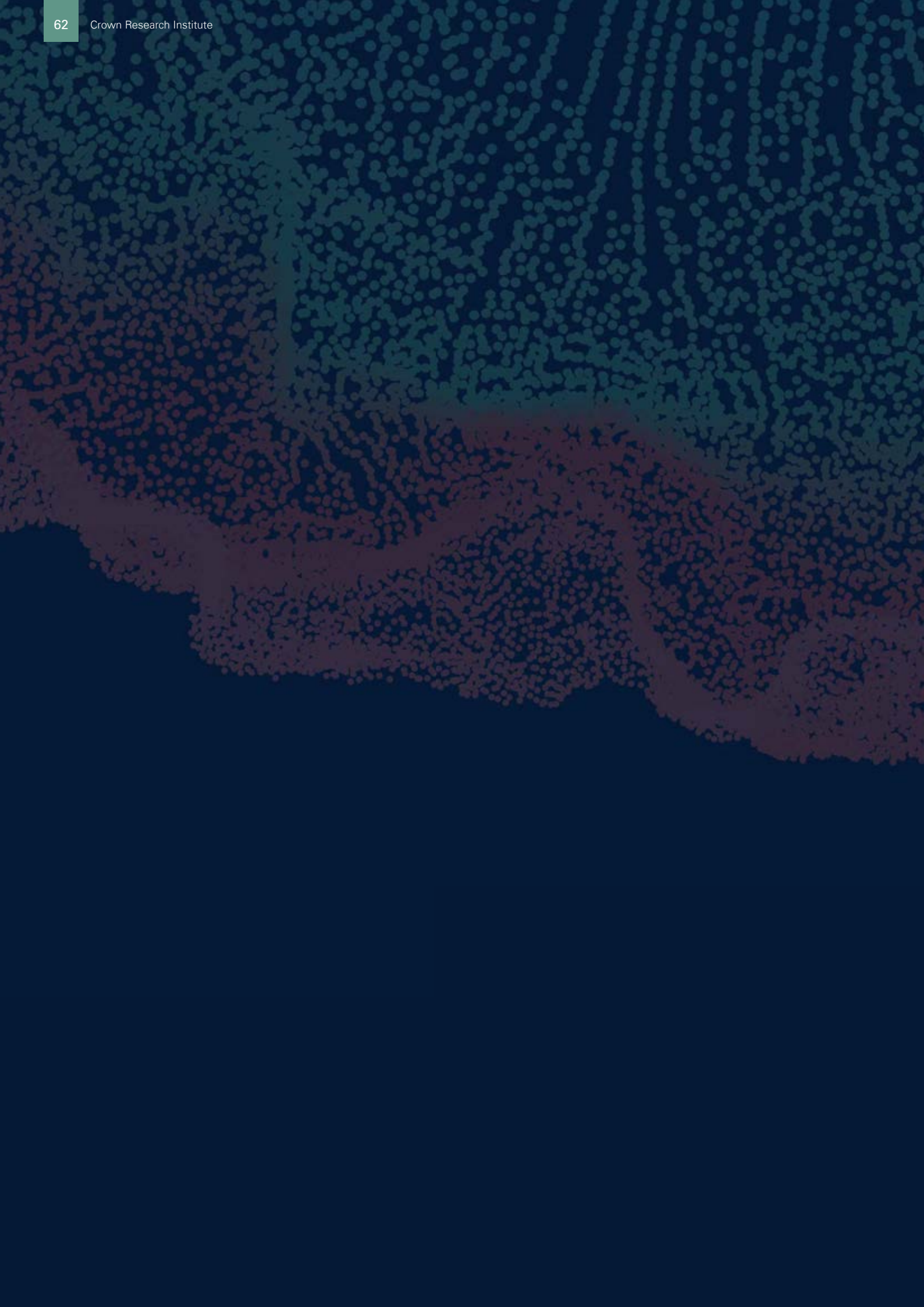
The study assesses how a child's first exposure to the flu virus – or flu vaccine – influences their ongoing immune responses. The objective is the production of more effective and longer lasting flu vaccines.

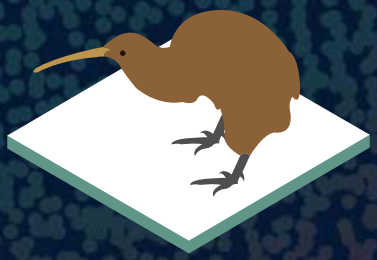
Some six hundred Wellington-based mother-infant pairs will be followed up for up to seven years through to 2026. The children may hold the clues to save millions of lives around the world, as influenza is a serious illness, with young children and the elderly particularly vulnerable.

It appears that the human immune system is primed by its first exposure to flu in childhood. Unravelling the codes of this childhood imprinting may allow identification of those imprints that 'memorise' certain flu viruses which change little and differ little between flu strains.

This information may help scientists design a vaccine that could 'wake up' this memory and produce broadly reactive and longer lasting antibodies to protect a population against multiple flu strains, including new pandemic strains.

This could mean a future time when people would receive a vaccine shot once every three to five years or even longer– rather than annually.

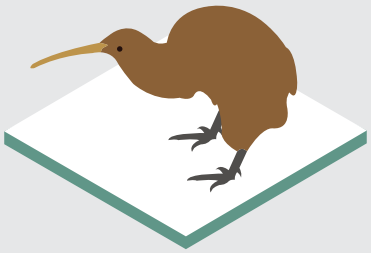




FOCUS AREA 3

BIODIVERSITY

FOCUS AREA 3 – INTRODUCTION



BIODIVERSITY

Reverse the decline, maintain, protect, and restore Aotearoa New Zealand's unique biodiversity.

Biodiversity (the variety of life) was first introduced as a resource management concept at the Rio Earth Summit in 1992. The Convention on Biological Diversity 1992 recognised for the first time in international law that the conservation of biological diversity is a common concern. The Convention covers all ecosystems, species and genetic resources and helps guide national strategies for conservation and sustainable use of biodiversity. The convention defines biodiversity as 'the variability among living organisms from all sources, inter alia, terrestrial, marine and aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and ecosystems'.[8]

Te Mana o Te Taiao is Aotearoa New Zealand's Biodiversity Strategy 2020 and aims to guide the way all in the motu work to protect and restore nature. The strategy has a core focus on collaboration and partnership to achieve the best outcomes for the restoration and sustainable use of biodiversity.

Aotearoa New Zealand has an estimated 80,000 endemic species, where unique biodiversity has developed due to our climate, isolation and diverse geology. However, biodiversity is in decline and many species are being pushed towards extinction. Before 2018 nearly 40% of the total number of Aotearoa New Zealand indigenous plant species and 74% of indigenous freshwater fish had suffered a great decline and some extinction.[8] Aotearoa New Zealand relies on the maintenance and health of its ecosystems for economic, social, environmental and cultural reasons.

Economic benefits – The use of ecosystem services, fisheries and tourism helps build Aotearoa New Zealand's unique value. In 2013 it was estimated that the value of Aotearoa New Zealand land-based ecosystem services were around $57 billion per annum and this has likely increased since then.[8]

Social benefits – Aotearoa New Zealand's biodiversity is part of the country's national identity and holds recreational value for New Zealanders.[8]

Environmental/sustainability benefits – Healthy ecosystems support healthy life. They recycle and protect resources (water, soil and nutrients) provide food and have medicinal properties. Healthy biodiversity is more resilient to disasters, and natural and human harm which means that healthy biodiversity also offers sustainability benefits.[8]

Cultural benefits – Biodiversity is important to all New Zealanders, particularly Māori who view all components of ecosystems, both living and non-living, to posses the spiritual qualities of tapu, mauri, mana, and wairua and that the people are the kaitiaki (guardians) of these ecosystems which means responsibility and guardianship relies on the people.[9]

The Crown Research Institutes and Biodiversity:

The CRIs have key lead and contributing capabilities that support Aotearoa New Zealand's efforts in biodiversity. The CRIs provide essential lead science and research for Aotearoa New Zealand's biodiversity efforts in:

- Collections and databases that provide an understanding of our ecosystem to enable more informed decisions, conservation and management.
- Improved knowledge and understanding of biodiversity for better protection of the unique biodiversity in the motu.
- Innovative methods, tools and techniques to better conserve and manage biodiversity.

The lead CRIs in biodiversity are:

- Manaaki Whenua: focus predominantly on identification, characterisation, management, restoration and conservation of terrestrial biodiversity.
- NIWA: focus on identification, characterisation, management, and conservation of biodiversity in aquatic environments.

Manaaki Whenua Landcare Research	83 FTE
NIWA	30 FTE

The contributing CRIs in biodiversity are:

- AgResearch
- ESR
- GNS
- Plant & Food Research
- Scion.

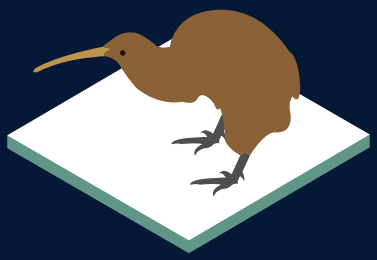
The CRI capabilities have been grouped under the headings below to articulate the key outcomes and impacts their science and research jointly has on biodiversity.

Identification and characterisation – Identification and characterisation of biodiversity to measure change, support current state and trend analysis, and assessment of biodiversity on a range of different scales. Includes understanding whenua and empowering iwi and hapū in its care and protection as the Kaitiaki. This understanding supports evidence-based responses to changes in ecosystems and the risks this poses to Aotearoa New Zealand.

Management and conservation – The increased knowledge to conserve, restore, protect, manage and ensure resilience of biodiversity. This includes sourcing potential economic applications of biodiversity and understanding, valuing and using Te Ao Māori and Treaty-informed approaches to sustaining the relationship between people and biota (the plant and animal life of a region).

8. Environment Guide. 'New Zealand Biodiversity [website], http://www.environmentguide.org.nz/issues/biodiversity/, (accessed 8 April 2021)
9. What is biodiversity and why is it important, 'Greater wellington regional council' [website], http://www.gw.govt.nz/what-is-biodiversity-and-why-is-it-important/, (accessed 8 April 2021)

FOCUS AREA 3 – LEAD CAPABILITIES



BIODIVERSITY

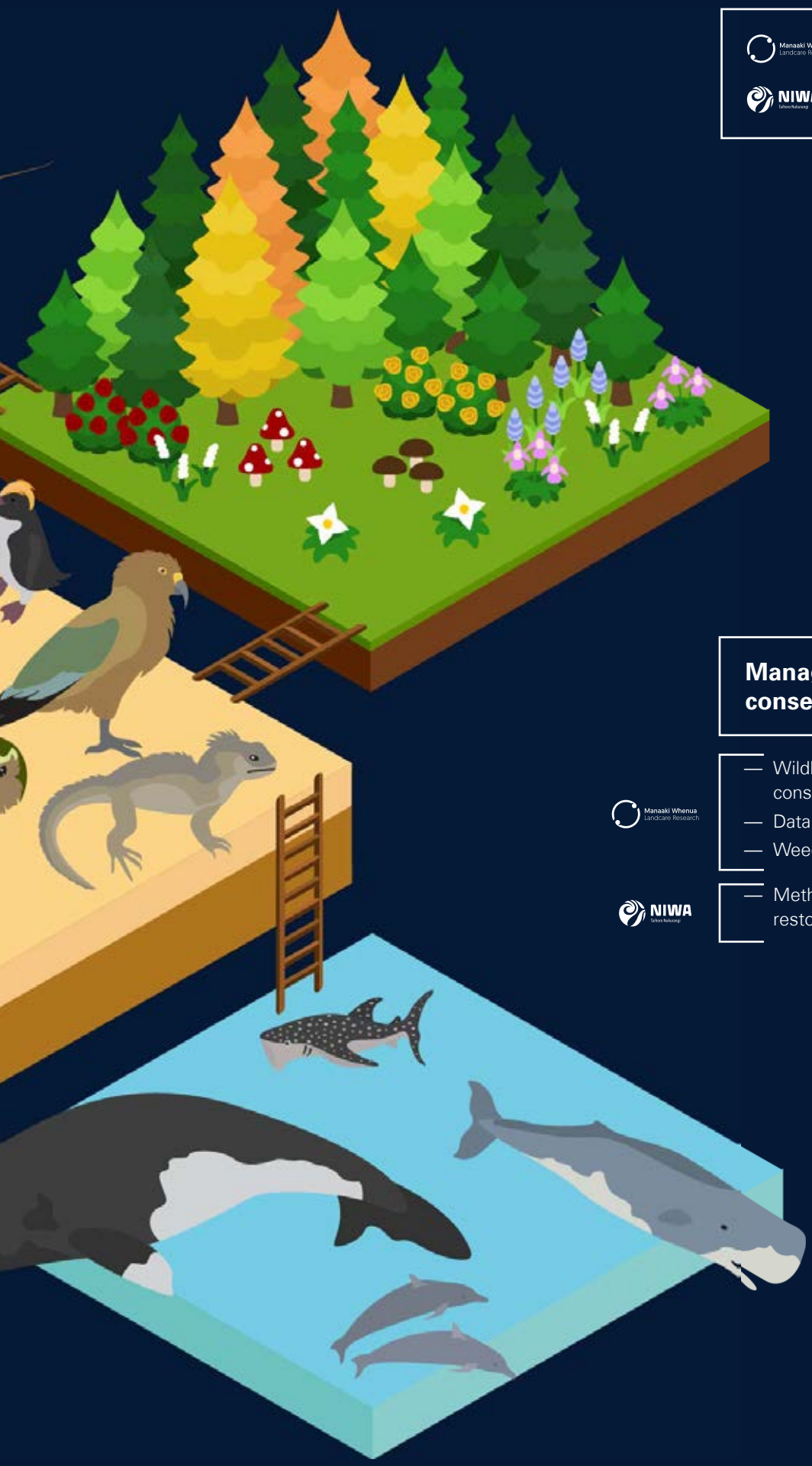
Identification and characterisation

NIWA

- Marine invertebrate, aquatic biodiversity, flora and fauna of aquatic environments biodiversity

Manaaki Whenua Landcare Research

- Identification and understanding of indigenous and introduced biota
- Management and improvement of collections and databases
- Environmental informatics
- Commercial use of collections and knowledge
- Quantitative ecology modelling
- Molecular ecology – ancient and environmental DNA
- Paleoecology unit
- Economic use of indigenous biota
- Plant biodiversity



Manaaki Whenua Landcare Research **83 FTE**

NIWA Taihoro Nukurangi **30 FTE**

Management and conservation

Manaaki Whenua Landcare Research

- Wildlife management and conservation ecology
- Data management
- Weed and biological control

NIWA Taihoro Nukurangi

- Methods and tools to protect and restore aquatic environments

FOCUS AREA 3 – KEY OUTCOMES

KEY OUTCOMES FOR AOTEAROA NEW ZEALAND'S BIODIVERSITY

Manaaki Whenua
Landcare Research

Key biodiversity outcomes

Drive innovation in Aotearoa New Zealand's management of terrestrial biodiversity.

Enable others to better safeguard Aotearoa New Zealand's biodiversity by providing underpinning:

- Identification and characterisation of biota and ecosystems.
- Detection, identification and characterisation of invasive species to support evidence-based responses.
- Research infrastructure (databases and collections)
- Accessible and usable data and information on the nation's biodiversity is available to stakeholders.
- Improved biosecurity tools and approaches to reverse the decline of Aotearoa New Zealand's biodiversity.

NIWA
Taihoro Nukurangi

Key biodiversity outcomes

Protection of Aotearoa New Zealand's aquatic ecosystems and the species they support.

Provide knowledge, tools and services for biodiversity management through:

- Description and identification of the fauna and flora of Aotearoa New Zealand's aquatic ecosystems, including Antarctica.
- Data bases and collections of marine and freshwater species.
- Maps of aquatic species distributions, habitats and ecosystems.
- Identification of the adverse effects of environmental change on aquatic biodiversity.
- Development of methods to protect, restore and co-manage aquatic environments.

FOCUS AREA 3 – ENABLING CAPABILITIES

ENABLING CAPABILITIES BIODIVERSITY

The CRIs have the following enabling capabilities that support their lead scientific capabilities in the biodiversity focus area.

Manaaki Whenua Landcare Research

Enabling capabilities

- Nationally significant collections/ databases e.g., National Vegetation Survey Databank, NZ Anthropod Collection, Fungarium, the Allen Herbarium, International Collection of Microorganisms from Plants, NZ Flax collection
- Māori engagement
- Social capabilities e.g. social license
- Citizen science

NIWA Taihoro Nukurangi

Enabling capabilities

- Research vessels – RV Tangaroa, RV Kaharoa, RV Ikatere
- Te Kūwaha, National Centre for Māori Environmental Research
- Sensor networks & Internet of Things (IoT)
- High performance supercomputing, data analytics and modelling
- Remote sensing, enterprise data products and services
- National Marine Invertebrate Collection
- Databases e.g. environmental classifications

FOCUS AREA 3 – CRI COLLABORATIONS

CRI COLLABORATIONS BIODIVERSITY

Below are examples of CRI collaborations in this area. Some CRIs contribute to this work – although it is not their core focus – through other expertise they bring.

Plant & Food Research
Rangahau Ahumāra Kai

Manaaki Whenua
Landcare Research

Provenance of Manuka: the Honey Landscape Model looks at building resilience and provenance into an authentic Māori honey industry. Running from October 2016 – September 2021.

E/S/R
Science for Communities

NIWA
Taihoro Nukurangi

Development of a Groundwater Health Index - includes the development of environmental DNA (genomics) to better understand Groundwater biodiversity. The Groundwater Health Index is used to inform land owners, land users, and Territorial Local Authorities (Regional Councils).

Manaaki Whenua
Landcare Research

(Host)

E/S/R
Science for Communities

agresearch
āta mātai, mātai whetū

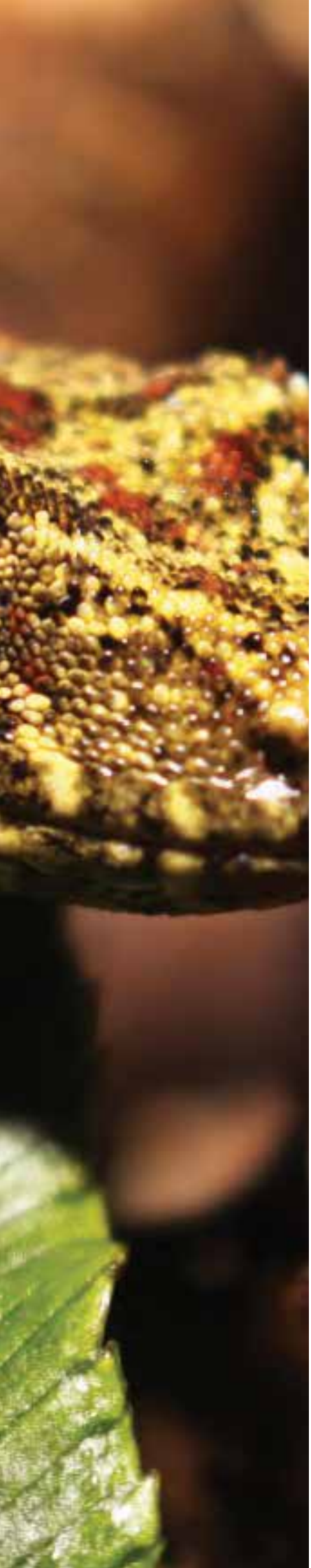
GNS SCIENCE TE PŪ AO

NIWA
Taihoro Nukurangi

Plant & Food Research
Rangahau Ahumāra Kai

SCION
FORESTS • PRODUCTS • INNOVATION

National Science Challenge: New Zealand's Biological Heritage | Ngā Koiora Tuku Iho: To protect and manage Aotearoa New Zealand's biodiversity, improve biosecurity, and enhance resilience to harmful organisms.



FOCUS AREA 3 – KEY END USERS

KEY END USERS BIODIVERSITY

Key end users for each CRI are shown below. The list is illustrative, not exhaustive. Some organisations – such as large government departments – appear more than once, as CRIs provide different services for different groups within them. The end users vary in scale and specialisation, therefore different CRIs connections with end users generally do not overlap.

Manaaki Whenua Landcare Research

Government agencies: Ministry of Business, Innovation and Employment, Department of Conservation, Ministry for Primary Industries, Ministry of Foreign Affairs and Trade.

Regional council: Local government (regional and district councils).

Industry bodies: Food and fibre industry.

Māori trusts & companies: Iwi and hapū, Tuawhenua Trust.

Other/private organisations: OSPRI (Animal Disease Management), National Biocontrol Collective, Community groups e.g. Predator Free Wellington, Predator-Free 2050 Ltd.

NIWA Taihoro Nukurangi

Government agencies: Department of Conservation, Ministry for the Environment, Biosecurity New Zealand, Ministry for Primary Industries, Ministry of Fisheries.

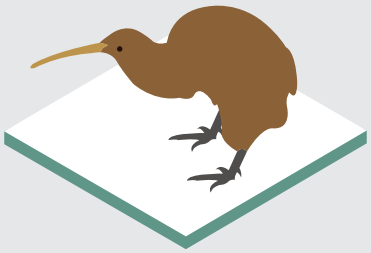
Regional council: Local government (regional and district councils).

Research organisations: National and international research organisations.

Māori trusts & companies: Iwi and hapū, Māori agencies/groups.

Other/private organisations: Non-Governmental Organisation.

FOCUS AREA 3 – CASE STUDIES



BIODIVERSITY CASE STUDIES

Manaaki Whenua

Kiwi are part of Aotearoa New Zealand's cultural identity and a nationally significant bird. There are about 70,000 kiwis in Aotearoa New Zealand, with five species and ten regional genetic forms recognised. However, despite decades of management and research by agencies and communities, kiwi populations are still at risk.

Manaaki Whenua has undertaken a programme of work, from October 2016 to March 2021 called Kiwi Rescue, aimed at reducing the decline and improving the management of kiwi protection in Aotearoa New Zealand.

Manaaki Whenua worked with the Department of Conservation, Kiwis for Kiwi, Māori and community groups to make new, cost effective tools to help "everyone help the Kiwi".

This programme included working with tangata whenua to identify Kiwi on their land and devise new tools for the science, modelling and monitoring techniques required to meet information needs on Kiwi.

This information will ensure land management and restoration decisions are more effective for Kiwi.

The outcomes of their work include:

- Creating more efficient restoration and management of kiwi.
- Modelling that gives insight into predators diet and effectiveness of predator controls.
- Increased Māori participation in kiwi management collaborating to develop a kiwi habitat assessment tool.
- Cost effective methods to determine the number of predators for kiwi.

Manaaki Whenua

Fungi have long been a traditional food source used across the globe. Within Aotearoa New Zealand's fungal realm at least 7,000 to 8,000 unique species have been identified and there are an expected 1,000 more.

There is a growing demand for high-quality non-animal-based protein products and a lack of Aotearoa New Zealand native food products or traditional Māori food available to New Zealanders. So, Manaaki Whenua researchers and iwi co-designed a project that investigated whether three types of fungi species, once traditional Māori foods, could be grown and reproduced at a commercial scale.

The outcomes of this project included:

- Using capabilities in the understanding of biodiversity, Manaaki Whenua identified two species of fungi, suggested by iwi, that have been passed to Ngāti Whātua to operate their own business using container-style production.
- The research provided data on the costs of operating and production to better understand the risks and inputs associated with providing these mushrooms as a product to the Aotearoa New Zealand market.

Evaluating the effectiveness of the Ross Sea Marine Protected Area

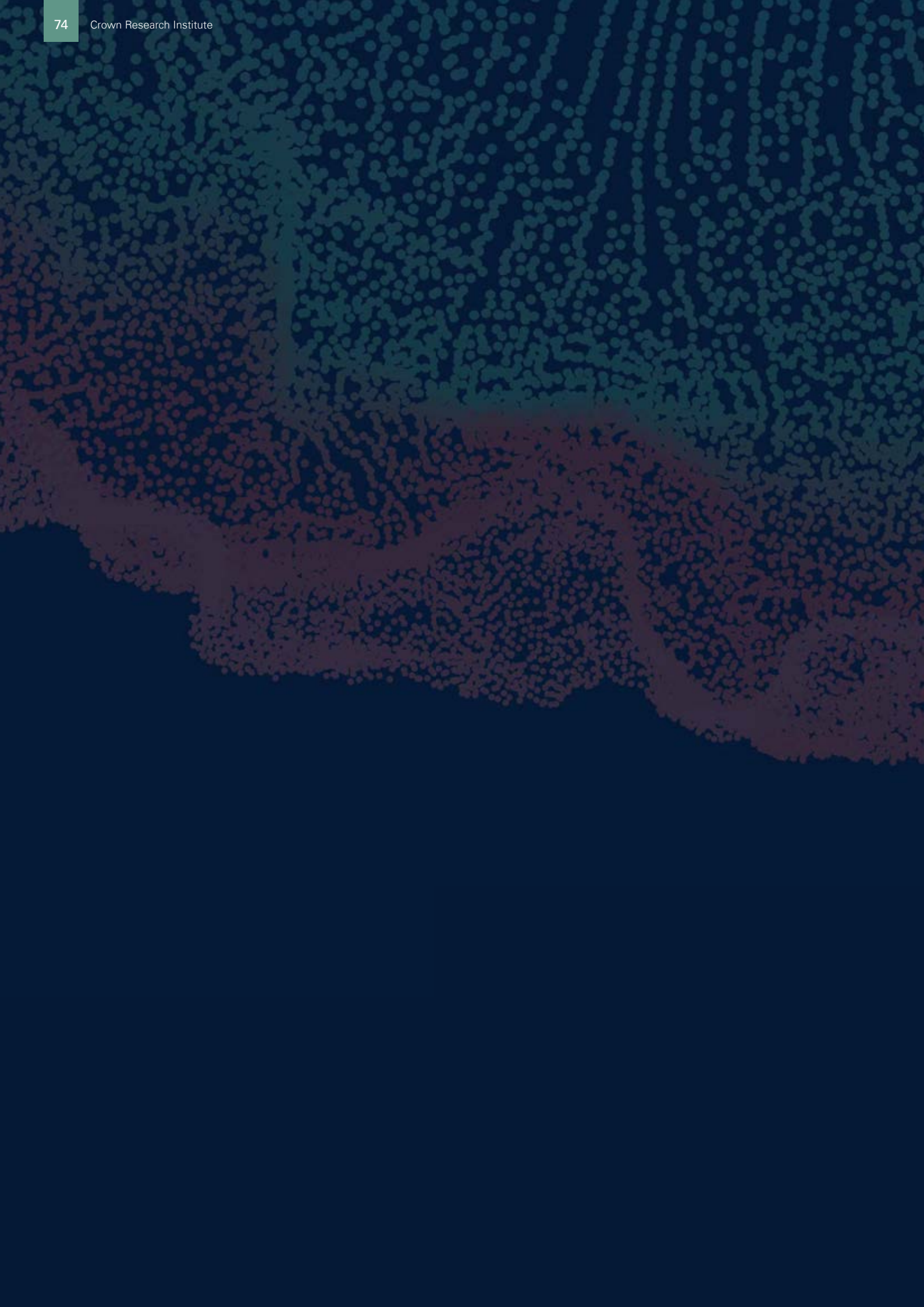
NIWA (lead), Manaaki Whenua (contributing)

There is significant effort in global marine protection to conserve ecology, mitigate threats to ecosystems from fishing, provide reference for degradation and changes in marine environments over time, and to help guide decision making for restoration efforts.

The Ross Sea Marine Protected Area is one of the rare places on Earth little affected by human activity and has abundance of biodiversity and marine life. In efforts to ensure this area is being protected, NIWA runs the Ross Sea Research and Monitoring Programme. It is funded by the Ministry of Business Innovation and Employment to evaluate the effectiveness of the Ross Sea Marine Protected Area. This work will involve research voyages, Antarctic fieldwork, fishing vessel research and computer modelling capabilities. It includes: characterising the baseline of the protected areas, determining methods to measure change over time, and analysing / modelling approaches to evaluate the effect of the Marine Protected Area work.

The outcomes will ensure:

- The Ross Sea Marine Protected Area is being protected effectively, and remains unharmed by human activity.
- The biological diversity and abundant marine life remain a refuge for open-water marine life.
- The Area continues to be an ideal place where scientific research can be undertaken to better understand marine systems.



FOCUS AREA 4

WATER RESOURCES

FOCUS AREA 4 – INTRODUCTION

WATER RESOURCES

Enhance the safety, management, sustainability, value, and maintenance of Aotearoa New Zealand's drinking, recreational, and other water resources.

Water is one of the most important natural resources in the world. It is fundamental to life and supports a healthy sustainable economy. Water is essential across all of Aotearoa New Zealand's key industries, is used recreationally, and is home to many aquatic species. Due to the high demand for the natural resource, there is increased competition for water resulting in degradation and problems with water quality. This, combined with any uncertainty surrounding policies for water use, may result in ineffective, inequitable and unsustainable uses of Aotearoa New Zealand's water.

Understanding the water systems and their characteristics across Aotearoa New Zealand is important. Such knowledge enables durable water policy to be developed, and aids equitable outcomes and decision making for water use, including the way water is used and valued.

There are multiple issues facing Aotearoa New Zealand's water resource. Whether freshwater, groundwater, marine or wastewater, all are essential to maintain environmental integrity, social wellbeing and economic productivity.

The areas of water and their importance are described below:

Freshwater – Protecting and restoring the health of Aotearoa New Zealand's freshwater is a priority.

Pressures such as growing populations and land-use changes have deteriorated water quality, affected land, ecosystems, fish, drinking water supplies and recreational use of water.[10]

Groundwater – Groundwater accounts for roughly 40% of Aotearoa New Zealand's water usage.

The sustainability and effectiveness of groundwater usage, management and quality is essential for economic productivity, environmental integrity and social wellbeing.[11]

Wastewater – Ineffective disposal and management of wastewater can effect waterways, aquatic life, public health and ecosystems through contamination and pollution. This will also incur high response costs to the contamination and leave harmful, lasting effects on the contaminated areas.[12]

The CRIs have lead and contributing capabilities that support efforts to address effective management, water quality, use and partnership with Māori in how to optimise water resources, and to ensure everyone has access to clean drinking water. The CRIs provide essential science and research for the nation's water resource efforts in:

- Capabilities that help with understanding the quality and quantity of water resources to help make informed decisions and understand the current state of Aotearoa New Zealand's water resources.
- Prediction tools and methods that help inform efficient use and allocation of wastewater so the economic and sustainable outcomes for wastewater can be achieved.
- Focusing on the impact internal and external changes have on water resources and the effect on the use and management of these resources.

— Methods, tools and collaborations for better management of water. Particularly focussing on partnership with Māori and honouring Te Tiriti o Waitangi.
— Capabilities to ensure the restoration and protection of water resources because they are essential to all life.
— Science and research capabilities to support and uphold the safety and equitable access to clean drinking water as a critical resource for public health and communities.

The lead CRIs in water resources are:

— NIWA: focus on Aotearoa New Zealand's marine and freshwater ecosystems and allocation of water resources.
— ESR: focus on fresh and drinking water quality and safer use of biowastes for a cleaner water environment.
— GNS: focus on research that establishes risks to the security of groundwater aquifers, how land use and water extraction impacts groundwater and surface water, the impact of climate change on groundwater security.

The contributing CRIs in water resources are:

— AgResearch
— Manaaki Whenua
— Plant & Food Research
— Scion.

Key CRI capabilities in this focus area, by type of water resource, can be grouped as:

Freshwater – Improvements in freshwater quality, safety, allocation and ecosystem health. This includes improvement in equitable freshwater management and enabling Māori-led science and research for the use of freshwater, using an approach that honours Te Tiriti o Waitangi.

Groundwater – Enhance understanding of groundwater process, quality, availability and reservoir resources to enable water management. Better understanding the natural system that produces energy and powers Aotearoa New Zealand and research to explore tolls/techniques to protect and preserve groundwater.

Wastewater – Developing sustainable solutions for managing organic waste, effluent, wastewater, greywater and sewage sludge, so as to improve the health of the environment and the people that interact with it. This also includes improving public surveillance and data science and the safer use of biowastes.

10. Freshwater. 'Ministry for the Environment' [website], https://www.mfe.govt.nz/fresh-water/freshwater-and-government, (accessed 8 April 2021)
11. Groundwater, 'GNS' [website], https://www.gns.cri.nz/Home/Our-Science/Environment-and-Climate/Groundwater#:~:text=Addressing%2 water%20exploration%2C%20quality%20and,well%2Dbeing%20and%20economic%20productivity./, (accessed 8 April 2021)
12. Wastewater, 'Ministry for the Environment' [website], https://www.mfe.govt.nz/publications/waste/sustainable-wastewater-management-handbook-smaller-communities-part-1-0, (accessed 8 April 2021

FOCUS AREA 4 – LEAD CAPABILITIES

WATER RESOURCES

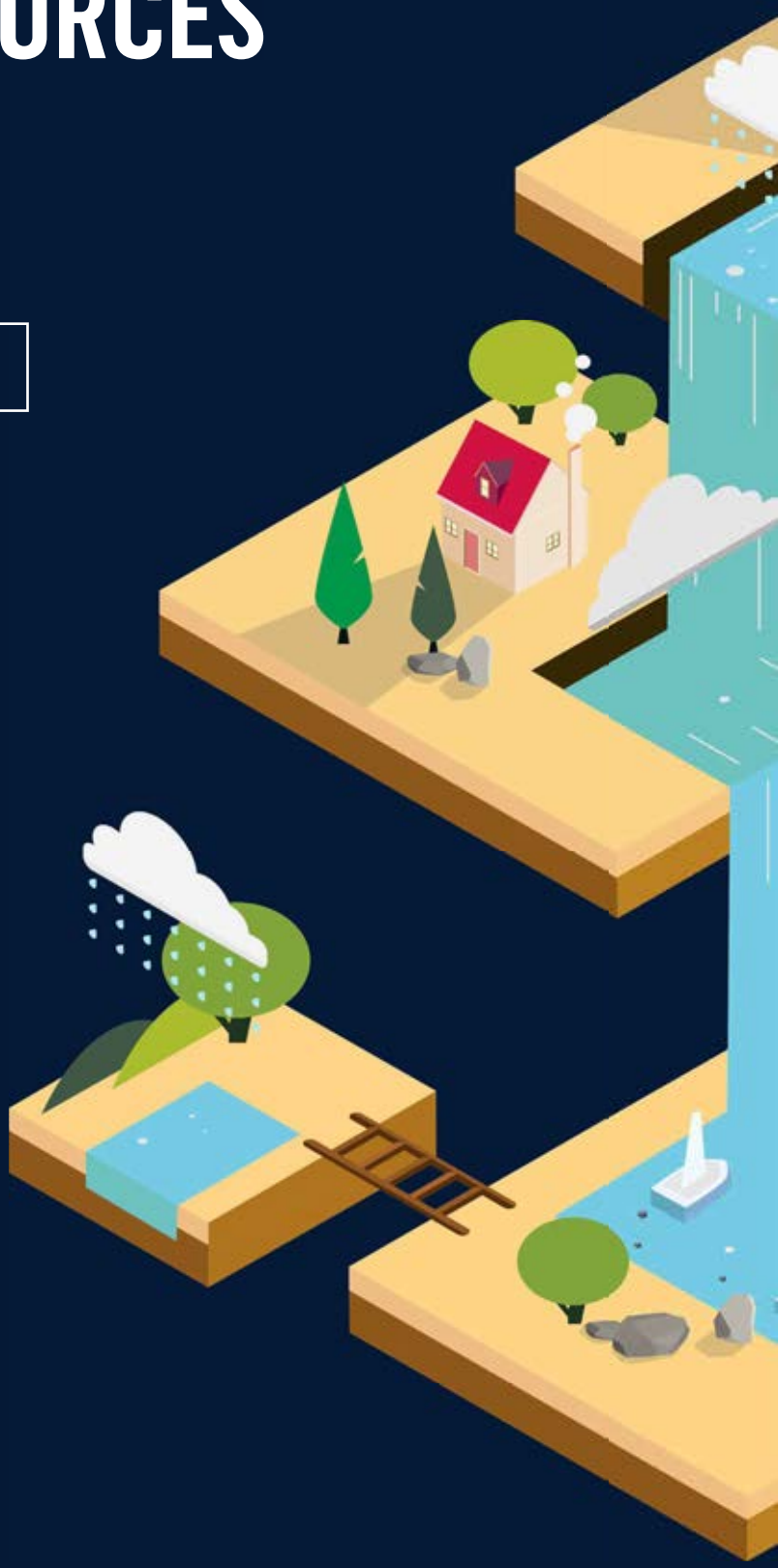
Freshwater

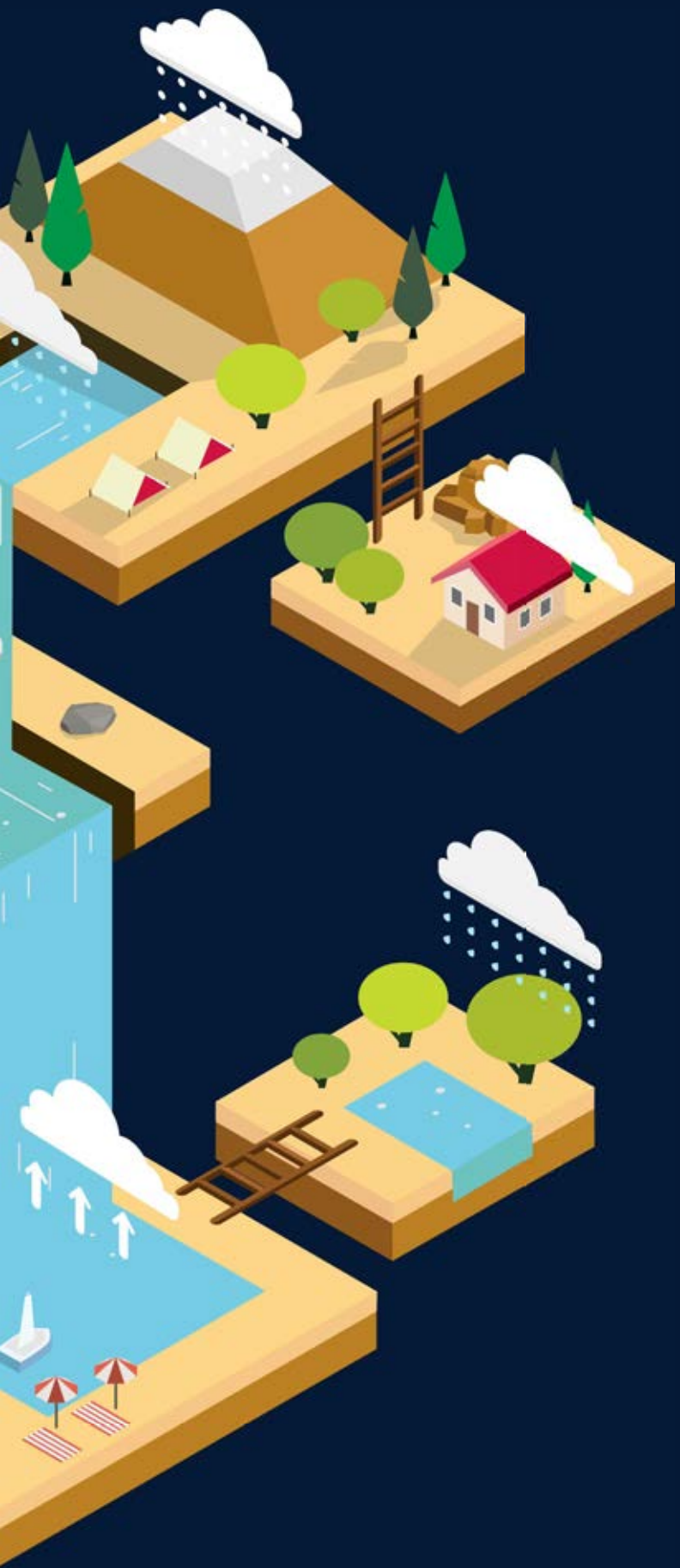
NIWA

- Monitoring and measurement of freshwater resources
- Information on current state
- Predications and tools to inform use and adaptation of freshwater allocation
- Preventative and mitigation measures for water quality
- Methods and tools for iwi and Māori research and management
- Restoration techniques

E/S/R Science for Communities

- Improve impacts on human health and safety of freshwater
- Exploration, analysis and advice to support the provision of safe drinking water
- He Wai Māpuna (Iwi/ Māori specific research)





NIWA	120 FTE
E/S/R Science for Communities	33 FTE
GNS Science Te Pū Ao	40 FTE

Groundwater

- Aquifer characterisation
- Groundwater modelling
- Groundwater dynamics and environmental pressure
- Translating science into policy

- Improve impacts on human health and safety of groundwater
- He Wai Māpuna (Iwi/ Māori specific research)
- Restoration tools and techniques

Wastewater

- Safer use of biowastes – biowaste science
- He Wai Māpuna (Iwi/ Māori specific research)
- Public health surveillance

FOCUS AREA 4 – KEY OUTCOMES

KEY OUTCOMES FOR AOTEAROA NEW ZEALAND'S WATER RESOURCES

NIWA
Taihoro Nukurangi

Key outcomes for water resources

Enhanced health of Aotearoa New Zealand's freshwater ecosystems through improved water quality, ecosystem restoration and sustainable allocation of water resources.

Provide knowledge, tools and services for freshwater management through:

- Monitoring and measurement of the quality and quantity of freshwater.
- Identification of the state of Aotearoa New Zealand's water resources.
- High resolution forecasting of freshwater resources.
- Water allocation guidance to ensure ecosystem health of waterways.
- Development of mitigation measures to improve water quality in lakes, rivers, and estuaries.
- Co-development of tools with iwi for the management of freshwater taonga species.
- Techniques and methods for restoring degraded freshwater environments.

E/S/R
Science for Communities

Key outcomes for water resources

Deliver science and research services for fresh and drinking water quality and safe use of biowaste for cleaner water and environment.

GNS SCIENCE TE PŪ AO

Key outcomes for water resources

Enhance the health of Aotearoa New Zealand's freshwater ecosystems through improved water quality, restoration of degraded waterways and sustainable and equitable allocation of water resources.

FOCUS AREA 4 – ENABLING CAPABILITIES

ENABLING CAPABILITIES WATER RESOURCES

The CRIs have the following enabling capabilities that support their lead scientific capabilities in the water resources focus area.

NIWA
Taihoro Nukurangi

Enabling capabilities

- Te Kūwaha, National Centre for Māori Environmental Research
- Hydrometric, water quality and ecosystem monitoring networks and Internet of Things (IoT)
- High performance supercomputing, data analytics and modelling
- Remote sensing, enterprise data products and services
- Databases (e.g. water quantity and quality, freshwater fish)

E/S/R
Science for Communities

Enabling capabilities

- Data science
- Kaupapa Māori research
- Portable computing power
- Internet speed (REANNZ)
- Access to data other organisations have custodianship over
- Fit-for-purpose science infrastructure
- Public health

GNS SCIENCE TE PŪ AO

Enabling capabilities

- Data science
- Social science
- Nationally significant collections
- National laboratories
- IODP/ICDP (global geoscience)
- High performance computing
- Tritium and Water Dating Laboratory

FOCUS AREA 4 – CRI COLLABORATIONS

CRI COLLABORATIONS WATER RESOURCES

Below are examples of CRI collaborations in this area. Some CRIs contribute to this work – although it is not their core focus – through other expertise they bring.

GNS SCIENCE TE PŪ AO

E/S/R Science for Communities

Groundwater Science and Research Alliance Aotearoa. This alliance is focused on raising awareness and improving understanding of the groundwater systems in Aotearoa New Zealand.

E/S/R Science for Communities

SCION FORESTS ▪ PRODUCTS ▪ INNOVATION

Manaaki Whenua Landcare Research

NIWA Taihoro Nukurangi

Centre for Integrated Biowaste Research (CIBR). CIBR is a collaborative programme that delivers innovation solutions for the re-use of biowastes.

NIWA Taihoro Nukurangi

GNS SCIENCE TE PŪ AO

Manaaki Whenua Landcare Research

The New Zealand Water Model - Hydrology (NZWaM-Hydro). The key aim of the NZWaM-Hydro is to enable the prediction of hydrological flow and transport processes from national to sub-catchment scale (relevant scales for The National Policy Statement for Freshwater Management).

FOCUS AREA 4 – KEY END USERS

KEY END USERS WATER RESOURCES

Key end users for each CRI are shown below. The list is illustrative, not exhaustive. Some organisations – such as large government departments – appear more than once, as CRIs provide different services for different groups within them. The end users vary in scale and specialisation, therefore different CRIs connections with end users generally do not overlap.

NIWA
Taihoro Nukurangi

Government agencies: Ministry for the Environment, Ministry for Primary Industries, Department of Conservation, Land Information New Zealand.

Industry bodies: Industry bodies.

Research organisations: National and international research organisations.

Māori trusts & companies: Iwi/hapū, Māori agencies/groups.

Other/private organisations: Energy sector organisations.

ESR
Science for Communities

Government agencies: Ministry for the Environment, Ministry of Health, Ministry of Foreign Affairs and Trade, Department of Internal Affairs - Taumata Arowai establishment unit (safer drinking water).

Industry bodies: Industry bodies.

Regional council: Territorial Local Authorities.

GNS SCIENCE
TE PŪ AO

Government agencies: Ministry for the Environment, Ministry for Primary Industries, Ministry of Health, District Health Boards, Public Health Officers, Ministry of Business, Innovation, and Employment.

Industry bodies: Industry bodies.

Regional council: Regional council.

Other/private organisations: Electricity generators.

FOCUS AREA 4 – CASE STUDIES

WATER RESOURCES CASE STUDIES

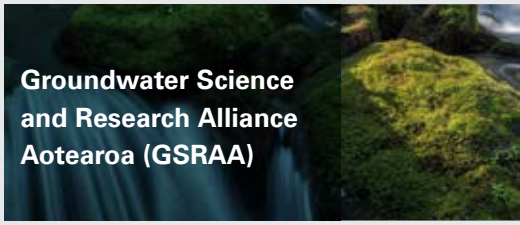
NIWA

NIWA staff were members of the Ministry for the Environment's Freshwater Science and Technical Advisory Group (STAG), providing the evidence base for new water quality and ecosystem health attributes. These were added to the National Policy Statement for Freshwater Management (NPS-FM). The NPS-FM provides local authorities with direction on how to manage freshwater.

The role of NIWA was to support officials in updating the NPS-FM by ensuring they interpreted information from the existing scientific evidence correctly and to identify data gaps to direct future focus/research efforts in the right areas. The intent of the existing NPS-FM was to maintain or improve water quality in Aotearoa New Zealand. The STAG found that objectives within the existing framework required greater clarity to avoid further degradation of aquatic ecosystems. The STAG suggested that regional councils should be required to report on their performance in achieving freshwater objectives to provide a comprehensive picture of the state of water and effectiveness of management actions. The STAG developed recommendations on implementing ecosystem health metrics with an integrated view of what must be measured and managed to protect and enhance the shared value of Aotearoa New Zealand's water.

Outcomes:

— Stricter reporting metrics and frameworks within NPS-FM. This will ensure local authorities are held to account for and preserve Aotearoa New Zealand's freshwater resources in an integrated manner to cover freshwater preservation, including water quality, water quantity, habitat, aquatic life and ecological process, among others.
— By increasing the accountability and focus of preservation efforts, the NPS-FM will better protect the cultural, economic and health importance of Aotearoa New Zealand's water resources, which are central to the energy, transportation, recreation, jobs and drinking water it provides to the community.



GNS Science, ESR

Freshwater ecosystems are crucial in providing water for drinking, energy, transportation, recreation and employment. Ground water is critical to the freshwater system, with 40% of New Zealanders depending on groundwater for their drinking water and 80% of annual river flow coming from groundwater. The quality of freshwater is declining in Aotearoa New Zealand and freshwater systems are under pressure.

Improving the quality and quantity of freshwater relies on better management of the country's groundwater. The GSRAA is a collaboration between ESR, GNS Science, Lincoln Agritech and Aqualine that brings together scientists who provide diverse range of expertise in groundwater science and the management of groundwater resources. The aim of this collaboration is to understand the impacts and outcomes that will improve the supply and resilience of groundwater systems, how demand is managed and how this will ultimately improve the outcomes for freshwater. This increased knowledge is also crucial to avoiding health crises

such as the Havelock North campylobacteria outbreak. The group works closely with Regional Councils, government agencies and Māori to understand their priorities and needs.

Outcomes:

— Raised awareness by central and local government of the importance of groundwater management in the hydrological cycle and its economic importance to New Zealanders (providing freshwater for energy, transportation, recreation and jobs for the country as well as drinking water for 40% of the community).
— Increased knowledge on how to successfully manage groundwater resources to continue to provide water for drinking, energy, transportation, recreation and many jobs by increasing the quality and quantity of freshwater resources available to Aotearoa New Zealand.

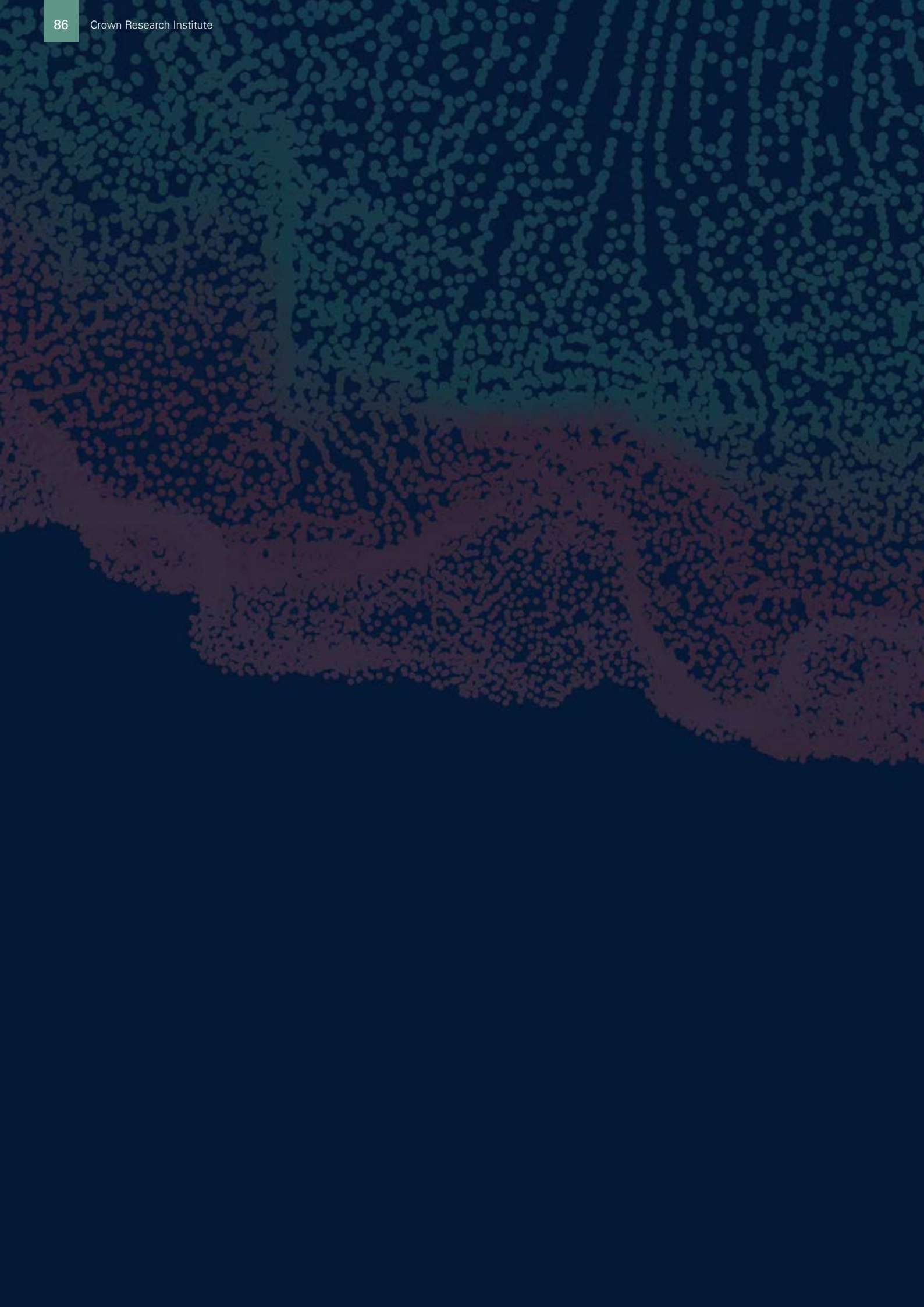
Ngā Kete o te Wānanga: Mātauranga, Science and Freshwater Management

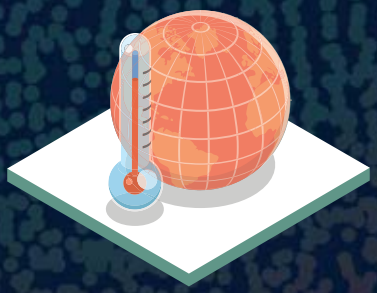
NIWA

Freshwater provides significant cultural, economic, social and environmental benefits to people, but competition for the use of such resources is intensifying. In addition, it is essential to honour Māori decisions on the use and development of freshwater as they hold distinct perspectives concerning their identity, knowledge and custodial obligations in managing tribal waters. Despite the critical role Māori play in the co-management of freshwaters, as key elements of numerous Treaty settlements, Māori interests / cultural values are not always fully considered in planning and resource management decision-making. Ngā Kete o te Wānanga is a multi-disciplinary research programme designed to develop and optimise synergies between science, Mātauranga Māori and other relevant factors by bringing together knowledge from the systems to inform and improve decision-making and collaborative management in Aotearoa New Zealand. The programme aims to overcome the challenges posed in co-management of the environment between iwi/ Māori and the Government to benefit the health and wellbeing of Māori communities as well as national freshwater assets.

Outcomes:

— Greater acknowledgement of the critical role Māori play in the co-management of freshwaters, honouring Te Tiriti o Waitangi, and how to best manage the complex water systems that exist aligned with Māori values to ensure more equitable benefits of freshwater systems.
— Increased equality and representation of Māori values in freshwater systems in Aotearoa New Zealand through development of Māori capacity in freshwater research, management and policy.
— Increased collaboration, inclusion of Mātauranga Māori and current best science practice in the use of freshwater management processes to ensure the natural resources are used in a way to maximise economic benefit while upholding the cultural importance of the asset.

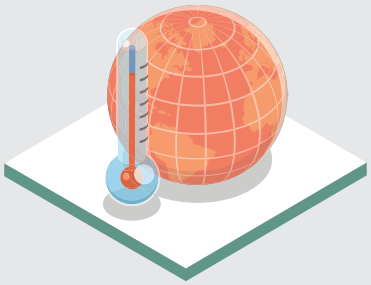




FOCUS AREA 5

CLIMATE CHANGE

FOCUS AREA 5 – INTRODUCTION



CLIMATE CHANGE

Enhance Aotearoa New Zealand's resilience to climate risks and support transition to a zero-carbon future.

Evidence for climate change and its effects are extensive. The changing climate will have widespread impacts by changing the way the world works through introduction of new risks and challenges. The Climate Change Response (Zero Carbon) Amendment Act provides the framework for responding to these climate challenges and is a focus for many public and private organisations in Aotearoa New Zealand.

Climate change is caused by many aspects of human activity. The level of methane and carbon dioxide (as well as other greenhouse gasses) is at the highest level in at least 800,000 years and is continuing to rise. This warming of the planet leads to changes in the environment and new risks and challenges that will affect all of Aotearoa New Zealand.

The changing climate will impact our economy, environment and way of life. Some of the likely impacts will be:

- Higher temperatures leading to change in environmental conditions that have a holistic effect on the economy, environment and social wellbeing of New Zealanders and the world.[13]
- An increase in extreme weather events such as flooding, fires and long lasting draughts.[13]
- An increase in the demand for water resources and issues across water quality and quantity.[13]
- Sea-level rise increasing the risk of erosion, coastal flooding and saltwater intrusion.[13]
- Impacts on human health and wellbeing including effects to global trade, primary production and manufacturing and energy use.[13]
- Warmer temperatures effecting biodiversity and biosecurity by causing greater introduction of new pests and diseases and added environmental stress on ecosystems and people.[13]
- An effect on primary production and manufacturing and Aotearoa New Zealand's major export sectors through increased risks of draught, spreading of pests and diseases and changes in land-use activities. There is also likely to be changes in consumer demand.[13]
- Transition of the transport and energy sector.[13]
- Climate related financial disclosure required of business/ organisations to give greater visibility of the impact of organisations on the environment, and the risks they hold associated with climate change that have direct liability on the organisation.[13]

Aotearoa New Zealand needs to have the necessary research available to make evidence- based decisions and ideate solutions and mitigations to adapt to the changing climate and its effects on the country. The CRIs play an important role in the research and development that is needed to address the issues above and their unintended consequences on Aotearoa New Zealand.

The CRIs provide essential science and research for New Zealand's climate change efforts in:

- Understanding environmental change (climate, ocean and atmosphere).
- Tracking emissions for Aotearoa New Zealand to ensure the country is doing its part to reduce the scale of impact of climate change, including optimisation of carbon sequestration.
- Assessing climate risks and determining the likely impact of these on sectors: biodiversity, land use, biosecurity, emergency response, primary production, manufacturing and water resources.
- Resilience and adaptation of communities and land.
- Supporting adaptation in New Zealand industries and sectors, including increased carbon storage, so transition risks are mitigated.
- Creating new ideas for reducing emissions and ensuring New Zealand reaches its emissions target utilising carbon substitution alternatives for high-emissions, non-renewable pollutant materials.

All CRIs consider climate change as foundational to the future, and have a role to play. The lead CRIs in climate change are:

- NIWA: focus on long-term modelling of climate and its impact on water and the atmosphere.
- AgResearch: focus on methane reduction, particularly across agriculture, for climate-smart primary production systems.
- Manaaki Whenua: focus on reducing emissions and improving Aotearoa New Zealand's resilience to climate change and its effects across communities and the primary sector.
- Scion: focus on progression towards a circular bioeconomy, predicting risks and supporting adaptation for their sectors.
- GNS: focus on clean energy, carbon cycle, understanding the earth's surface and subsurface environments, the dynamic response of Antarctica and the geological component of understanding climate change.

NIWA	172 FTE
agresearch *āta mātai, mātai whetū*	52 FTE
Manaaki Whenua Landcare Research	70 FTE
scion	75 FTE
GNS SCIENCE TE PŪ AO	85 FTE

The contributing CRIs in climate change are:

- ESR
- Plant & Food Research.

Key CRI capabilities in this focus area can be grouped as:

Understanding change – Understanding change across climate, atmosphere, geology/ natural system and environmental processes.

Reducing emissions – Developing ways to reduce emissions now and in the future, e.g. related to farming (low-carbon emitting and high-carbon sequestering systems), ecological restoration, and use of afforestation and soil carbon stocks.

Energy – Using different sources of energy to support adaptation by understanding the natural system that produces energy and powers

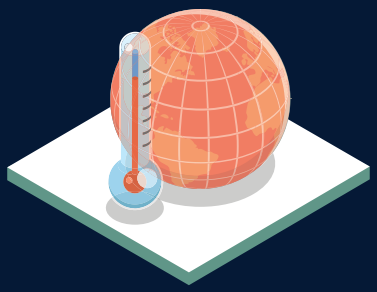
Aotearoa New Zealand, improving understanding of atmospheric-based energy resources, bioenergy applications and contributions to high-value manufacturing with lower emissions in the energy space.

Assessing risk – Assessing and understanding the risk that climate change poses to Aotearoa New Zealand's primary production sectors, specifically biotic and abiotic risks. Predicting, monitoring and mitigating the impact of climate change on biodiversity and ecosystem services.

Supporting adaptation – Designing low-carbon emitting and high carbon sequestering systems, breeding for low emission producing animals, mitigating emission and habitat destruction leading to climate change, building new systems, process, technologies and tools to unlock value and support change and utilising circular bioeconomy concepts to reduce and optimise energy and water usage.

13. Why climate change matters. 'Ministry for the Environment' [website], https://www.mfe.govt.nz/climate-change/why-climate-change-matters/evidence-climate-change, (accessed 8 April 2021)

FOCUS AREA 5 – LEAD CAPABILITIES



CLIMATE CHANGE

Understanding change

NIWA
- Monitoring climate and the composition of the atmosphere
- Quantifying the sources and sinks of greenhouse gases from our land and oceans

agresearch
- Nitrogen emission modelling
- Climate change modelling

GNS Science
- Environmental change – rising tide, carbon cycle dynamics and Antarctic science
- Understanding geological change
- Ocean floor exploration – processes and mapping

SCION
- Modelling of climate change impacts on forests, trees, pathogens and pests, and benefits of forestry in carbon capture

Reducing emissions

Manaaki Whenua Landcare Research
- Services for emissions measurement, management and offset
- Society, culture and policy regarding climate change
- Data driven models and deep learning algorithms for carbon sequestration

SCION
- Climate change solutions - mitigation of climate effects using forests and development of renewable biomaterials, bioenergy and biofuels

agresearch
- Biogenic methane

NIWA
- Validation of emission mitigation measures

Assessing risk

NIWA
- Abiotic and biotic climate risks

SCION
- Predicting climate change impacts and associated risks to inform adaptation

NIWA	172 FTE
agresearch	52 FTE
Manaaki Whenua Landcare Research	50 FTE
SCION	75 FTE
GNS Science	85 FTE

Supporting adaptation

Manaaki Whenua Landcare Research
- Climate change adaptation and mitigation
- Ecosystem services and wellbeing
- Resilience and adaptation of communities and land use
- National emissions and carbon storage inventory

SCION
- Materials and manufacturing from trees and biomass

agresearch
- Animal science – animal breeding and rumen microbiology
- Farm systems and environmental science
- Forage science

NIWA
- Climate projections to inform land use planning and investment

Clean energy

GNS Science
- Geothermal energy
- Energy producing gasses
- Mineral resources
- Hydrogen futures
- Energy storage innovation
- Energy for low-carbon future

NIWA
- Assessment of renewable energy resources

SCION
- Renewable solid, liquid and gas bioenergy and biofuels

FOCUS AREA 5 – KEY OUTCOMES

KEY OUTCOMES FOR AOTEAROA NEW ZEALAND'S CLIMATE CHANGE

NIWA
Taihoro Nukurangi

Key outcomes for climate change

Guidance that enables Aotearoa New Zealand to adapt to climate variability and change and reduce emissions.

Support Aotearoa New Zealand's transition to zero carbon and response to climate impacts through:

- Monitoring Aotearoa New Zealand's climate and the composition of the atmosphere, especially greenhouse gases.
- Measurements of ocean change, including acidification, and its influence on Aotearoa New Zealand's climate and fisheries resources.
- Quantifying the flux of carbon from our land and oceans.
- Validation of emission mitigation and carbon sequestration initiatives.
- Predictions (seasons to decades) of climate variability, changes, impacts and risks.
- Development of plans and tools for adaptation, especially to sea level rise and climate extremes.

agresearch
āta mātai, mātai whetū

Key outcomes for climate change

Contributing to achieving global climate outcomes; climate smart primary production systems and reducing emissions from the agricultural sector.

Indicators of success include:

Climate change adaptation and mitigation:

- High-throughput measurement technology developed to accurately measure cattle methane emissions in a pastoral system.
- Taking a methane and a nitrous oxide mitigation platform to commercial scale and deployed in the sector.
- Novel pest management strategies and technologies developed that are effective in reducing management costs by >50% for animal and plant diseases and are adaptable to future threats.

Minimised resource loss:

- Products taken to pilot scale that increase value from target secondary processing streams five-fold.
- Agri-industry value chains adopt decision support tools that benchmark current energy, carbon and water footprints and are used to inform development of solutions generating 25% use reductions.
- Transition pathways to a circular bioeconomy designed and documented with identified international co-development partners.

Manaaki Whenua
Landcare Research

Key outcomes for climate change

To understand and improve Aotearoa New Zealand's mitigation and resilience to climate change and its effects.

- An accurate greenhouse gas inventory to support policy to transition to a low carbon economy, and for reporting.
- Mitigation of factors contributing to climate change.

— Help sectors to transition to a low carbon economy.
— Improved adaptation to climate change.
— Increased resilience to climate change.

SCION
FORESTS ▪ PRODUCTS ▪ INNOVATION

Key outcomes for climate change

To contribute to beneficial environmental and social outcomes for New Zealand. The outcomes, each with specific KPIs include:

— Forests and Landscapes – Impact to 2030
— Forest to Timber products– Impact to 2030
— Forests to Bio-based Products – Impact to 2030.

Key Performance Indicators

Forests and Landscapes – Impact to 2030:

— 8 million tonnes increase in ground carbon storage in new forests sequestered (above and below ground).
— 100% increase in the value of Māori owned standing forests with maximum carbon net returns defined by land owner values.
— Converting 30% of under-utilised Māori land to standing forest plantations.

Forest to Timber products – Impact to 2030:

— 10 million tonnes carbon locked up in urban environments through adoption of the principles of circularity.

Forest to Bio-based Products:

— Holistic sustainable packaging solutions
— Biojet, Marine Biofuels, Solid industrial energy carrier, Biohydrogen manufacture and uptake in NZ.

Forests to Bio-based Products – Impact to 2030:

— 300M Litres & $2B Fuel & Plastics Substitution
— 10M Tonnes Reduction in CO2 Equivalents.

GNS SCIENCE
TE PŪ AO

Key outcomes for climate change

Undertake science and research that informs Aotearoa New Zealand of the consequences of climate change so decision making and policy can ensure resilience to environmental changes.

— Understanding of timescales and capacity for change in earth surface and subsurface environments.
— Understanding dynamic response of Antarctica and role in climate change.
— Carbon cycle dynamic – reaching the national carbon emission goal.
— Ensuring carbon accounting works through the geological component.
— Driving Aotearoa New Zealand's future as a globally connected 'green-hydrogen' economy through the Green Hydrogen Technology Platform which delivers these transformative technologies.

Undertake research that drives innovation and economic growth in Aotearoa New Zealand's geologically, materials and technically based energy and mineral industries.

Key Performance Indicators

— Understanding dynamic response of Antarctica and role in climate change.
— Carbon cycle dynamic – reaching the national carbon emission goal.
— Ensuring carbon accounting works through the geological component.

FOCUS AREA 5 – ENABLING CAPABILITIES

ENABLING CAPABILITIES CLIMATE CHANGE

The CRIs have the following enabling capabilities that support their lead scientific capabilities in the climate change focus area.

NIWA
Taihoro Nukurangi

Enabling capabilities

- Te Kūwaha, National Centre for Māori Environmental Research
- Climate, hydrometric and ocean sensor networks & IoT
- High performance supercomputing, data analytics and modelling
- Specialised laboratories, networks and technologies for measuring greenhouse gases and other atmospheric constituents, from ground level to the upper atmosphere
- Remote sensing, enterprise data products and services
- Databases e.g. greenhouse gases, atmospheric constituents, ocean variabilities, freshwater resources and climate
- Research vessels – RV Tangaroa, RV Kaharoa, RV Ikatere

agresearch
āta mātai, mātai whetū

Enabling capabilities

- Free Air Carbon Dioxide Enriched (FACE) site
- PC3 Laboratory
- Large Animal Containment Unit and Research farms
- Sheep and cattle fixed methane chambers
- Rumen microbiology isolate and genetic bank
- Climate change models
- Portable sheep methane chambers
- Inventory measures

Manaaki Whenua
Landcare Research

Enabling capabilities

- Nationally significant collections/ databases e.g. National Vegetation Survey Databank, NZ Anthropod Collection, Fungarium, the Allen Herbarium, International Collection of Microorganisms from Plants, NZ Flax Collection. Land Resource Information System
- Other national databases e.g., Land Cover Database, S-Map
- Māori engagement
- Specialised equipment for measuring greenhouse gases in the field

SCION
FORESTS • PRODUCTS • INNOVATION

Enabling capabilities

- Experimental forests and long-term global database sites
- Long standing research sites (permanent sample plots)
- Modelling conversion conditions (emissions and longevity of equipment)
- Wildfire and climate modelling
- Capability in timber construction
- GMO field trials and glasshouse
- Soil database
- National herbarium and Xylarium
- Techno-economics
- Molecular and Biological chemistry

Enabling capabilities

- Data science
- Social science
- Nationally significant collections
- National laboratories
- IODP/ICDP
- High performance computing
- NIWA collaboration/access to assets
- Resilient coastlines – dynamic evolution of the coastal region from the interplay of geological, climate and ocean processes
- International and national collaborative programmes (e.g. Antarctica collaboration with Victoria University)
- National core facilities – radiocarbon laboratory
- National ice core facility
- Nuclear science methods
- Geology and geophysical science – land and marine geoscience
- Reservoir modelling
- Materials physics
- Surface catalytics

FOCUS AREA 5 – CRI COLLABORATIONS

CRI COLLABORATIONS CLIMATE CHANGE

Below are examples of CRI collaborations in this area. Some CRIs contribute to this work – although it is not their core focus – through other expertise they bring.

GNS Science Te Pū Ao
NIWA Taihoro Nukurangi

Offshore geophysics capability.

GNS Science Te Pū Ao
NIWA Taihoro Nukurangi

Sea level and coastal inundation (e.g. SeaRise Project).

GNS Science Te Pū Ao
E/S/R Science for Communities

Groundwater Science and Research Alliance. This alliance works to raise awareness on the need to improve and understand groundwater systems in Aotearoa New Zealand.

Manaaki Whenua Landcare Research
agresearch *āta mātai, mātai whetū*
+ other research providers

New Zealand Agricultural Greenhouse Gas Research Centre.

GNS Science Te Pū Ao (Host)
NIWA Taihoro Nukurangi
SCION FORESTS • PRODUCTS • INNOVATION
Manaaki Whenua Landcare Research

Resilience to Nature's challenges | Kia manawaroa – Ngā Ākina o Te Ao Tūroa: To enhance New Zealand's resilience to natural disasters.

NIWA Taihoro Nukurangi (Host)
GNS Science Te Pū Ao

Sustainable Seas | Ko ngā moana whakauka: To enhance utlilisation of our marine resources within environmental and biological constraints.

NIWA Taihoro Nukurangi (Host)
GNS Science Te Pū Ao
Manaaki Whenua Landcare Research
E/S/R Science for Communities

The Deep South | Te Kōmata o Te Tonga: To understand the role of the Antarctic and the Southern Ocean in determining our climate and our future environment.

SCION
FORESTS ▪ PRODUCTS ▪ INNOVATION

Plant & Food Research
Rangahau Ahumāra Kai

Mitigating the effects of climate change on plant development, understanding changes in drought stress, developmental shifts triggered by environment, changing biotic and abiotic risk factors.

SCION
FORESTS ▪ PRODUCTS ▪ INNOVATION

GNS SCIENCE
TE PŪ AO

agresearch
āta mātai, mātai whetū

Spearhead project for 3D and 4D printing of bio-composites which can substitute for non-renewable carbon emitting products.

agresearch
āta mātai, mātai whetū

Plant & Food Research
Rangahau Ahumāra Kai

SCION
FORESTS ▪ PRODUCTS ▪ INNOVATION

Biopolymer network (New Zealand based company) that works to exploit specific niche areas of bio-research to create new bio-based chemicals, biopolymers and applications.

SCION
FORESTS ▪ PRODUCTS ▪ INNOVATION

agresearch
āta mātai, mātai whetū

Biorefining – of purpose-grown biomass and residual waste from primary production sectors, to add value and enable the movement of value rather than volume.

SCION
FORESTS ▪ PRODUCTS ▪ INNOVATION

Plant & Food Research
Rangahau Ahumāra Kai

agresearch
āta mātai, mātai whetū

New packaging development and solutions, with biomimicry design, and smart bioelectronics to monitor performance. Supported by compostability and biodegradation science to ensure circularity.

FOCUS AREA 5 – KEY END USERS

KEY END USERS CLIMATE CHANGE

Key end users for each CRI are shown below. The list is illustrative, not exhaustive. Some organisations – such as large government departments – appear more than once, as CRIs provide different services for different groups within them. The end users vary in scale and specialisation, therefore different CRIs connections with end users generally do not overlap.

NIWA
Taihoro Nukurangi

Government agencies: Ministry of Business, Innovation and Employment, Ministry of Foreign Affairs and Trade, Department of Conservation, Land Information New Zealand, National Emergency Management Agency, Earthquake Commission.

Regional council: Local government (regional & district councils).

Research organisations: National and international research organisations.

Māori trusts & companies: Iwi/hapū, Māori agencies/groups.

Other/private organisations: Energy sectors, Primary sector organisations.

agresearch
āta mātai, mātai whetū

Government agencies: Ministry for Primary Industries, Ministry of Business Innovation and Employment, Ministry of Foreign Affairs and Trade, Ministry for the Environment.

Industry bodies: Beef and Lamb, DairyNZ, Meat Industry Association.

Regional council: Regional councils.

Research organisations: Pastoral Greenhouse Gas Research Consortium, NZ Agricultural Greenhouse Gas Research Centre, Global Research Alliance.

Other/private organisations: Fertiliser companies, Climate change commission, He Waka Eke Noa (Primary sector Climate Action Partnership and end user), Industry bodies; companies.

Manaaki Whenua
Landcare Research

Government agencies: Ministry of Business, Innovation and Employment, Ministry of Foreign Affairs and Trade, Ministry for Primary Industries.

Industry bodies: primary and other sectors, businesses and sector bodies.

Regional council: Local government (regional and district councils).

Other/private organisations: Communities, Kaikoura, Carbon Zero Certification.

Māori trusts & companies: Māori iwi and hapū.

SCION
FORESTS ▪ PRODUCTS ▪ INNOVATION

Government agencies: Ministry of Business, Innovation and Employment, Ministry of Foreign Affairs and Trade, Ministry for Primary Industries, Department of Conservation.

Industry bodies: Fire Protection Association, Fire and Emergency New Zealand.

Research organisations: Callaghan Innovation, Universities (University of Canterbury, University of Auckland), Forest Management companies (Timberlands).

Māori trusts & companies: Ngāti Hine Forestry, Ngāti Whare Nursery.

Other/private organisations: Carbon forestry businesses, Companies interested in adaptation and mitigation to reduce climate change on their supply chain activities, Air NZ, Fletcher, Thinkstep, Circularity, Fisher & Paykel Healthcare, Sustainable Business Network.

GNS SCIENCE
TE PŪ AO

Government agencies: Ministry of Business, Innovation and Employment, Ministry of Foreign Affairs and Trade, New Zealand Transport Agency, Department of Conservation, New Zealand Climate Commission, Ministry for Primary Industries, Department of Internal Affairs, The Treasury, KiwiRail, National Emergency Management Agency, Civil Defence Emergency Management sector, National Emergency Management Agency, Land Information NZ, Energy Efficiency & Conservation Authority.

Industry bodies: Transport sector, Manufacturing sector, Energy and Resource sector.

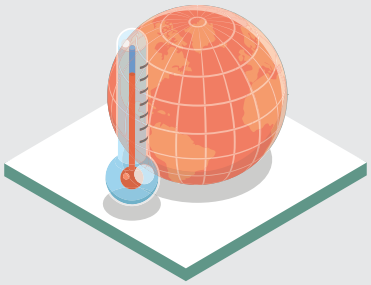
Regional council: Coastal communities.

Research organisations: Callaghan Innovation.

Māori trusts & companies: Iwi/ Māori, Māori trusts and businesses.

Other/private organisations: Environmental Resources Management, Major infrastructure asset owners, Insurance/building sectors, International end users e.g. Scientific Committee Antarctic Research, Pacific Partners, Antarctica treaty system members, Major Energy Users, Contact Energy.

FOCUS AREA 5 – CASE STUDIES



CLIMATE CHANGE CASE STUDIES

AgResearch

Agriculture is responsible for almost half of the country's emissions, mostly methane and nitrous oxide. Methane is produced by sheep, cow and other animals and is a contributor to global warming. AgResearch is working on innovative ways to reduce emissions, one of which is reducing the methane gas released from ruminant livestock.

AgResearch have used their capabilities in genetics to breed sheep that produce less methane from their diet. Results to date show they can breed the animals safely for lower methane emissions. A positive unintended consequence of this is that low methane producing animals may also have leaner meat and grow more wool.

The outcomes of this research are:

- Reducing the amount of methane produce by livestock.
- Helping Aotearoa New Zealand reach its carbon emission goals.
- Preparing the agricultural industry for future transition risks for climate change including reduced demand for agricultural products if they are associated with a level of emissions that contribute to hastening climate change.

Manaaki Whenua

Sustainable land management for climate change is an essential part of ensuring Aotearoa New Zealand reaches its climate emission targets. Building up soil carbon through soil carbon stocks can help remove greenhouse gases from the atmosphere and improve soil quality.

Manaaki Whenua helps to understand what controls soil carbon. It has developed methods to assess changes to soil carbon stocks in Aotearoa New Zealand. This helps untap the potential of increasing soil carbon stocks and reducing greenhouse gases.

Manaaki Whenua found that protected soil carbon is controlled by soil specific surface area. The higher the surface area the more carbon that can be protected.

They also run a national-scale monitoring programme which will determine the trajectory of soil carbon through time across a range of land uses. This will be important for bench marking the changes in soil carbon (potentially both increase and decreases) which will underpin future policy decisions for achieving carbon zero primary industries.

The outcomes of this work are to:

- Reduce atmospheric greenhouse gases through the management of soil carbon stocks.
- Underpin future policy decisions to achieve carbon zero primary industries.
- Increase the carbon contained in soil to help meet Aotearoa New Zealand's greenhouse gas mitigation targets.

Circular plastics solution as key contributor to climate change mitigation

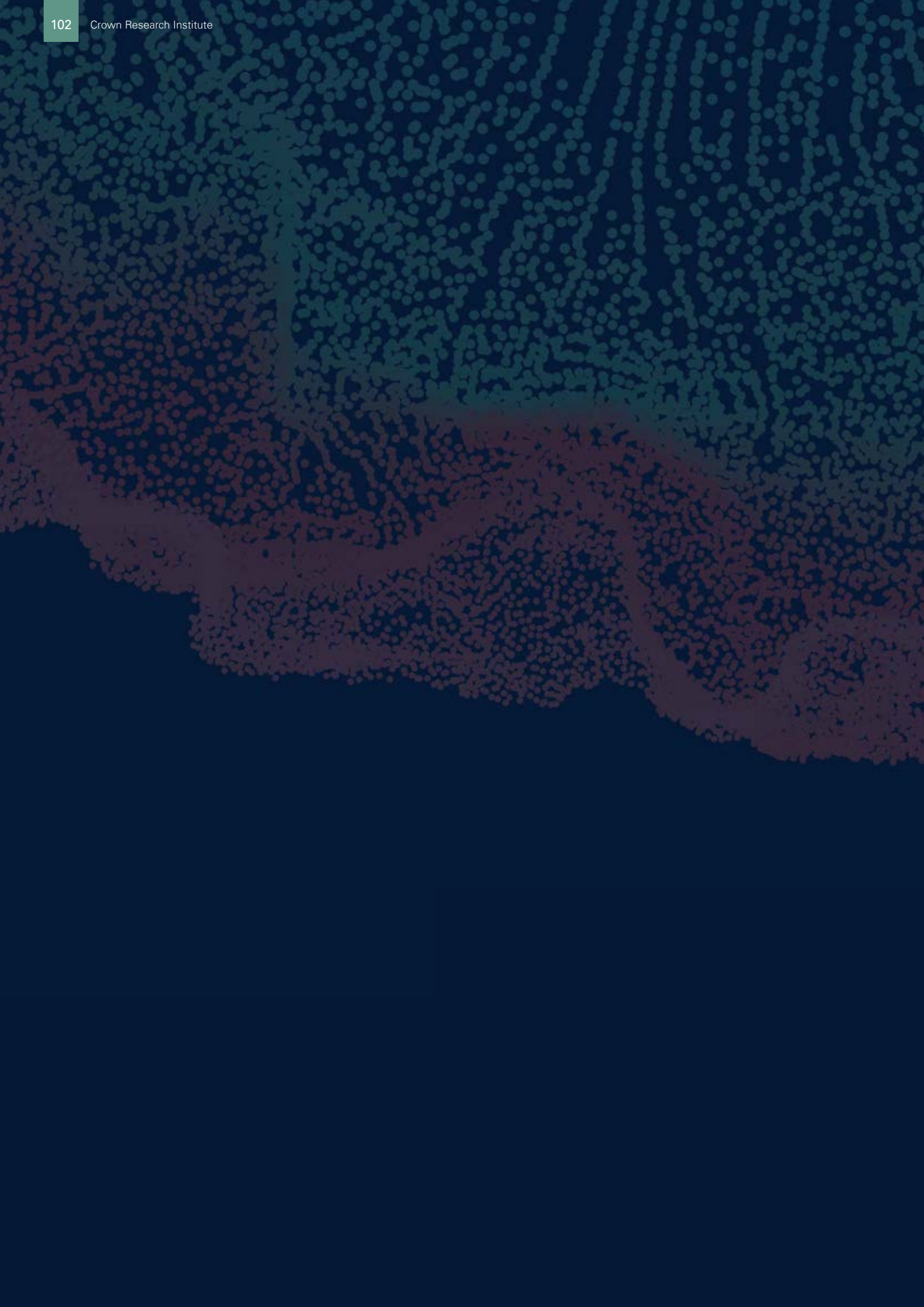
Scion

Plastics have many advantages over other materials; however they also cause environmental and economic issues.

Scion is developing the *Roadmap for the New Zealand Plastics Economy* with an aim of eliminating plastic waste by using circular economy principles. Aotearoa New Zealand's unique roadmap will focus on the plastics industry with a solution-focused, rather than Government-led approach.

The outcomes of the roadmap are to:

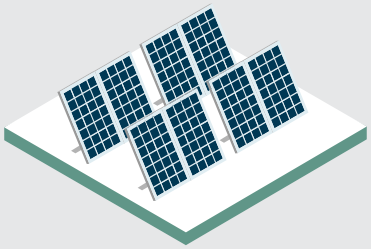
- Customise the global vision for a New Plastics Economy.
- Guide Aotearoa New Zealand specific NGOs and Government departments on plastic related issues/decisions.
- Outline the barriers, challenges and opportunities the Aotearoa New Zealand plastics industry faces to move towards a circular economy.
- Recommend the action to develop alongside the industry.
- Bring together key stakeholders to raise awareness and drive action to lessen the impacts of the plastics industry on pollution, emissions and climate change.



FOCUS AREA 6

ENERGY

FOCUS AREA 6 – INTRODUCTION



ENERGY

Enhance the availability of clean energy for Aotearoa New Zealand's societal welfare, economic competitiveness and support the transition to a zero-carbon future.

Energy powers the economy and underpins the prosperity and wellbeing of communities. It powers homes and workplaces, and is necessary to grow and manufacture food, building materials, clothes and other necessities. It is critical for clean air and water, health care, transport, reliable lighting, and telecommunications.

Energy generation and use are inextricably linked to environmental impacts, including greenhouse gas emissions. Like other countries, Aotearoa New Zealand is grappling with how it can meet changing demands for energy without causing irreversible impact to our environment. There is growing demand for a low-carbon energy supply and for more equitable access to energy resources. Technologies that increase electrification, use bioenergy and hydrogen and provide demand management will be key to this clean energy future.

Many significant developments in the 20th century were based on access to cheap and abundant energy. There was an unseen cost to using some of that energy: greenhouse gas emissions. Even in Aotearoa New Zealand, which has an internationally high level of renewable electricity generation (around 85% in an average year), around 60% of energy is sourced from fossil fuels. Over 40% of that is imported in the form of oil products and coal to be used in transport, process heat and electricity.

Worldwide, energy use contributes to nearly three-quarters of greenhouse gas emissions.

Today, the energy system is central to the nation's economy. Changing this complex system to reduce reliance on fossil fuels whilst maintaining security of supply and affordability will test the nation for years to come.

Aotearoa New Zealand has committed to achieving net-zero carbon emissions by 2050. Progress will need to be accelerated to meet that goal and other international commitments to reduce energy emissions.

Meeting the challenge is not a straightforward matter. The changes needed must be sustainable, fair, equitable and have minimal environmental impacts. This will require a large-scale transformation of the energy system and how energy is used and distributed.

The path to net-zero emissions appears to have limited options. A key immediate action includes large scale deployment of clean and efficient energy technologies. This will generate significant opportunities for new industries and the growth of clean technologies for producing, harvesting, transporting, storing and utilising energy.

The recent IEA report *Net Zero by 2050* predicts an unparalleled clean energy investment boom, and that half of the energy emissions reduction will come from technologies that are not available in the market today.

This is where CRI research can play a critical part for Aotearoa New Zealand, in:

- Developing technologies to support 100% renewable electricity generation.
- Providing solutions to replace fossil fuels in transport and process heat.
- Identifying and developing the innovative solutions to produce and store low-emissions energy.
- Understanding the sustainable capacity of existing energy supplies in the face of continued extraction and a changing climate. For example, the long-term capacities of hydro-lakes.
- Ensuring the energy system is resilient to climate change and the natural hazards that are prevalent in Aotearoa New Zealand.
- Assessing the environmental impacts of new energy sources and changes to the use of existing energy sources.

The lead CRIs in energy are:

- GNS: focus on geothermal energy, hydrogen futures, energy storage innovation, materials for reducing energy demand, critical minerals.
- Scion: focus on renewable solid, liquid and gas bioenergy and biofuels.
- NIWA: focus on solar, hydro, marine (tidal, wave and offshore wind), wind, and biofuel (gas and oil) from wastewater treatment and algal production from livestock or human effluent.

GNS Science Te Pū Ao	60 FTE
SCION	12 FTE
NIWA	35 FTE

The contributing CRIs in energy are:

- Plant & Food Research.

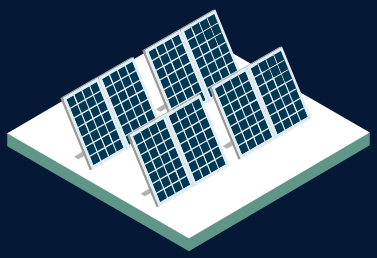
Key CRI capabilities in this focus area can be grouped as:

Energy storage – Hydro lakes, hydrogen gas, new battery technologies, standing biomass, subsurface storage of energy, critical minerals.

Energy resources and production – Wind energy, geothermal energy, bioenergy and biofuels, water availability (including from seasonal snow) for hydroelectric energy, solar energy, tidal energy and distributed energy production.

Energy utilisation – How to drive behavioural change, avoided energy demand, improved energy transmission and use efficiency, new technologies for energy use.

FOCUS AREA 6 – LEAD CAPABILITIES



ENERGY

Energy production

GNS SCIENCE

- Geological modelling
- Geophysical surveys and analysis
- Magnetotelluric surveys and inversions
- Wellbore logging
- Reservoir modelling
- Production fluid geochemistry
- Gas geochemistry
- Resource consent advice
- Analytical laboratory services
- Contributing international policy organisation

SCION

- Awareness of Technology Developments and Policy
- Contributing international policy organisations eg IEA Bioenergy
- Pyrolysis and catalytic pyrolysis, and mild upgrading
- Torrefaction of biomass
- Biomass pelletisation and briquetting
- Techno-economics assessments
- Systems modelling
- Socio-economic modelling of bioenergy systems
- Dedicated Energy Forestry – species, regimes, harvesting, risks
- Woody biomass availability
- Fundamental physics and chemistry of biomass conversion technologies

NIWA

- Realtime monitoring of riverflows, hydro lake levels, inflows and outflows, snowmelt, sediment transport.
- Analysis of the effects of climate variability and trends on historical snow accumulation, snowmelt, hydro lake levels and inflows
- Forecasts of snowmelt, hydro lake levels, inflows and outflows
- Wind energy (including offshore) suitability assessments
- Solar energy (rooftop and utility-scale) suitability assessments
- Wave energy potential assessments
- Assessment of the effects of weather and climate on energy transmission and historical system outages
- Forecasts of extreme weather for operational management, resource mobilisation optimisation and damage assessment

GNS Science	60 FTE
SCION	12 FTE
NIWA	35 FTE

Energy storage

GNS Science
- Materials physics and chemistry
- Materials engineering
- Ion beam science
- Catalyst design
- Prototype development
- Subsurface reservoir characterisation
- Reservoir modelling
- Critical minerals

SCION
- Biomass feedstock assessment, preparation and preprocessing
- Woody biomass availability

NIWA
- Monitoring of riverflows and hydro lake levels, inflows and outflows
- Seasonal snowpack observations
- Hydrological modelling
- Water quality monitoring and modelling
- Ecological impacts assessment associated with hydro lake management

Energy utilisation

GNS Science
- Social science
- Systems modelling
- Materials physics and chemistry
- Materials engineering
- Ion beam science

SCION
- Industrial symbiosis/clustering of processing plants
- Systems modelling
- Socio-economic modelling of bioenergy systems

NIWA
- Assessment of river flows (especially low flows) and the ecological impacts of flow variability
- Water quality assessments downstream of hydro lakes
- Air quality monitoring and modelling associated with home heating, industrial processes and transport
- Energy supply and demand modelling
- Energy market information systems (NZX)
- Seasonal climate forecasts
- Climate change projections and impacts assessments
- Transmission line load management modelling

FOCUS AREA 6 – KEY OUTCOMES

KEY OUTCOMES FOR AOTEAROA NEW ZEALAND'S ENERGY

GNS SCIENCE TE PŪ AO

Key outcomes for energy

Undertake science and research that directly contributes to reducing greenhouse gas emissions from energy use and increases the security of supply.

- Increased availability of sustainable geothermal energy sources for electricity generation and use in industrial and horticultural processes.
- Assessing the potential for large-scale utilisation of superhot geothermal fluids.
- Driving Aotearoa New Zealand's future as a globally connected 'green-hydrogen' economy through the Green Hydrogen Technology Platform which delivers transformative technologies.
- Transforming Aotearoa New Zealand's energy system through the availability of distributed large-scale storage of energy.
- Reduced demand for energy through new materials that improve the efficiency of industrial processes.

SCION FORESTS • PRODUCTS • INNOVATION

Key outcomes for energy

To contribute to beneficial environmental and social outcomes for Aotearoa New Zealand.

- Platform for Sustainable Aviation Fuels, and a production plant, developed for Aotearoa New Zealand with local and international partners.
- Developed technology for right scale (between forest and port) biofuel for marine applications with pyrolysis as a central technology.
- Solid industrial energy carrier, from woodchip through to bio-coal using torrefaction.
- Distributed Biohydrogen production from low value resources. Coupling H2 production and carbon capture and storage/utilisation.
- 300M litres & $2B Fuel & Plastics Substitution.
- 10M tonnes reduction in CO2 equivalents.

NIWA Taihoro Nukurangi

Key outcomes for energy

- Predictions of climate changes related to energy demand and resource availability.
- Provision of real-time flow information for hydropower generators, including inflows and outflow, maximising hydropower generation, while maintaining the minimum outflows for ecological health.
- Provision of meteorological data that effects lines (sag and snow accumulation), and regular lines sag surveys, enabling lines companies to maximise electricity transmission.
- Flood, drought and extreme wind predictions to increase the resilience of energy generating infrastructure to weather hazards.
- Supporting hydropower companies understand and manage sediment transport and its impacts.
- Supporting hydropower companies to manage invasive weeds in lakes.
- Provision of spatial and temporal variability of solar and wind energy potential at 1.5km, 6-hourly resolution, supporting energy investment decisions.

- Provision of information for wave and tidal energy potential (e.g., wave forecasts, tidal current modelling).
- Provision of advice to government on the viability of the NZ Battery Project, including the ecological impacts of using Lake Onslow for pumped hydro, the extent of associated additional greenhouse gas emissions from repeated wetting and drying of land, and whether it can be useful as a buffer to create more efficiency or reduce adverse effects in non-drought years.
- Provision of advice to government on the coincident electricity potential of wind/hydro/solar (e.g., if it's a drought year, does that mean more solar or less wind?)

FOCUS AREA 6 – ENABLING CAPABILITIES

ENABLING CAPABILITIES ENERGY

The CRIs have the following enabling capabilities that support their lead scientific capabilities in the energy focus area.

GNS SCIENCE TE PŪ AO

Enabling capabilities

- Data science
- Social science
- National laboratories
- High performance computing
- National ion beam facility
- Geology and geophysical science
- Reservoir modelling
- Materials physics
- Surface catalysts
- Access to international synchrotron facilities
- International collaborations (e.g. International Partnerships for Geothermal Technologies)

SCION FORESTS • PRODUCTS • INNOVATION

Enabling capabilities

- Analytical services
- Forestry Ecology and Environment
- Materials, Engineering and Manufacturing
- Distributed production
- High value Biorefining
- Wood processing
- Tree Development and Physiology
- Te Ao Māori

NIWA Taihoro Nukurangi

Enabling capabilities

- Hydrology, air and water quality, and climate science
- Data science
- Social Science
- High performance computing
- National hydrological and climatological data bases
- National hydrological and climate monitoring networks
- 14 regional offices
- Greenhouse gas measurements and modelling
- In-shore and off-shore vessels

FOCUS AREA 6 – CRI COLLABORATIONS

CRI COLLABORATIONS ENERGY

Below are examples of CRI collaborations in this area. Some CRIs contribute to this work – although it is not their core focus – through other expertise they bring.

GNS SCIENCE TE PŪ AO

SCION FORESTS • PRODUCTS • INNOVATION

Bioenergy and Hydrogen – How bioenergy fits into suite of other sustainable energy technologies to provide a reliable and resilient future energy system for Aotearoa New Zealand. Specifically supporting hydrogen production research through biohydrogen and its interaction with the bioenergy system.

GNS SCIENCE TE PŪ AO

SCION FORESTS • PRODUCTS • INNOVATION

Integration of geothermal energy into wood processing and bioenergy. Interactions with the New Zealand Geothermal Association and individual producers.

GNS SCIENCE TE PŪ AO

SCION FORESTS • PRODUCTS • INNOVATION

Wood energy industrial symbiosis – Endeavour programme: Scion, GNS and Waikato University.

FOCUS AREA 6 – KEY END USERS

KEY END USERS ENERGY

Key end users for each CRI are shown below. The list is illustrative, not exhaustive. Some organisations – such as large government departments – appear more than once, as CRIs provide different services for different groups within them. The end users vary in scale and specialisation, therefore different CRIs connections with end users generally do not overlap.

Government agencies: Ministry of Business, Innovation and Employment, Department of Conservation, New Zealand Climate Change Commission, Energy Efficiency & Conservation Authority.

Research organisations: MacDiarmid Institute, Science for Technological Innovation.

Regional councils: Waikato Regional Council, Bay of Plenty Council.

Māori trusts & companies: Ngati Tuwharetoa Geothermal Assets, Tauhara North No. 2 Trust, Māori land trusts.

Other / private organisations: Contact Energy Limited, Mercury, Top Energy, Major energy users, Venture Taranaki, Amplify (Taupo).

Other / private organisations: Ecogas (Biomethane), SAF (Sustainable Aviation Fuel group, AirNZ, Z Energy), Biofuels for Marine (Interislander, Swire group, Ports of Auckland/Tauranga, exporters (eg Zespri), Solid biofuels producers and users – e.g. Natures Flame, Fonterra, Genesis Energy etc.

- Hydropower generators
- Lines companies
- Transpower
- NZX - Hydro.

Government agencies: Ministry of Business, Innovation and Employment, Ministry of Environment, Department of Conservation, Parliamentary Commissioner for the Environment, New Zealand Climate Change Commission, Energy Efficiency & Conservation Authority.

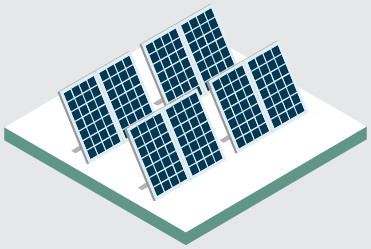
Research organisations: Cawthron Institute.

Regional councils: Regional Councils throughout Aotearoa New Zealand, LAWA.

Industry bodies: New Zealand Geothermal Association, NZ Hydrological Society, NZ Meteorological Society, Freshwater Sciences NZ.

Other / private organisations: Solar and wind energy generators (especially with respect to building new capability); Lines companies; Hydropower generators; communities (e.g. on SolarView).

FOCUS AREA 6 – CASE STUDIES



ENERGY CASE STUDIES

GNS Science

GNS Science is working with international collaborators to significantly increase the amount of energy produced from deeper and hotter geothermal resources in Aotearoa New Zealand. These geothermal resources offer a near limitless baseload energy supply that has the potential to transform our domestic energy sector.

Scientists anticipate that these resources will be an important contributor to achieving the Government's goal of 'net-zero carbon' emissions by 2050 – which cannot be reached by using conventional geothermal alone. This work will open the way for investment opportunities and new employment, especially in industrial-scale use of energy.

The project is aiming to find underground energy sources at greater than 400 degrees Celsius in Aotearoa New Zealand. There is a particular focus on the Taupō Volcanic Zone - the area between Lake Taupō and Whakatane – and for resources favourable for the development and study of the distinct chemical characteristics of these underground environments.

At present, conventional geothermal wells are drilled to a maximum depth of about 3.5km. However, by drilling beyond this, possibly to 6km, scientists believe more energy will be available at the surface for the same amount of geothermal fluid extracted. As well as the uncertainty of our understanding of parts of the earth that have never been drilled, the extreme physical and chemical conditions at the deeper depths make it a challenging undertaking.

The project is aiming to identify the best areas for exploratory drilling. It is also exploring the potential for re-injecting carbon dioxide produced as a result, to enable emissions-free 'deep heat' energy. It also includes laboratory simulations to see how these very hot fluids react with rock, and how their use will affect deep reservoirs and neighbouring shallower reservoirs.

Alongside this work, GNS experts will evaluate how these deep resources might best be managed under legislative and planning frameworks. The project team is planning significant consultation and engagement with Māori, central and local government, and industry as the project develops.

Deep or very hot geothermal initiatives are underway in several countries – notably Japan, Italy, Iceland, Mexico, and the United States. However, no-one has successfully managed to harness the very hot geothermal resources from these depths yet.

The energy industry is looking to research such as this to reduce the uncertainties and lower the risks of exploring this new frontier. Deep geothermal generation will only go ahead in Aotearoa New Zealand when there is confidence that it can be done safely, sustainably, and economically.

NIWA

From its origins, NIWA and its predecessor organisations has worked collaboratively with all the major hydropower generators to ensure safe and efficient hydro energy generation. Today, NIWA provides most of Aotearoa New Zealand's major hydropower generators with critical day-to-day operational services enabled by a nationwide network of field offices.

NIWA provides 24/7 real-time monitoring of the inflow and outflow water rates from hydropower stations. Generators use this critical information, plus forecasts of weather and seasonal climate, to understand the impact of weather and climate on hydropower generation, optimise their operations and to ensure they are compliant with resource consents. NIWA meets these needs by providing user-tailored decision-ready data, information, tools and support.

NIWA's location and time-specific hazard, impact and potential damage forecasts associated with extreme weather events, including high winds, coastal storm surges, hot spells, cold spells, heavy rain, snow falls, lightening and floods, allow

hydropower generators and other key energy sector partners such as lines companies to best protect and manage their infrastructure.

NIWA's goal is to help the energy sector build resilient long-lasting energy infrastructure in a country that experiences frequent extreme and disruptive weather.

NIWA enables hydropower generators to monitor and maintain the ecosystem health of waterways, including the management of pest aquatic plants in hydro lakes and ensuring minimum flows are maintained downstream of hydropower stations.

Also, NIWA conducts water resource investigations and climate change analyses to assess opportunities for the enhancement or development of new hydropower generation capacity, including any associated environmental impact assessments.

Scion

Ecogas has broken ground at Reporoa on the site of its new bioenergy plant that will turn food waste into resources including renewable heat, power, carbon dioxide and biofertiliser.

The plant will process 75,000 tonnes of food waste collected from households and businesses around the North Island. The process, anaerobic digestion, uses microorganisms to breakdown the food waste.

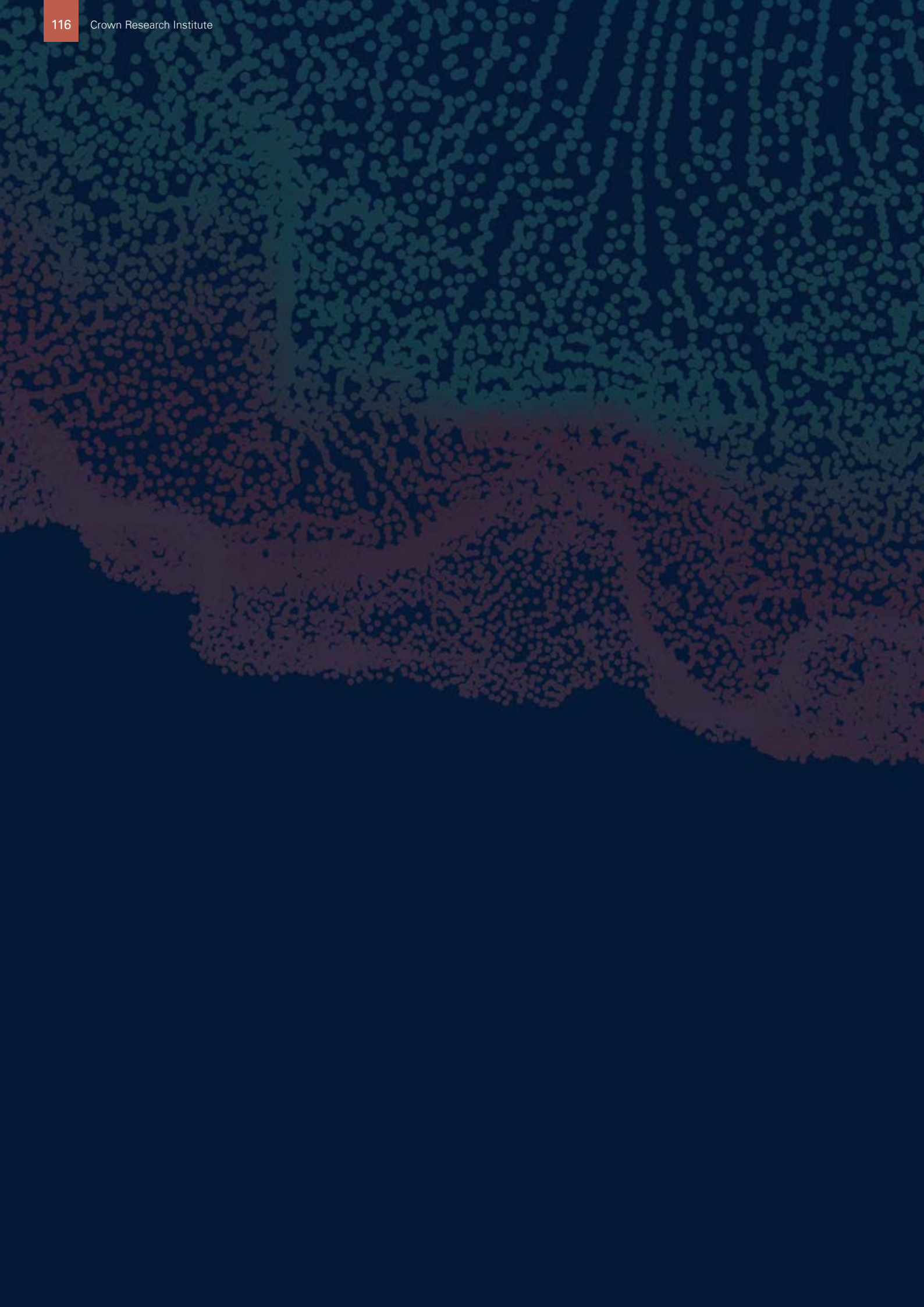
Scion scientists have been involved in de-risking the key technologies since 2016. Anaerobic digestion plants are common internationally but the varying composition, particle size and possible non-biodegradable contaminants are long-term challenges that the Scion team will continue to finesse.

Ecogas' new plant will be a commercial showcase, sitting on two hectares of farmland beside T&G Global's five hectares of tomato-growing greenhouses. Heat generated by burning the biogas will warm the greenhouses; and CO2 will be pumped in to enhance plant growth. Biofertiliser will also be produced and applied onto more than 1,500 hectares of productive farmland, reducing imported and manufactured synthetic fertilisers.

This system will see food waste from households, production, logistics and manufacturing used to enhance the growth of more food, creation of local clean energy and showcase what is possible in other parts of Aotearoa New Zealand.

There are opportunities to reduce climate change emissions by diverting food waste from landfill (where it releases methane and CO2 into the atmosphere); using heat and CO2 generated from biogas will reduce the fossil fuel use from the glasshouse operation, and finally, biofertilisers will replace synthetic fertilisers, made from fossil-fuel sources.

A blessing and ground-breaking ceremony took place in Reporoa on 4 August 2021, and the plant is expected to be up and running in 2022.



FOCUS AREA 7

FOOD AND FIBRE SECTORS AND MANUFACTURING

FOCUS AREA 7 – INTRODUCTION

FOOD AND FIBRE AND MANUFACTURING

Enhance the economic, environmental, social and cultural sustainability, value, innovation and growth of Aotearoa New Zealand's food and fibre sectors – and of associated manufacturing.

The food and fibre sectors and associated manufacturing sectors drive Aotearoa New Zealand's economy and provide employment to over 350,000 people.[14] Some of the major industries include agriculture, dairy, forestry, horticulture and seafood. Dairy plays a large part in Aotearoa New Zealand's food and fibre sectors making up 35% of national export value, followed by red meat and forestry. Food and fibre export revenue is forecast to increase 3.6 percent to $49.2 billion in 2022 with continued strength in horticultural exports and forestry.[14] The health and continued strength of these sectors are essential to maintain the economy and Aotearoa New Zealand's prosperity.[14]

The food and fibre and associated manufacturing sectors offer several benefits to Aotearoa New Zealand, putting the country at the forefront of some global markets. There has been strong growth in the food and fibre sectors largely due to industries where Aotearoa New Zealand has a comparative advantage. However, there are continuing pressures on production and a need for more efficient production systems, higher value products and adaptive efficient value chains and systems. The future performance of the food and fibre sectors will be determined by the responses of individuals and firms in the sectors to these changes.[15]

Some of the external factors demanding change in the food and fibre sectors are:

- Competing demands or resources and how to generate the most value from the resources used.
- Climate change and increasing risks from climate which effects the natural resources that give the sectors their comparative advantage.
- Changing consumer preferences and a move to high-value, ethically sourced, sustainable products, including plant-based products for some consumers.
- The need to reduce greenhouse gas emissions to meet the country's climate commitments and the likelihood of impact of potential to mandated climate financial risk disclosure.[15]
- Trade-off decision making for sectors to be phased out and built up with a focus on the future of the food and fibre sector.[15]
- The need for environmental sustainability across the sectors including sustainability of Aotearoa New Zealand's biodiversity that is being affected.

The CRIs play a key role in ensuring new knowledge, technologies and innovative ideas continue to flow and support these industries.

The CRIs provide essential lead science and research for Aotearoa New Zealand's food and fibre efforts in:

- Supporting the move from volume to value by understanding the drivers of consumer preference.
- Understanding genetics and breeding to create premium products and lift productivity.
- Supporting the development, validation and adoption of sustainable production processes. Focussing on materials and manufacturing that is sustainable, efficient in its use of resources, and reduces the impact of these activities on the environment.
- Developing technology to allow maximum use of biological

materials in manufacturing including the use of by-products.

The lead CRIs in food and fibre and associated manufacturing are:

- AgResearch: focus on enhancing the value, productivity and profitability of Aotearoa New Zealand's pastoral, agri-food and agri- technology sector and value chains.
- Plant & Food Research: focus on enhancing the value, productivity and profitability of Aotearoa New Zealand's horticultural, arable, seafood (wild catch technologies, breeding and seafood processing) and food and beverage industries (food processing).
- NIWA: focus on enhancing the economic value and sustainable management of Aotearoa New Zealand's aquatic resources and environments through land-based aquaculture and fisheries stock assessment.
- Scion: focus on driving innovation and growth from Aotearoa New Zealand's forestry, wood products and wood-derived materials, other biomaterials and manufacturing sectors.

agresearch ātia mātai, mātai whetū	190 FTE
Plant & Food Research Kangahau Ahumāra Kai	575 FTE
NIWA Taihoro Nukurangi	133 FTE
SCION	83 FTE

The contributing CRIs in primary production and manufacturing are:

- ESR
- GNS
- Manaaki whenua.

Key CRI capabilities in this focus area can be grouped as:

Horticulture – Increasing the value of novel fruits, vegetables and crop cultivars for the horticultural and arable industries. Specifically enhancing the sustainability of production and processing systems.

Pastoral – Increasing the value of the pastoral sector and developing new technologies and innovations to diversify and improve products and processes. This includes policy and change/transition pathways, understanding global consumer trends, robust evidence on high-value products for consumer health and wellbeing, networking Māori properties and agri-food businesses built on aligned kaupapa, developing business models to reflect Te Ao Māori and developing tools, processes and systems to enable implementation of effective practices and behaviour change within the sector.

Seafood – Development of the seafood sector to increase efficiency of production and processes using tools and technologies to implement improvements.

Forestry – Protection and enhancement of indigenous and exotic forestry. Understanding forest ecosystems and enhancing complex supply chains for the forestry sector.

Marine fisheries and aquaculture – Improving the value and sustainability of marine fisheries and aquaculture through new technologies and efficient ways of production.

Bio-based products – Science and research to protect and enhance high-value bio-based materials manufacturing and processes, producing sustainable packaging for the products in the food and fibre sectors, biorefinery concepts and technologies and industrial biotechnology and bio-based high-value manufacturing.

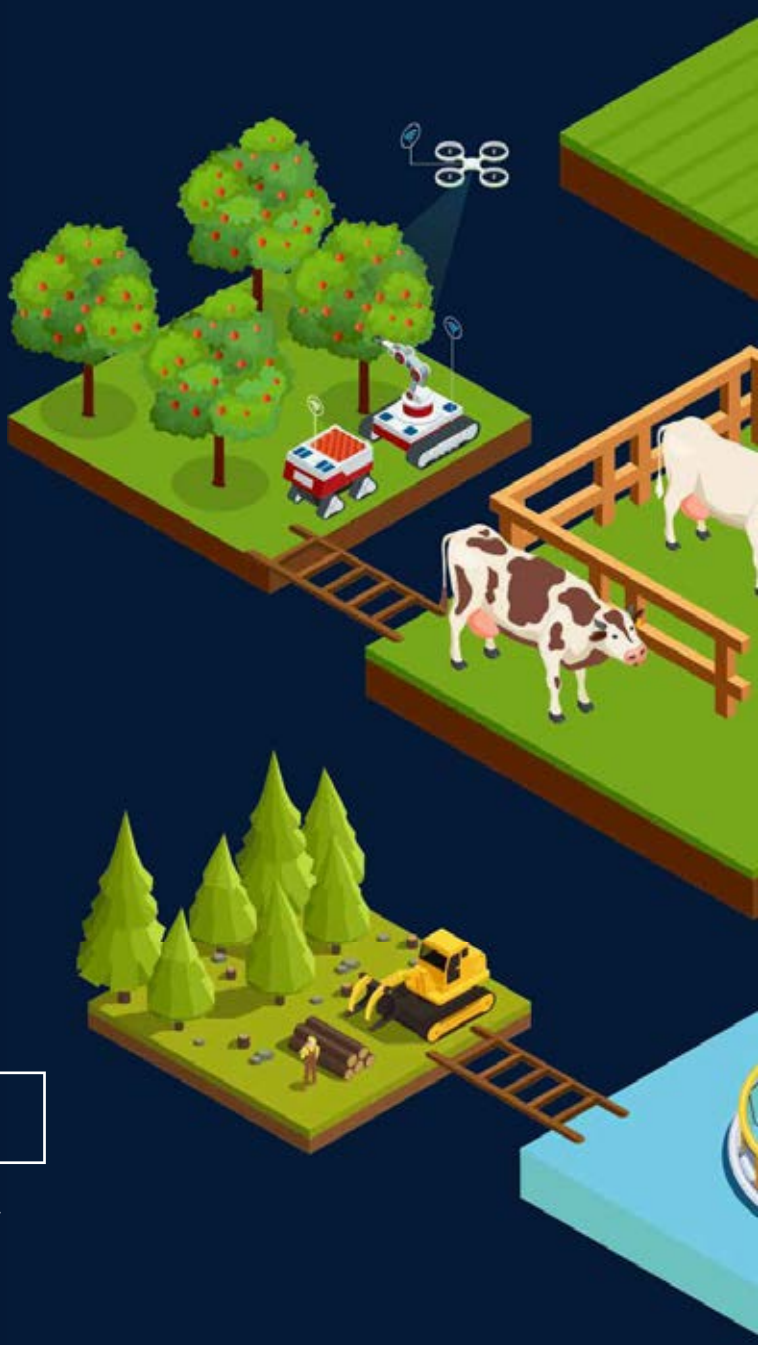
Food and beverage – Improving the efficiency of the food and beverage sector, developing new tools, methods and innovations to improve production and value of end products.

14. Introduction to primary production legislation. 'Ministry for Primary Industries' [website], https://www.mpi.govt.nz/legal/legal-overviews-legislation-standards/primary-production-legislation/introduction-to-primary-production-legislation/, (accessed 8 April 2021)

15. The contridution of teh Primary Setcor to New Zeland Economic Growth. 'The treasury' [website], https://www.treasury.govt.nz/publications/wp/contribution-primary-sector-new-zealands-economic-growth-pp-05-04-html/, (accessed 8 April 2021)

FOCUS AREA 7 – LEAD CAPABILITIES

FOOD AND FIBRE AND MANUFACTURING



Horticulture

Plant & Food Research

- New cultivar innovation
- Root stocks innovation
- Integrated pest and disease management systems and technology
- Harvest Management Technologies
- Sustainable production
- Sustainable production and harvest management technologies

Bio-based products

SCION

- Materials and manufacturing from trees and biomass
- Novel biomaterials and bio-processing
- Distributed manufacturing and processing

agresearch

- Bio-based products

Pastoral

agresearch

- Food products for dairy and protein-based products
- Forage Science Farm systems and environment
- Animal science
- Māori agribusiness
- Animal behaviour and welfare

NIWA

- Freshwater – primary sector land and water use

agresearch	190 FTE
Plant & Food Research	575 FTE
NIWA	133 FTE
SCION	83 FTE

Seafood, fisheries, aquaculture

NIWA

- Fisheries research surveys, assessment and modelling of fish stocks
- Development of new technologies for fisheries
- Aquaculture diversification, commercial scale development and improved productivity

Plant & Food Research

- Fish breeding and genetics
- Whole breeding operating and production systems
- Harvest and post-harvest technologies
- Whole of catch utilisation

Forestry

SCION

- Plant science propagating plant species, plant physiology breeding, genetics and durability
- Understanding forest ecosystems
- Forest establishment
- Enhance and protect through forest pathology, entomology, diagnostics
- Complex supply chains and value adding
- Enhance and protect forests

Food and beverage

Plant & Food Research

- Post-harvest activities
- Food innovation

FOCUS AREA 7 – KEY OUTCOMES

KEY OUTCOMES FOR AOTEAROA NEW ZEALAND'S FOOD AND FIBRE AND ASSOCIATED MANUFACTURING

agresearch
āta mātai, mātai whetū

Key outcomes for food and fibre

Enhance the value, productivity and profitability of Aotearoa New Zealand's pastoral, agri-food and agri-technology sector and value chains.

The outcomes will be measured through:

— Added value foods and bio-based products.
— Transformed sectors.

Key Performance Indicators

Added value foods and bio-based products:

— A validated integrated meta-omics pipeline for ingredient screening has selected at least five Aotearoa New Zealand-based candidate ingredients for functional foods and processes by 2023.
— AgResearch has developed competencies in three aspects of consumer-centric research that drive differentiation of at least three Aotearoa New Zealand raw materials and whole / processed foods by 2025.
— Developed at least five enabling technologies for shelf-life extension, smart packaging, and new uses for downgraded surplus foods and bio-products by 2027.

Transformed sectors:

— AgResearch is working with five new stakeholder groups in non-traditional focus areas to develop and implement new ways of progressing sector transformation by 2022.
— AgResearch is leading a globally recognised integrative initiative that has increased by 50% (2020 baseline) the proportion of New Zealand research informing and supporting the agri-sector's social licence to operate by 2022.
— An agri-sector education outreach programme has directly engaged with 15% of Aotearoa New Zealand schools by 2025.

Plant & Food™ Research
Rangahau Ahumāra Kai

Key outcomes for food and fibre

Enhance the value and productivity of Aotearoa New Zealand's horticultural, arable, seafood and food and beverage industries to ensure economic, environmental and social sustainability by creating world leading:

— Cultivars and rootstocks.
— Integrated pest and disease management systems and technologies.
— Sustainable production systems and harvest management technologies.
— Innovative food products, processing technologies and product claims.

NIWA
Taihoro Nukurangi

Key outcomes for food and fibre

Increase the economic value and sustainable use of Aotearoa New Zealand's aquatic resources and environments

Support sustainable practices, regional economic growth and diversification in the food and fibre sectors through:

- Surveys, modelling and assessments of fish stocks to inform fisheries quota management.
- Development of methods to reduce the environmental impacts of fishing.
- Technical input into the management of high-seas fisheries.
- Diversification of the aquaculture sector through commercialisation of new high-value finfish species.
- Development of commercial scale land-based aquaculture systems.
- Improved productivity and environmental management of sea-based aquaculture.
- Tools to ensure efficient water use and reduce nutrient loss by the primary sector.
- Development of forecasting products to enable the primary sector to manage the risks of environmental variability and change.

SCION
FORESTS • PRODUCTS • INNOVATION

Key outcomes for food and fibre

Drive innovation and growth from Aotearoa New Zealand's forestry, wood product and wood-derived materials and other biomaterial sectors:

- Forests to Timber products – Impact to 2030.
- Transition Aotearoa New Zealand to a Circular Bioeconomy; forests to bio-based products; and forests to bio-based products – Impact to 2030.

Key Performance Indicators

Forests to Timber Products – Impact to 2030:

- $7 billion in new houses and engineered timber applications.
- 50% increase in new species (non radiata pine) commercial plantings, harvest and high-value applications,
- 50% increased exports of processed timber and substitution for imported timber and products.
- An increase in net biomass gain (a productivity measure) from radiata pine of an average of 35m² per year, with improved wood quality, uniformity and resilience to pests and pathogens.
- 30% of non-productive Māori land has been cultivated for structural timbers (including indigenous) leading to a 60% increase in high value jobs for Māori and 300% increase in Māori investment in timber manufacturing and bio-based co-innovation.

Transitioning Aotearoa New Zealand to a Circular Bioeconomy:

- Forest to Bio-based Products.
- High value bioactives and specialty chemicals largely for export into the global chemical supply chains.
- Thriving regions through distributed manufacturing and customized product design.
- Designed bio-based products from high value biomaterials.
- Forests to Bio-based Products – Impact to 2030.
- 3 Biorefineries (1 indigenous).
- $20B Sustainable GDP Growth.
- 2500 Regional High Value Jobs.

FOCUS AREA 7 – ENABLING CAPABILITIES

ENABLING CAPABILITIES FOOD AND FIBRE AND MANUFACTURING

The CRIs have the following enabling capabilities that support their lead scientific capabilities in the food and fibre and manufacturing focus area.

agresearch
āta mātai, mātai whetū

Enabling capabilities

- Systems Biology platform (genomics, proteomics, metabolomics)
- Free Air Carbon Dioxide Enriched (FACE) site
- Infectious diseases PC3 Laboratory
- Large Animal Containment Unit and Research farms
- Margot Forde Forage Germplasm Centre
- Methane Chamber System
- Farm models e.g. Overseer, Farmax, Aginform, Hyperfarm
- Soil collections
- Microbiome collections

Plant & Food™ Research
Rangahau Ahumāra Kai

Enabling capabilities

- Germplasm and the associated data including the National Collections
- Germplasm storage facilities (orchards, farms, tissue culture facilities and cryogenic preservation)
- Research orchards and crop evaluations facilities including graders and cool stores storage
- Post-harvest trialling facilities
- Insect rearing facility, Disinfestation Unit and Fumigation facility
- PC2 and PC3 laboratories for plant pathogens
- Consumer sensory facilities
- NZ Food Composition Database
- Marine finfish facility & hatchery
- Marine products and extracts processing pilot plant

NIWA
Taihoro Nukurangi

Enabling capabilities

- Research vessels – RV Tangaroa, RV Kaharoa, RV Ikatere
- Te Kūwaha, National Centre for Māori Environmental Research
- Sensor networks & IoT
- High performance supercomputing, data analytics and modelling
- Remote sensing, enterprise data products and services
- National Marine Invertebrate Collection
- Databases (e.g. atmospheric constituents, ocean variables, climate, river hydrometric measurements and water quality)
- Northland Marine Research Centre

SCION
FORESTS ▪ PRODUCTS ▪ INNOVATION

Enabling capabilities

- Māori co innovation
- Precision forestry through remote technology
- Hyperspectral imaging
- Centre for Forest Pathology
- Diagnostic Laboratories (PC level 3)
- Pilot Scale mechanical pulping plant
- GMO field trial and glass house
- Compostability testing
- Degradation testing
- Industrial box testing facility
- Polymer processing equipment
- Thermal chemical biological conversion and processing
- Forestry Nursery
- Forestry genetics and breeding
- Research Forests
- Additive manufacturing – 3D and 4D printing of bio composites

FOCUS AREA 7 – CRI COLLABORATIONS

CRI COLLABORATIONS FOOD AND FIBRE AND MANUFACTURING

Below are examples of CRI collaborations in this area. Some CRIs contribute to this work – although it is not their core focus – through other expertise they bring.

NIWA Taihoro Nukurangi

agresearch āta mātai, mātai whetū

"Irrigation Insight" programme focused on understanding the environmental and economic aspects of on-farm irrigation management.

SCION FORESTS ▪ PRODUCTS ▪ INNOVATION

agresearch āta mātai, mātai whetū

Plant & Food Research Rangahau Ahumāra Kai

Bioresource Processing Alliance is the gateway to primary sector bioprocessing in Aotearoa New Zealand.

SCION FORESTS ▪ PRODUCTS ▪ INNOVATION

Manaaki Whenua Landcare Research

agresearch āta mātai, mātai whetū

Plant & Food Research Rangahau Ahumāra Kai

Regenerative agriculture – an approach to food and farming systems, including on-farm forestry for riparian protection, erosion prevention, carbon sequestration emissions mitigation.

SCION FORESTS ▪ PRODUCTS ▪ INNOVATION

Owned and contracts with the CRIs

Packaging and compostability facility (packing equipment for resources purposes and industry utilisation).

NIWA Taihoro Nukurangi

agresearch āta mātai, mātai whetū

High performance computing system.

agresearch āta mātai, mātai whetū

Manaaki Whenua Landcare Research

Animal containment facility.

ESR Science for Communities

GNS Science Te Pū Ao

Manaaki Whenua Landcare Research

NIWA Taihoro Nukurangi

Plant & Food Research Rangahau Ahumāra Kai

SCION Forests • Products • Innovation

agresearch *āta mātai, mātai whetū*

National Science Challenge: Our Land and Water | Toitū te Whenua, Toiora te Wai: To enhance primary sector production and productivity while maintaining and improving Aotearoa New Zealand's land and water quality for future generations.

agresearch *āta mātai, mātai whetū*

(Participating)

Plant & Food Research Rangahau Ahumāra Kai

(Participating)

National Science Challenge: High-value nutrition: To develop high-value foods with validated health benefits to drive economic growth.

ESR Science for Communities

agresearch *āta mātai, mātai whetū*

Plant & Food Research Rangahau Ahumāra Kai

New Zealand Food Safety Science and Research Centre. This Centre has an aim to provide an internationally credible science base for decision-making in public health and the food industry.

FOCUS AREA 7 – KEY END USERS

KEY END USERS FOOD AND FIBRE AND MANUFACTURING

Key end users for each CRI are shown below. The list is illustrative, not exhaustive. Some organisations – such as large government departments – appear more than once, as CRIs provide different services for different groups within them. The end users vary in scale and specialisation, therefore different CRIs connections with end users generally do not overlap.

agresearch
āta mātai, mātai whetū

Government agencies: Ministry of Foreign Affairs and Trade, Ministry of Business, Innovation, and Employment, Ministry for Primary Industries, Department of Conservation.

Industry bodies: New Zealand Beef and Lamb, Meat Industry Association, Dairy NZ.

Regional council: Regional councils.

Research organisations: NZ Food Safety Science & Research Centre, Our Land & Water, NZ Agricultural Greenhouse Gas Research Centre, Pastoral Greenhouse Gas Research Consortium.

Māori trusts & companies: Māori trusts & companies.

Other/private organisations: High value nutrition companies, Seed companies primary production companies, fertiliser companies, agrichemical and agritech companies.

Plant & Food™ Research
Rangahau Ahumāra Kai

Government agencies: Ministry of Business, Innovation, and Employment, Ministry for Primary Industries, Ministry of Health, Ministry of Foreign Affairs and Trade.

Industry bodies: NZ Apple and Pears, Horticulture NZ, NZ Onions, Potatoes NZ. NZ Avocado, NZ Wine, Foundation for Arable Research.

Regional council: Environment Canterbury.

Research organisations: AgResearch, Manaaki Whenua, NIWA, Scion, Cawthron, Australian Research Council, Bragato Research.

Other/private organisations: Zespri, T&G Global, PGG Wrightson, Sanford, Sealord, Fonterra, Manuka Health, Ngāi Tahu Seafood, Nga Uri o te Ngahere Trust, AgroFresh, Simplot, Lintbells, World Bank.

NIWA
Taihoro Nukurangi

Government agencies: Ministry for Primary Industries, Ministry of Fisheries, Ministry of Foreign Affairs and Trade, Ministry of Business, Innovation, and Employment.

Industry bodies: Local government (regional and district councils).

Research organisations: National and international research organisations .

Māori trusts & companies: Iwi/hapū, Māori agencies/groups.

Other/private organisations: Primary production organisations, Irrigation companies, Fertiliser companies, Seafood companies.

Government agencies: Ministry of Foreign Affairs and Trade, Ministry of Business, Innovation, and Employment, Ministry for Primary Industries, Department of Conservation.

Industry bodies: Forest Owners Association, NZ Farm Foresters Association, Agriculture and horticulture industry bodies (e.g. New Zealand Plant Producers Incorporated).

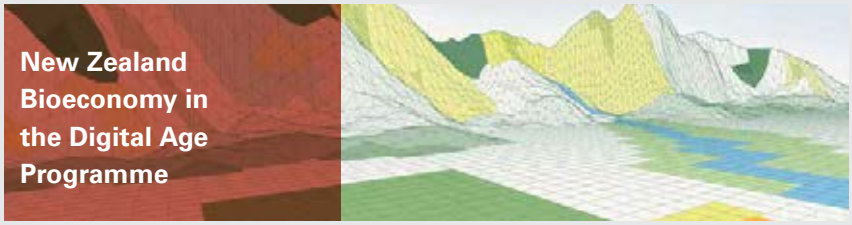
Regional council: Environment Southland.

Research organisations: Forest Growers, University of Auckland, Callaghan Innovation, ArborGen, Plant & Food Research.

Other/private organisations: Radiata Pine Breeding company, Oji, NZ Manuka, James Hardie NZ, Juken, Minginui Nursery, Pulp and Paper companies, Zespri, Comvita, Fonterra, Wakatipu Wilding Conifer Control Group, Manufacturing and advanced manufacturing companies, Packaging and sustainability solutions for agriculture and viticulture companies, Agriculture/ horticulture business – specifically around packaging and use of compostable material where recycling/reuse is not an option.

FOCUS AREA 7 – CASE STUDIES

FOOD AND FIBRE AND MANUFACTURING CASE STUDIES



AgResearch

Advances in digital technologies and data availability are changing the way agriculture works around the world. AgResearch is positioning itself at the cutting edge of this change and looking to invest in technology and understanding of data in order to be at the forefront of advances in the pastoral sector.

Investment was made by AgResearch to develop the *New Zealand Bioeconomy in the Digital Age Programme*. AgResearch has developed proof of concepts to demonstrate how digital technologies can support the transformation of Aotearoa New Zealand's pastoral sector. Some of the outcomes and proof of concept areas are:

- Hyper farm - a digital tool which helps farmers visualise land-use opportunities and future scenarios for their land. It also provides key insights on the impact changes have on nutrient loss and biodiversity.
- Virtual fencing technology – AgResearch scientists worked in collaboration to test the eShepherd system. This virtual fencing system for cattle allows users to place a GPS-enabled collar on an animal and so 'virtually' fencing off an area by use of alarms and mild electrical stimulus. The technology has also enabled remote monitoring of animal behaviours to give further insights into animal behaviour.

Some of the benefits of this work are:

- Increased efficiency in farming and lower costs to the pastoral sector.
- Aotearoa New Zealand being viewed as a global leader in the pastoral sector for innovative technologies and providing sustainable, efficient solutions for farming.

NIWA (lead), AgResearch (contributes)

Irrigation is used to ensure farmers can grow agricultural crops, maintain landscapes and revegetate distributed dry soils for higher value use. If irrigation is ineffective it will limit pasture growth, cause nutrient loss and use ineffective amounts of water which will likely have adverse impacts on the production of agricultural products.

AgResearch and NIWA are part of the *Irrigation Insight Programme,* funded by the Ministry of Business, Innovation and Employment, which aims to provide working farms with the knowledge, tools and confidence to better manage irrigation. The focus of the CRIs was to understand the environmental, social and economic aspects of on-farm irrigation management. Programme partners include AgResearch, DairyNZ, Fonterra and Irrigation NZ. This was to ensure farmers would be current supply and future demand ready, reduce water and nutrient loss and use less water while maintaining pasture growth.

The outcomes of the irrigation tools are to:

- Support improved water use efficiency by integrating high-resolution weather forecast data with on-farm soil moisture measurements.
- Provide dairy farmers with the knowledge to actively manage irrigation, applying precisely the water needed – when, where and how much.

Forestry meets machine learning

Scion

Phenotyping, which is the act of quantifying and describing a forest's physical, physiological and biochemical properties presents a variety of new challenges for the forestry industry but enables the opportunities to improve the productivity and value of forests. Scion has made advances in remote sensing technologies which allows for the accurate assessment of forest characteristics and growing conditions. Scion has developed a novel phenotyping platform which includes new concepts of describing forest characteristics across large areas. Scion assembled stand management, genetic, soils, terrain, and climatic datasets (supplied by Timberlands) for the purpose of accurately describing the growing conditions experienced by crop trees. In the past year, Aotearoa New Zealand's largest plantation forest has been characterised for forest phenotype and terrain characteristics and the techniques developed during this process have been extended to other large forests. This compilation of information results in extremely large datasets that can have more than a billion records. Scion's new machine-learning techniques simplify this data, analysing the large volume and turning it into applicable information that will be invaluable to forest growers, tree breeders, investors and to other researchers. Some of the outcomes of this research and continued research in this area:

- Enabling forest growers to make best use of Aotearoa New Zealand's existing forests by maximising their profitability and enabling investors to have greater confidence in investing in regional infrastructure.
- Increased knowledge and understanding/discoveries about tree growth and the deployment of new genetic material increasing the potential of the forestry industry through efficiency and productivity gains.
- Improved understanding of linkages between genotypes, environments and silviculture to increase productivity and value of forests.

FOCUS AREA 7 – CASE STUDIES

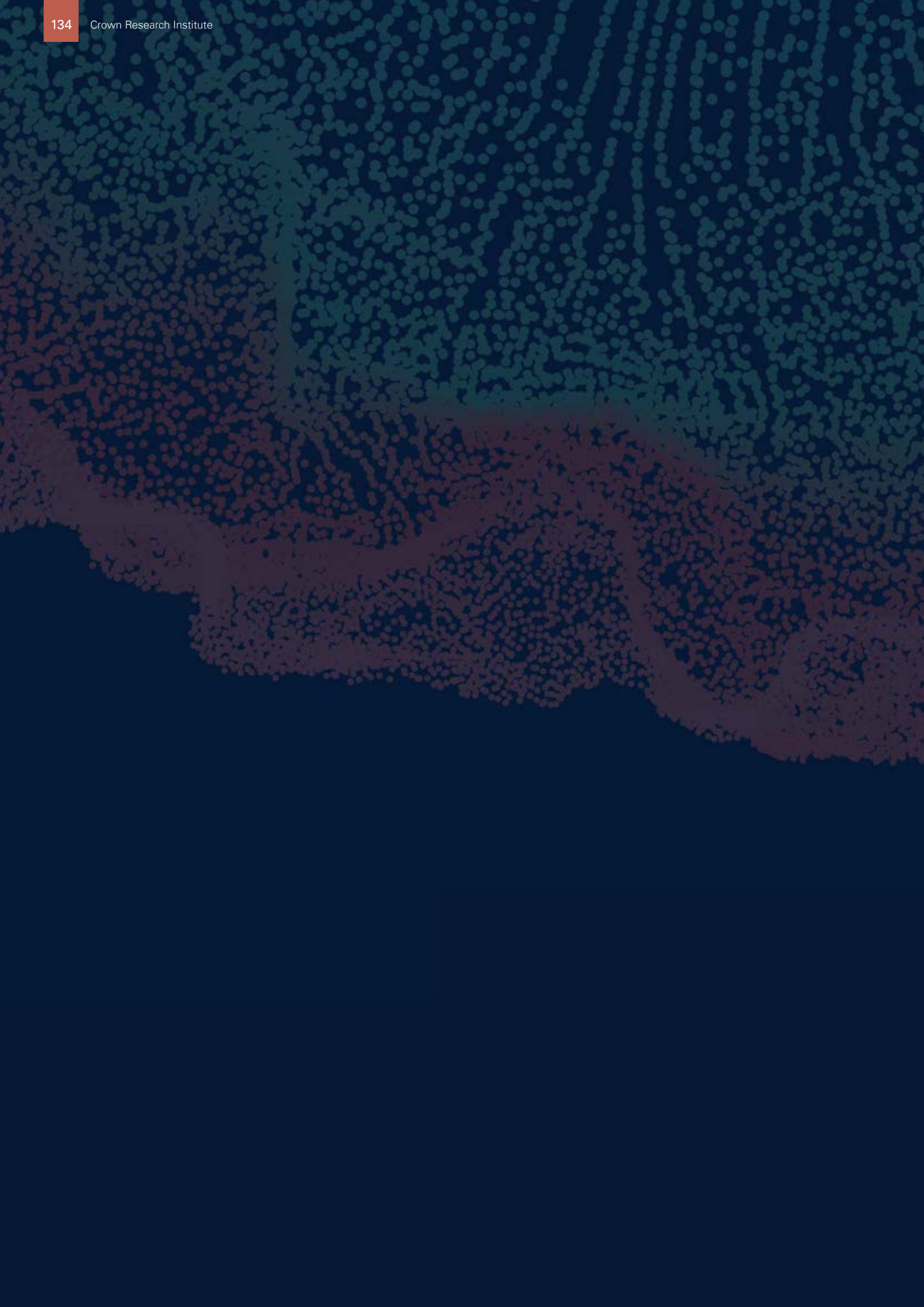
Increasing orchard gate returns

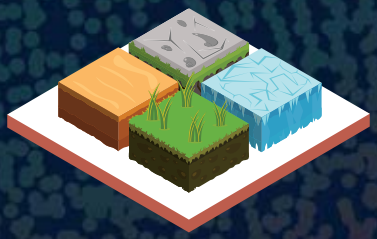
Plant & Food Research

Gold Kiwifruit exports are expected to achieve around $6 billion export value in 2030. Plant & Food Research has the largest kiwifruit breeding programme in the world and is the sole research provider to the New Zealand Kiwifruit Research Consortium. Plant & Food Research provides insight into improving crop management and establishing activities that will optimise the orchard design and increase orchard gate returns. The Future Orchard Planting System (FOPS), designed by Plant & Food Research, was based on their understanding of plant physiology and developmental biology to create a three-dimensional orchard design which has more than doubled the yield of high-quality fruit. The design improves access, leaving space for innovation and automation in the future, and made orchard management simpler.

The outcomes of this research are:

- Increased orchard gate returns (Gold versus Green Kiwifruit at orchard gate returns - $800,000,000 per year value creation for Gold Kiwifruit).
- Improved effectiveness, efficiency, management and future automation potential of orchards.

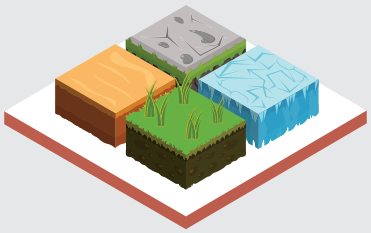




FOCUS AREA 8

LAND USE

FOCUS AREA 8 – INTRODUCTION



LAND USE

Ensure that Aotearoa New Zealand's land is valued, protected managed and used effectively.

Land is one of Aotearoa New Zealand's most important assets and is an essential resource for the food and fibre sectors as well as other economic sectors, and for environmental performance and the wider ecosystem. However, land use is continually under pressure, and some of Aotearoa New Zealand's critical natural land resources are reaching their environmental thresholds. The understanding of how land is used and responds to pressures, and the limits of land use are of significant importance, particularly in informing key natural resource decisions.

Land use covers the physical aspects of land, as well as the intangible rights of land. These include rights to airspace (as height is necessary for the use and enjoyment of the land and the structures on it).[16] Land is also an important part of Māori culture and Te Tiriti o Waitangi, heightening the need to protect and restore it.

Some of the requirements for land use in Aotearoa New Zealand include:

- Fair and equitable use and protection of land.
- Better allocation and management of land resources including restoration and efficient use of under-utilised land.
- Understanding, valuing and using Te Ao Māori and Treaty-informed approaches to land decisions and respecting the key kaitiaki of land.
- Informed understanding of land use and land types to improve decision making for land use in Aotearoa New Zealand.

Land use underpins and links to the other CRI focus areas making it a priority for science, research and innovation to ensure the sustainability and equitability of land use.

The CRIs have lead and contributing capabilities that support the nation's efforts in land use. The CRIs provide essential science and research for land use efforts in:

- Improving land use across the food and fibre industries and other land users to ensure suitability of land use into the future.
- Partnership with Māori to understand, value and use Te Ao Māori and Treaty-informed approaches to land decisions.
- Understand and mitigate impacts of land-use on freshwater supply and quality.
- Tools and methods to enhance services that inform land-use decisions, function, evaluation and improving diversification of landscapes.
- Understanding land use and land types and how to ensure there is suitable economic use of land across the country including land use complex supply chains.
- Understanding social systems, integrated land use and improving utilisation and management of land.

The lead CRIs in land use are:

- Manaaki Whenua: focus on innovation and management of Aotearoa New Zealand's land resources to protect and enhance the terrestrial environment.
- AgResearch: focus on primary production by enhancing land and soil management through minimisation of resource loss and sustainable agri-food production systems.
- Scion: focus on sustainable forest management and effective land use decisions across forests and landscapes, timber products and bio-based products.
- NIWA: focus on freshwater and climate for land-based sectors to ensure the sustainable management of Aotearoa New Zealand's land use.
- Plant & Food Research: focus on developing tools and methods that allow growers to meet sustainability requirements through optimising water and nitrogen levels, chemical inputs and reducing the financial costs and environmental footprint of production.

Manaaki Whenua Landcare Research	81 FTE
agresearch *āta mātai, mātai whetū*	64 FTE
SCION	33 FTE
NIWA	32 FTE
Plant & Food Research Rongohau Ahumāra Kai	55 FTE

Key CRI capabilities in this focus area can be grouped as:

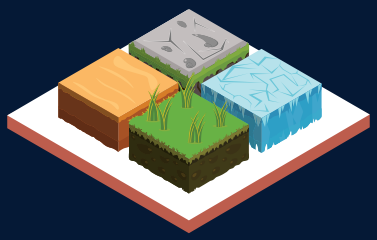
Land health – Increasing the suitability and durability of land across Aotearoa New Zealand through improved land use decisions, design of diversified landscapes and enterprises, and improved support for regional economies while operating within natural resource limits. This includes developing improved practices for monitoring and evaluating the impacts to land within Aotearoa New Zealand's complex systems.

Land Management – Increasing the accuracy of monitoring and mitigating key risks to land, soil and water from external pressures. Better understanding whenua and empowering iwi and hapū to care and protect land as the key kaitiaki. Promoting robust and integrated longer-term natural resource policy, planning and investment scenarios and supporting decisions.

Land use prioritisation – Understanding economic value and modelling land use to understand where land can be better prioritised and utilised. This includes complex systems analysis to support multifactorial and multi-stakeholder decision-making about land-use, enhancing forestry and forestry-based ecosystem services and designing holistic land use configurations centred on kaitiakitanga principles to ensure prioritisation of land is appropriate.

16. LINZ. 'Land types and areas' [website], https://www.linz.govt.nz/overseas-investment/what-you-need-do-if-you-are-selling-new-zealand-assets-overseas-investors-non-residential/land-types-and-areas/, (accessed 9 April 2021)

FOCUS AREA 8 – LEAD CAPABILITIES



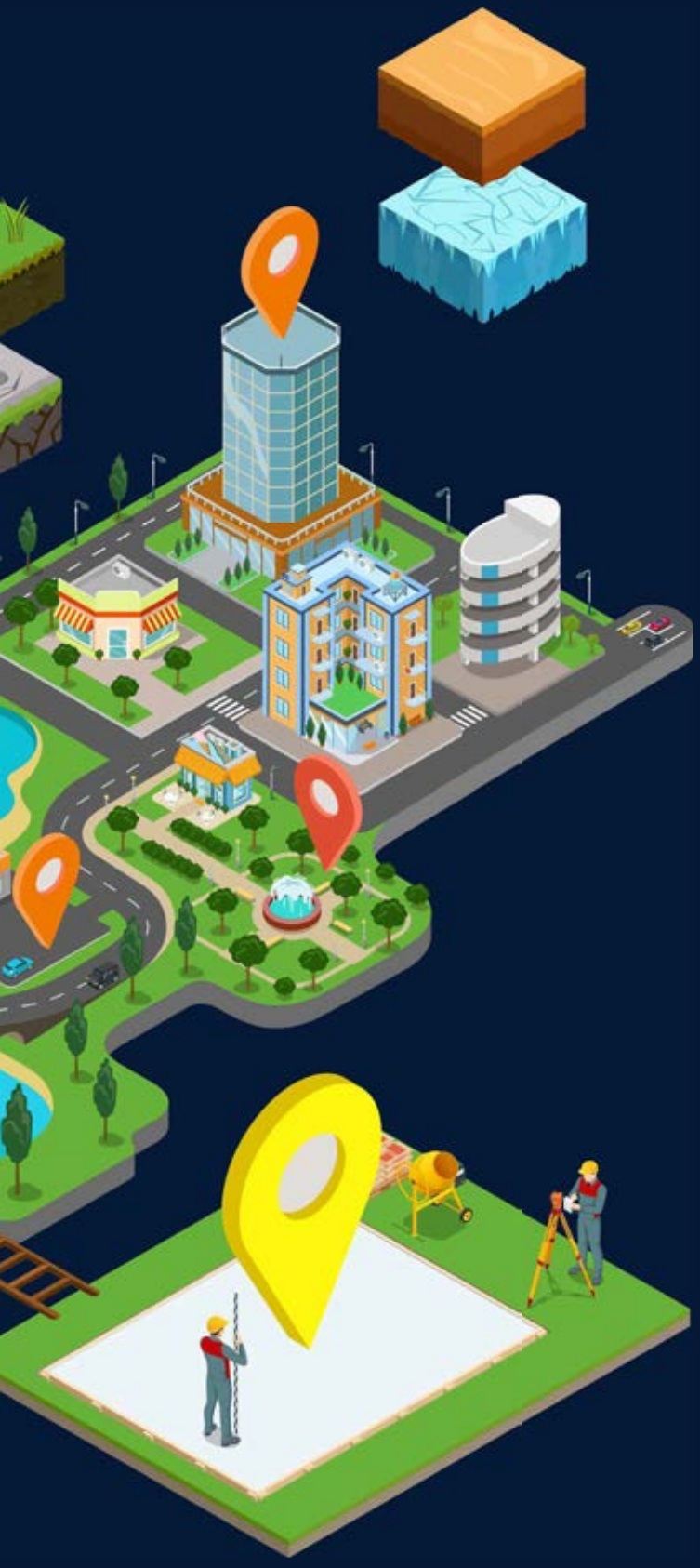
LAND USE

Land health

- SCION — Plant science forest resilience
- AgResearch — Soil science
- Plant & Food Research — Soil Function and Health
- Manaaki Whenua Landcare Research
  - Data science including land modelling, econometric analysis, remote sensing, Māori data sovereignty and ecosystem services
  - Soil health, characteristics, monitoring and spatial variety
  - Digital soil mapping

Land use prioritisation

- AgResearch
  - Data science
  - Life Cycle Assessment to agricultural products
  - Social science
- NIWA
  - Freshwater - wetland and riparian management
  - Freshwater - monitoring and forecasting for irrigation and nutrient management
  - Climate – climate projections to inform land use and carbon sequestration by forestry for reduction of methane emissions
- SCION
  - Integrated land use
  - Indigenous forest for standing value
  - Tailoring tree species for land in different regions and climatic zones
- Plant & Food Research
  - Land use impacts



Manaaki Whenua Landcare Research	81 FTE
agresearch āta mātai, mātai whetū	64 FTE
SCION	33 FTE
NIWA	32 FTE
Plant & Food Research	55 FTE

Land management

SCION

- Understanding forest ecosystems
- Forests for marginal land
- Value chain and supply chain modelling
- Social and economic research including input into policy, social change, and social license to operate

agresearch āta mātai, mātai whetū

- Environmental science
- Land use function and evaluation
- Modelling
- Agro-ecology

Manaaki Whenua Landcare Research

- Social and economic including policy, management, incentives, dynamism, social change, wellbeing indicators and social licence to operate
- Other land use and coupling systems including managing resources, Treaty informed approaches, co-governance, erosion processes and integrated land and water management
- Spatial soils data (S-Map) for land management decisions
- He whenua koiora

Plant & Food Research

- Modelling
- Climate smart systems

FOCUS AREA 8 – KEY OUTCOMES

KEY OUTCOMES FOR AOTEAROA NEW ZEALAND'S LAND USE

Manaaki Whenua
Landcare Research

Key outcomes for land use

Drive innovation in Aotearoa New Zealand's management of land resources in order to protect and enhance the terrestrial environment.

Key Performance Indicators

- Through identifying and characterising soil resources, enabling: Sustainable land use; Evidence-based spatial planning and management; Improved resilience of soil systems; Better monitoring, management and mitigation of key risks to land, soils and water; Businesses operating in a more sustainable and resilient way by having accurate and integrated data, information and knowledge of land resources.
- Enable sustainable land use across catchments and landscapes.
- He whenua koiora (better utilisation of resources for intergenerational wellbeing).
- Better protection of land and soil resources.
- Reduced impact of land use on aquatic environments, improved water quality and quantity.
- More robust and integrated longer-term natural resource policy, planning and investment decisions.
- Enable local to national decision making across landscapes for a sustainable and resilient Aotearoa New Zealand.
- Kia tautokohia te kaupapa kaitiakitanga (enabling kaitiakitanga to be practiced).
- Wider understanding, value and use of te ao Māori and Treaty-informed approaches to environmental management.
- Improved ability to account for people's values, attitudes and behaviours in managing environments.
- More inclusive and effective environmental policy, planning, governance and decision making.

agresearch
āta mātai, mātai whetū

Key outcomes for land use

Enhance land and soil management through objectives:

- Minimised resources loss.
- Sustainable agri-food production systems.

Key Performance Indicators

Sustainable agri-food production systems:

- AgResearch Smart Sensor Networks and Augmented Reality Decision Support Tools are being actively trialled at 10 representative on-farm and/or catchment-scale locations across Aotearoa New Zealand by 2022.
- At least three full-scale AgResearch solutions are being used to deliver farm and catchment sustainability improvements at double the regional average by 2025.
- AgResearch has actively leveraged three trans-sectoral initiatives (OLW NSC, NZAGGRC, PGGRC) to ensure productivity imperatives are appropriately balanced against environmental and social licence attributes by 2025.

SCION
FORESTS • PRODUCTS • INNOVATION

Key outcomes for land use

Ensure Aotearoa New Zealand has sustainable forest management and effective land-use decisions: The priority areas for Scion include:

- Forests and Landscapes - Impacts to 2030
- Forest to Timber products – Impacts to 2030
- Forest to Bio-based products – Impacts to 2030.

Key Performance Indicators

Forests and Landscapes – Impacts to 2030:

- 100% increase in afforestation of highly erodible land.
- Converting 30% of under-utilised Māori land to standing forest plantations.
- Integrating landscapes with forest clusters at a regional scale to enable continued agricultural output.

Forest to Timber products – Impacts to 2030:

- 30% of non-productive Māori land has been cultivated for structural timbers (including indigenous) leading to a 60% increase in high value jobs for Māori and 300% increase in Māori investment in timber manufacturing and bio-based co-innovation.

Forest to Bio-based products – Impacts to 2030:

- Distributed and Circular Manufacturing - Regional high value jobs & fuel and plastics substitutions (imports).

NIWA
Taihoro Nukurangi

Key outcomes for land use

Enhance the value and sustainable management of Aotearoa New Zealand's land-based sectors and the environments they depend on.

Support improved land management through:

- Monitoring and forecasting for irrigation and nutrient management.
- Climate projections to inform land-use planning and investment.
- Development of tools and techniques for riparian management.
- Verification of carbon sequestration by forestry and techniques to reduce agricultural emissions.

Plant & Food Research
Rangahau Ahumāra Kai

Key outcomes for land use

Deliver tools to industry to minimise the impacts of production systems on the environment while optimising yield, quality and economic performance.

This will be achieved through the following Sustainable Production targets:

- Complete set of measures and models for eco-verified production systems.
- Cost-efficient production systems that deliver high profitability.
- Closed production systems with inputs optimised to maximise efficiency and minimise environmental footprint.

FOCUS AREA 8 – ENABLING CAPABILITIES

ENABLING CAPABILITIES LAND USE

The CRIs have the following enabling capabilities that support their lead scientific capabilities in the land use focus area.

Manaaki Whenua Landcare Research

Enabling capabilities

- Nationally significant collections/ databases e.g., Land Resource Information System
- Other national databases e.g., Land Cover Database, S-Map, National Soils Database
- Māori engagement
- Survey of non-market values, Survey Rural Decision Makers, Manaaki Whenua pulse surveys

SCION FORESTS • PRODUCTS • INNOVATION

Enabling capabilities

- Māori co innovation
- Techno-economics of value chains
- Land slip models
- Forestry nursery
- Indigenous forest research sites
- Value chain developers and models
- Forest water flow network sensor systems
- Soil database

Plant & Food Research Rangahau Ahumāra Kai

Enabling capabilities

- High performance computing and a set of horticultural and arable crop models
- Rain shelter, lysimeters, and research orchards and farms
- Bioengineering workshop and prototyping facility

agresearch *āta mātai, mātai whetū*

Enabling capabilities

- PC3 Laboratory
- Mātauranga Māori capabilities
- High performance computing
- Responsible Innovation Platform
- Soil collections
- Soil models
- Systems biology platform for soil health

NIWA Taihoro Nukurangi

Enabling capabilities

- Te Kūwaha, National Centre for Māori Environmental Research
- Sensor networks & IoT
- High performance supercomputing & data analytics
- Remote sensing, enterprise data products and services
- Databases (e.g. atmospheric constituents, climate, river hydrometric measurements and water quality)

FOCUS AREA 8 – CRI COLLABORATIONS

CRI COLLABORATIONS LAND USE

Below are examples of CRI collaborations in this area. Some CRIs contribute to this work – although it is not their core focus – through other expertise they bring.

Manaaki Whenua Landcare Research

(Host)

agresearch *āta mātai, mātai whetū*

S–map technology – see case study.

agresearch *āta mātai, mātai whetū*

(Host)

Manaaki Whenua Landcare Research

NIWA Taihoro Nukurangi

Plant & Food™ Research Rangahau Ahumāra Kai

E/S/R Science for Communities

GNS SCIENCE TE PŪ AO

SCION FORESTS ▪ PRODUCTS ▪ INNOVATION

National Science Challenge: Our Land and Water | Toitū te Whenua, Toiora te Wai: To enhance primary sector production and productivity while maintaining and improving Aotearoa New Zealand's land and water quality for future generations.

agresearch *āta mātai, mātai whetū*

Manaaki Whenua Landcare Research

Using dairy effluent to grow crops.

agresearch *āta mātai, mātai whetū*

NIWA Taihoro Nukurangi

SCION FORESTS ▪ PRODUCTS ▪ INNOVATION

Manaaki Whenua Landcare Research

Plant & Food™ Research Rangahau Ahumāra Kai

Resilient & regenerative agriculture. This includes on-farm forestry for riparian protection, erosion prevention, carbon sequestration emissions mitigation, identification and afforestation of marginal land.

FOCUS AREA 8 – KEY END USERS

KEY END USERS LAND USE

Key end users for each CRI are shown below. The list is illustrative, not exhaustive. Some organisations – such as large government departments – appear more than once, as CRIs provide different services for different groups within them. The end users vary in scale and specialisation, therefore different CRIs connections with end users generally do not overlap.

Manaaki Whenua Landcare Research

Government agencies: Ministry for the Environment, Ministry for Primary Industries, Department of Conservation, Ministry of Business, Innovation and Employment, Ministry of Foreign Affairs and Trade, Stats NZ, Environmental Protection Authority, Three Waters Ltd, Land Information New Zealand.

Industry bodies: New Zealand Beef and Lamb, DairyNZ.

Regional council: Christchurch City Council, Local Government (Regional Councils and territorial authorities).

Māori trusts & companies: Iwi and Māori enterprise.

Other/private organisations: Fonterra, Synlait, Banking Institutions, Farmlands, Federated Farmers.

agresearch
āta mātai, mātai whetū

Government agencies: Ministry for Primary Industries, Department of Conservation.

Industry bodies: DairyNZ, Beef and Lamb New Zealand.

Regional council: Regional council.

Research organisations: CRIs, Universities, International research organisations.

Other/private organisations: Fertiliser companies, agrichem, other companies.

SCION
FORESTS • PRODUCTS • INNOVATION

Government agencies: Ministry for the Environment, Ministry for Primary Industries, Department of Conservation, Ministry of Business, Innovation and Employment, New Zealand Defence Force, Fire and Emergency NZ, Pāmu (Landcorp Farming Ltd).

Regional council: Rotorua Lakes Council, Hawkes Bay Regional Council, Bay of Plenty Regional Council, Venture Taranaki.

Research organisations: AgResearch, Manaaki Whenua, Plant & Food Research.

Māori trusts & companies: Ngā Tahu Forests.

Other/private organisations: Federated Farmers.

NIWA
Taihoro Nukurangi

Government agencies: Ministry for the Environment, Ministry for Primary Industries, Department of Conservation, Ministry of Business Innovation and Employment.

Regional council: Local government (regional and district councils).

Research organisations: International research organisations.

Māori trusts & companies: Iwi/hapū, Māori agencies/groups.

Other/private organisations: Primary production organisations, Irrigation companies, Fertiliser companies.

Plant & Food Research
Rangahau Ahumāra Kai

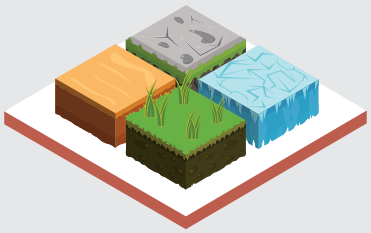
Government agencies: Ministry of Business, Innovation, and Employment, Ministry for Primary Industries, Ministry of Foreign Affairs and Trade.

Regional council: Environment Canterbury.

Industry bodies: NZ Apple and Pears, Horticulture NZ, NZ Onions, Potatoes NZ. NZ Avocado, NZ Wine, Foundation for Arable Research, Dairy NZ.

Other/private organisations: Zespri, T&G Global, PGG Wrightsons.

FOCUS AREA 8 – CASE STUDIES



LAND USE CASE STUDIES

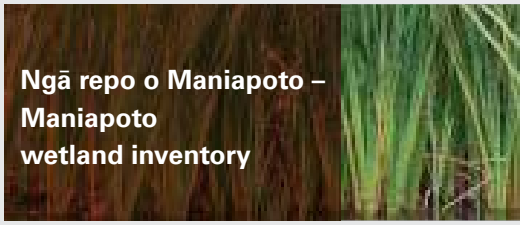
Manaaki Whenua, AgResearch

Soil mapping offers improved soil inventories, interpretations, and decision support systems which help the correct implementation of sustainable land management practices. The Manaaki Whenua S-map tool provides users access to information for farm environmental planning, monitoring and reporting to inform on-going land management decisions. Over the past 5 years, the S-map coverage has increased by 2.27 million hectares, meaning two thirds of Aotearoa New Zealand's more intensively used farmlands now have access to S-map data and the tools it provides. Among others, the services offered to S-map users allow them to:

- Access interactive soil maps of soil properties such as soil drainage and available water.
- Learn about the soil in backyards or paddocks.
- View detailed information about soil classes or attributes.
- Download soil factsheets that provide more detailed knowledge of soil properties and information relevant to a variety of potential uses.
- Generate a report of the areas of key soil properties within a land parcel or other boundary.

Outcomes:

- Sustainable use of natural farmlands across Aotearoa New Zealand to preserve natural resources through increased insights and information available to owners of intensively used farmlands on the benefits and importance of sustainable land management practices.
- Increased data availability to landowners for planning, monitoring and reporting of sustainable land use to assist in the implementation of sustainable land practices to protect Aotearoa New Zealand's natural land resources.
- A more sustainably focused private sector within Aotearoa New Zealand, resulting in greater protection and sustainability of natural assets through business practices, with 62% of S-map online users being private businesses.
- An estimated direct value of information to current users of $19.5 million per annum.
- Additional estimated wider community benefits of $9.6 to $11.4 million per annum.

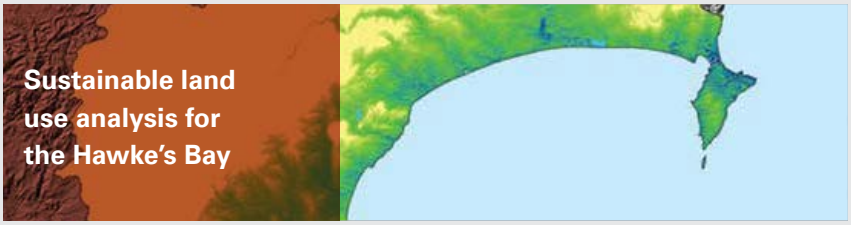


NIWA

Repo (wetlands) are highly valued as a traditional resource and are an integral component of the ancestral landscape for Ngāti Maniapoto. Currently however, only 10% of repo is remaining in Waikato. Loss of repo represents a loss of resources and knowledge for Ngāti Maniapoto and is therefore a distinct issue. Ngā repo o Maniapoto was a project that facilitated collaboration between NIWA and the Maniapoto Māori Trust Board (MMTB) Whanake Taiao team to develop an inventory of repo in the region and a framework to prioritise repo restoration efforts within the Maniapoto rohe. The framework developed was based distinctively on mātauranga-a-iwi values, uses, associations, resources and opportunities to ensure it best aligned with the needs and priorities of all stakeholders impacted. The resulting framework has enabled the MMTB Whanake Taiao team and Ngā Tai o Kāwhia Regional Management Committees to more effectively plan and strategically restore the wetlands within the region.

Outcomes:

- A strategy and plan to restore and maximise the sustainability of repo in Waikato, protecting the natural resources and knowledge they represent to Ngāti Maniapoto.
- Protection of repo within Waikato, preserving their unique natural characteristics such as protecting and improving water quality, providing fish and wildlife habitats, storing floodwaters and maintaining surface water flow during dry periods.
- An inventory to assess the current state and sustainability of repo in Waikato in terms of location, size and significance. The inventory was used to identify potential activities to be undertaken to preserve and restore repo as an important natural landscape.
- A framework, based on the inventory developed, to prioritise repo restoration activities on the basis of priorities, needs and values of all impacted stakeholders, such as Ngāti Maniapoto, the Maniapoto Māori Trust Board (MMTB) Whanake Taiao team and Ngā Tai o Kāwhia Regional Management Committees.

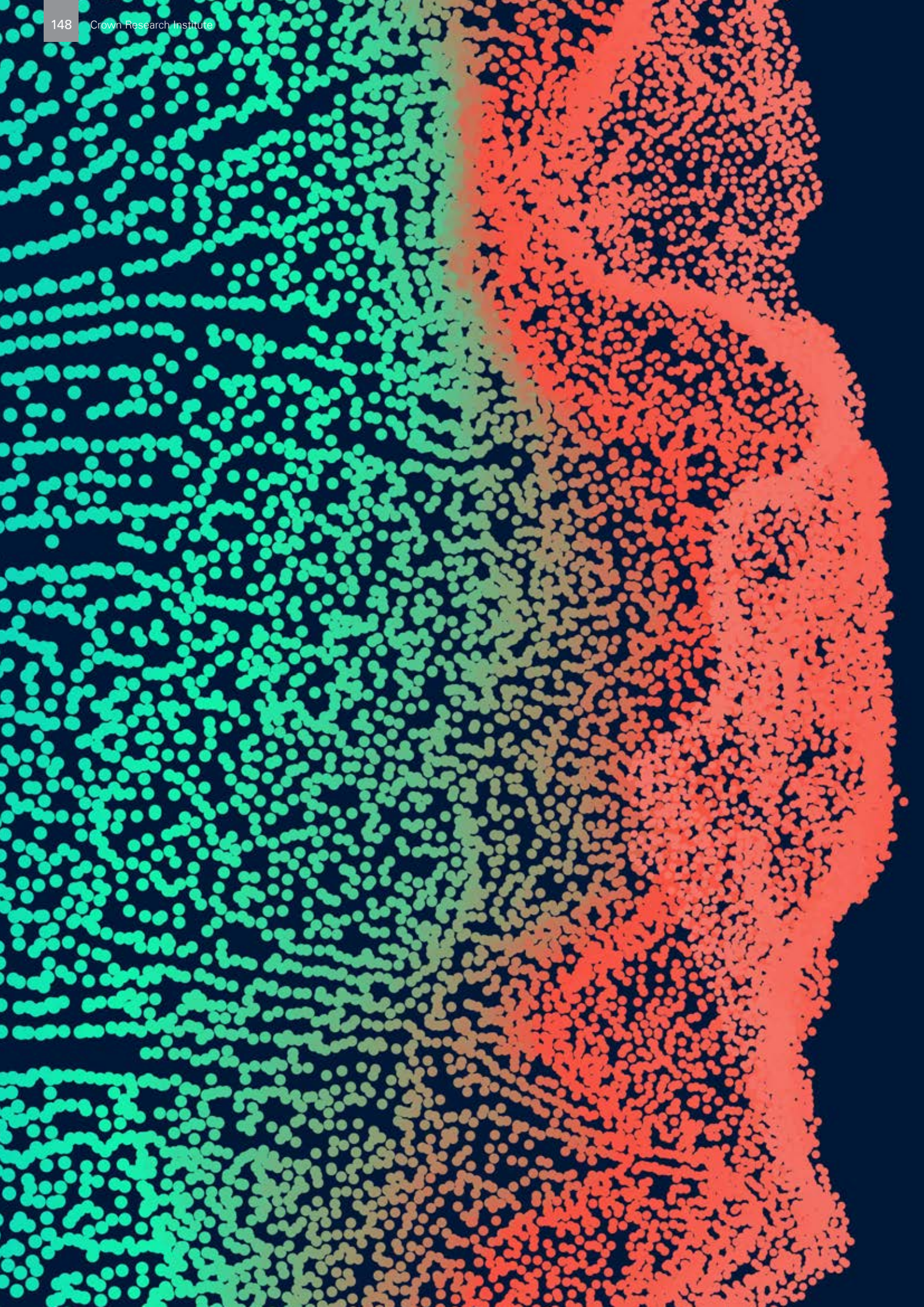


Scion

Afforestation is the establishment of a forest in an area lacking tree cover. Afforestation can be used to reduce erosion and therefore presents an opportunity to protect Aotearoa New Zealand's land for future use. Scion undertook the 'Right Tree, Right Place (RTRP)' study, alongside four other organisations, with the aim of understanding what environmentally and economically sustainable afforestation could do to combat erosion in Hawke's Bay. The study reinforced the idea that owners of land needed to see the social, environmental and financial benefits of afforestation and how it might impact local communities. Such results informed the Hawke's Bay Regional Council on how to partner with landowners to utilise land with a greater resilience, ecological integrity and function, and provided information to landowners on how to lower the risk of their decision making.

Outcomes:

- Protection of Aotearoa New Zealand's natural land resources by providing direction to the Hawke's Bay Regional Council on how to best approach afforestation to mitigate the natural deterioration of resources in Hawke's Bay through erosion.
- Increased use and effectiveness of afforestation in Hawke's Bay to mitigate the loss of natural resources through erosion by providing information to landowners on a range of factors, prior to considering planting, to de-risk their investments and how to maximise the gains of their projects.
- Up to $500 million in timber value (for radiata) planted on 100,000 hectares in Hawke's Bay.
- The potential for additional timber value increases of 150% through environmental benefits.
- Potential reduction of greenhouse gas emissions, through the identification of opportunities to develop self-sufficient primary production processing clusters, to protect Aotearoa New Zealand's natural land by mitigating the effects of climate change such as droughts, floods and storms.



APPENDICES

APPENDIX 1

DOCUMENTS AND INFORMATION USED IN THIS REVIEW

agresearch
āta mātai, mātai whetū

- Annual Report 2020
- Science Plan 2019
- AgResearch science review panel report 2019
- DRAFT strategy Tā Mātou rautaki 2021
- Leading Agri-based science innovation
- Statement of Core Purpose
- Statement of Corporate Intent 2020-2025
- Capability document A3
- AgResearch website

ESR
Science for Communities

- Statement of Core Purpose
- Annual Report 2019 - 2020
- Martin Jenkins Report 2018
- ESR Statement of Corporate Intent 2020-2025
- Forensics at ESR infographic
- Capability document A3
- ESR website

GNS Science Te Pū Ao

- Statement of Corporate Intent July 2020 – June 2025
- Statement of Core Purpose
- GNS Science profile
- Annual Report 2020
- Te Rautaki Umanga Māori – Te Rautaki
- Capability document A3
- GNS website

Manaaki Whenua
Landcare Research

- Annual Report 2020
- Statement of Core Purpose
- Statement of Corporate Intent 2020-2025
- About us collateral posters
- Capability document A3
- Manaaki Whenua website

NIWA
Taihoro Nukurangi

- Annual Report 2020
- Statement of Core Purpose
- Statement of Corporate Intent 2020-2025
- Capability document A3
- NIWA website

Plant & Food Research
Rangahau Ahumāra Kai

- Annual Report 2020
- Statement of Core Purpose
- Statement of Corporate Intent 2020-2025
- Capability document A3
- Plant & Food Research website

SCION
FORESTS • PRODUCTS • INNOVATION

- Annual Report 2020
- Statement of Core Purpose
- Statement of Corporate Intent 2020 - 2023
- Capability document A3
- Scion overview
- Scion website

General

- Letters of expectation for research, science and innovation portfolio crown entities
- Economics of Biosecurity
- Remarks by Hon Megan Woods MP, Minister of Research, Science & Innovation. 3 December 2020
- B3 annual report 2018-19
- CRI core purpose diagrams
- CRI collective report-back to the Minister of Research, Science and Innovation on: Māori partnership and co-innovation – December 2018
- Combined CRI A3 document used for the TPK review
- CRI capability mapping 16 November 2020
- CRI capability mapping data
- Biosecurity 2025 Strategic Direction
- Impact of science discussion paper summary of submissions – MBIE

APPENDIX 2

KEY CONTACTS

agresearch
āta mātai, mātai whetū

— Sue Bidrose – Chief Executive
— Trevor Stuthridge – Research Director

NIWA
Taihoro Nukurangi

— John Morgan – Chief Executive
— Rob Murdoch – General Manager, Research

E/S/R
Science for Communities

— Peter Lennox – Chief Executive
— Brett Cowan – Chief Scientist

Plant & Food Research
Rangahau Ahumāra Kai

— David Hughes – Chief Executive
— Richard Newcomb – Chief Scientist

GNS SCIENCE
TE PŪ AO

— Ian Simpson – Chief Executive
— Gary Wilson – General Manager Strategy
— Tania Gerrard – General Manager, Māori Strategy and Partnerships

SCION
FORESTS • PRODUCTS • INNOVATION

— Julian Elder – Chief Executive
— Roger Dungan – Strategic Relationships Director

Manaaki Whenua
Landcare Research

— Richard Gordon – Chief Executive
— Fiona Carswell – Chief Scientist

Science New Zealand

— Anthony Scott – Chief Executive
— George Slim – Policy Manager

APPENDIX 3

AgRESEARCH

agresearch
āta mātai, mātai whetū

AgResearch's purpose is to enhance the value, productivity and profitability of Aotearoa New Zealand's pastoral, agri-food and agri-technology sector value chains to contribute to economic growth and beneficial environmental and social outcomes for Aotearoa New Zealand. This page provides a snapshot of the key contributions and unique capabilities of AgResearch.

Core unique capabilities

- **Animal science** – understanding nutrition impacts on animal performance and products in Aotearoa New Zealand's farm system, animal behaviour science and welfare, tools and techniques to ensure animal health in current and future conditions, rumen microbiology, genetic and genomic approaches for genetic gain, understanding of cow and sheep fertility and biotechnology for genetic modification, and gene editing in large animals.
- **Forage science** – deep knowledge in forage genomics for pasture conditions, endophytes in plant species to alter plant characteristics, plant biotechnology for genetic modification and gene editing in large animals and forage plants, plant protection preserving biodiversity through expertise in the spread of weeds, pests and diseases contributing to biosecurity efforts, and evaluating and predicting climate change responses.
- **Farm systems and environment** – climate change, specifically GHG emissions from animal production systems and climate change impacts, protecting and restoring pastoral land for future generations by understanding resource flow and providing mitigating technologies while using a circular approach, depth of knowledge in Aotearoa New Zealand soils underpinning pastoral landscapes, transforming Aotearoa New Zealand's food systems through digital agriculture for future farming, agricultural innovation systems and applied social science to inform resilience to change and help transitions with design of food and agricultural innovation systems, and indigenous Māori knowledge system applied to land use from pastoral landscapes.
- **Food and bio-based products** – proteomics and metabolomics with a focus on protein rich food and materials from the pastoral system, green bio-based alternatives derived from pastoral production systems and zero waste targets, future foods for agriculture with tailored properties for lower environmental footprints, digestive health and microbiome knowledge to understand food health effects, evaluation of food safety, assurance, traceability and provenance from on farm to consumer focused on animal production systems.

Strategic Science Investment Fund platforms

- Agrifood production
- Premium agri-food services
- NZ's Bioeconomy in the Digital Age

Unique infrastructure

- **Nationally significant databases and collections** – Margot Forde Germplam Centre including NZ Indigenous Flora Seed Bank.
- **Other significant databases and collections** – Microbiology (soil and rumen including Hungate 1000); Animal biological, Longitudinal farm trials and samples.
- **Other** – Free Air Carbon Dioxide Enriched (FACE) site; PC3 Laboratory; Large Animal Containment Unit (HSNO approved), Research farms.

Core government contributions

- **Informing policy / regulatory changes** – animal welfare standards and management practices, GM animals and plants, plastics and waste, food and health claims, safety of new foods and farming systems, sustainable land management, and ETS and regenerative agriculture.
- **Impact** – animal pest and disease incursions and readiness response, agricultural related global commitments and national emissions management, Singapore strategic government imitative, and Vison Mātauranga.
- **Biosecurity efforts** – animal pest and disease incursion, readiness and response, alternatives to banned pesticides to control plant pests, risk mitigation, and International Biosecurity Forum Government initiative.

Public good contributions

- **Sustainability and productivity** – sustainable land and resource management and solutions to environmental issues.
- **Climate outcomes** – climate change resilience and restoration of native biodiversity, global climate outcomes (agriculture), climate smart primary production systems and reduced waste through efficient production systems.
- **Protection of Aotearoa New Zealand's primary production land-based systems** and conservation estate, indigenous species conservation, and enhancing Aotearoa New Zealand food brand.
- **Aotearoa New Zealand's public health and building Māori capability** – safety and wellbeing, community aspiration for social, environmental, economic and cultural outcomes, recognition and acknowledgement, and creating a diverse economy.

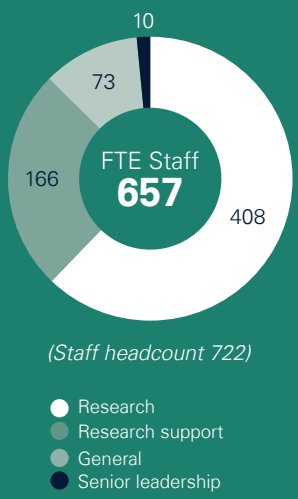
Industry contributions

- **Efficiency gains** – more efficient animal production systems, use of resources, animal welfare, product quality, forages and animals, plant productivity and persistence, farming productivity, and full value-chain integration.
- **Innovation** – innovation and technology and increased adoptions of technology.
- **Maintaining market access** – high-value and more traceable products and world class innovation in animal welfare practices.
- **Ability to meet regulatory requirements** – such as enabling lower emissions, lower environmental footprints of agriculture, climate smart animals, and climate change resilience.

Future direction and investment

- More research generating ideas, new capabilities, more partnering.
- **Enabling platforms** – eResearch, Systems biology, Responsible innovation.
- **Integrative, transformational initiatives** – NZ's Bioeconomy in the Digital Age, Biome-to-Biome, Towards circular bioeconomy.

Staff and locations



APPENDIX 3

ESR

E/S/R
Science for Communities

ESR's vision is to help make Aotearoa New Zealand's people and communities healthier and safer and to improve the environment. This page provides a snapshot of the key contributions and unique capabilities of ESR.

Core unique capabilities

- **Forensic science** – includes reconstructing crime science and recovering evidence, crime scene DNA analysis, world-leading separation of DNA mixtures (STRmix software), physical evidence analysis, alcohol and illicit drug use analysis including identification at borders and drug impairment, coronial toxicology, and methamphetamine clandestine laboratory recovery to identify and manage drugs, explosives, biological and chemical weapons.
- **Analytical chemistry** – workplace drug testing, safety of medicine, health products, devices and cosmetics for pharmaceutical analysis and being Aotearoa New Zealand's only laboratory for chemical warfare used to identify unconventional threats.
- **Population health and intelligence** – specialist microbiological and reference laboratory services for communicable diseases and population health intelligence to support response to communicable diseases and other emerging health threats.
- **Anti-microbial resistance** – surveillance for anti-microbial resistance to inform response.
- **Human genomics** – maximising the benefits from human genome analysis and personalised medicine to improve human health.
- **Food safety** – food microbiology, genomics and chemistry to ensure food safety domestically and internationally.
- **Water quality impacts on human health** – groundwater, surface water and drinking water quality to understanding sources, transport and mitigation of contaminants, and ensuring New Zealanders have a safe drinking water supply.
- **Waste science** – bio-solids and micro-plastics impact on human and environmental health and the circular economy through utilising waste as a resource.
- **Radiation science** – food and environment radiation compliance monitoring and testing.
- **Social systems science** – multidisciplinary approach to solving complex problems impacting humans and the environment, systems thinking, evaluation, and workshop design/facilitation.
- **Kaupapa Māori research** – wai, human health (genomics), data science and the justice sector.
- **Data science** – bioinformatics for DNA analysis and data visualisation, AI for image processing, machine learning and modelling and feature detection to automate and improve processes.

Strategic Science Investment Fund platforms

- Human and environmental health
- Forensic science

Unique infrastructure

- **EpiSurv** – Notifiable Disease Surveillance System.
- **New Zealand Reference Culture Collection** – Preservation and storage of bacteria culture of medical interest.
- **Police forensic DNA databank** – DNA Profiles of individuals and from crimes.

Core government contributions

- **Security and justice** – supporting integrity of the criminal justice system, broader security and the integrity of the criminal justice system, meeting legal requirements, safety testing/ standards, compliance and national security.
- **Societal health** – notifiable disease/public health threat control and management, public policy and services to improve wellbeing.
- **Food safety** – foodborne outbreaks and food standards.
- **Water** – water quality, recreational water standards and drinking water standards.
- **Informing policy** – policy evaluation, improving equity, Radiation Act, IAEA and international standards, resource management, and services to improve wellbeing.

Public good contributions

- Safer communities
- Population health biosecurity and food safety
- Public health and wellbeing

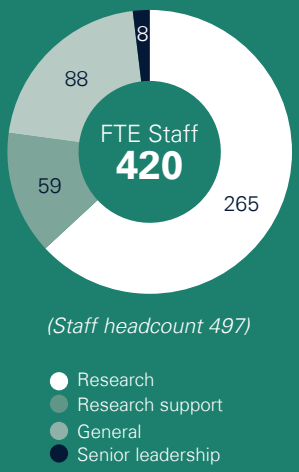
Industry contributions

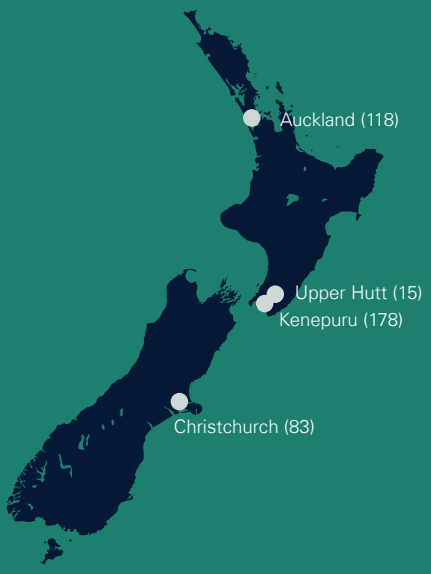
- Industrial accidents and safe workplaces
- Population health
- Biosecurity and Food safety
- Patient management
- Contamination tracing
- Export certification
- Ability to operate
- High quality food for export, low radiation impact on the environment, low radiation risk, and analysis of complex problems

Future direction and investment

- Kaupapa Māori research.
- Public health microbiology, human genomics and epigenetics, freshwater, bio-solids and micro-plastics, social systems thinking.
- DNA analysis and Police database, alcohol and illicit drug analysis, methamphetamine clandestine laboratory recovery, bioinformatics and statistics, artificial intelligence.

Staff and locations





APPENDIX 3

GNS SCIENCE

GNS' purpose is to understand the natural earth system processes and resources, and to translate these into economic, environmental and social benefits. This page provides a snapshot of the key contributions and unique capabilities of GNS.

Core unique capabilities

- **Natural hazards and risks**
  - Managing risk to the four capitals
  - Enabled and informed public, community and business
  - Effective early warnings and forecasts
  - Improved response decision-making and recovery planning
  - Improved risk governance
- **Environment and climate**
  - Groundwater systems
  - Antarctica in a 2°C warmer world
  - Ecosystem response to a warming world
  - Revealing the drivers of our climate
  - Carbon cycle dynamics.
  - Our rising tide
- **Energy futures**
  - Improved understanding of geothermal systems
  - Improved sustainable use of geothermal energy
  - New materials for energy applications
  - New and improved technologies
- **Land and marine geoscience**
  - Thermal processes
  - Plate boundary tectonic processes
  - Continental tectonic processes
  - Surface geological processes
  - Databases/geoscience information

Strategic Science Investment Fund platforms

- Geological resources
- Geological processes and hazards
- Nuclear and isotope science

Unique infrastructure

- **National Geohazards Monitoring Centre.**
- **GeoNet monitoring and associated GeoNet databases and digital assets.**
- **Nationally significant collection/databases** e.g. National Earthquake Information Database; NZ Fossil Record File, Regional Geological Map Archive & Data File, NZ Geomagnetic Database, and National Groundwater Monitoring Programme.
- **National Laboratories** e.g. Fleming Centre (Paleontology) Labs, Geomechanics Lab, Rock & Soil Mechanics Lab, Marine Geochemistry Lab, and Tritium & Water Dating Lab.

Core government contributions

- **Informing policy and regulation** – freshwater policy and regulation, climate change, ocean and Antarctic policies underpinned by science, climate change and adaptation policies, energy policy, minerals and energy, and global policy positions.
- **Monitoring, reporting, understanding, and achieving strategic goals** – Aotearoa New Zealand's Asia/Pacific aid objectives, management of groundwater systems, aquifer monitoring, environmental reporting, downscaled climate impact assessment, energy resource management, and underpinning knowledge of Te-Rui-a-Māui/Zealandia.
- **Emergency response** – national and local altering, response, and hazard outcomes.
- **Strategy** – implementation of national resilience strategy, informing low carbon transition, renewable energy strategy, and enabling the hydrogen economy.

Public good contributions

- **Community safety and knowledge** – awareness and preparedness of hazards, resilience to environmental changes, reduction in long term risk, regional development, distributed energy supply, security of supply, new knowledge and intensive employment, and engagement with NZ/s unique geology.
- **Māori aspirations, partnership and leadership** – Māori kaitiakitanga aspirations are honoured, Mātauranga Māori informs science, and Māori industry growth.
- **National safety/resilience** – lives saved, reduced impact from hazards, societal resilience, reduced transition cost and hazard outcomes.
- **Environmental impacts** – sustained freshwater quality and sustainable transition.

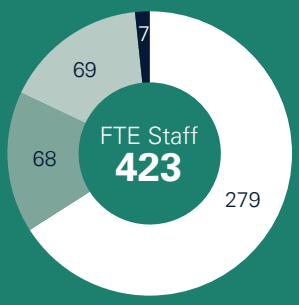
Industry contributions

- **Resilience** – hazards factored into decision making, and resilient buildings and infrastructure.
- **Efficiency** – false alerts reduced, lowering the cost impact of these, improved field monitoring/ management, enabling Māori–owned commercial development, efficiency in exploration operations, increased earnings (from hydrocarbon), and informed industry interests in the nation's continental resources.
- **Meeting policy / regulatory requirements** – low-C materials reducing industry footprints and future-proofing of infrastructure and other major investment from environmental change risks.
- **Ability to operate and industry growth** – geothermal field resource consent applications, reduced investment risk, new industry creation and growing export revenue.

Future direction and investment

- Fit-for-purpose organisational capability across leadership at all levels, people and project management capability, GNS engagement with Māori, and integration of science with enabling disciplines e.g. HR, finance health and safety.
- Next-generation science expertise enabled by new technologies and approaches,
- Organisational systems ad building infrastructure to ensure ongoing delivery of core business.

Staff and locations



(Staff headcount 442)

- Research
- Research support
- General
- Senior leadership

APPENDIX 3

MANAAKI WHENUA

Manaaki Whenua
Landcare Research

Manaaki Whenua's vision is Kia tupu matomato a Tāne, a Rongo, a Haumia-Tiketike. *Let it be that the land and all its fruits may flourish.* This page provides a snapshot of the key contributions and unique capabilities of Manaaki Whenua.

Core unique capabilities

- **Wildlife management and conservation ecology** – includes outcomes of management regimes for species and ecosystem conservation to reverse their decline, enable biocultural approaches to biosecurity and biodiversity, guide and evaluate effective landscape-scale predator eradication, develop safe and cost-effective vertebrate predator control techniques, and enable TB freedom and wildlife disease management.
- **Plant biosecurity and biodiversity** – tools and methods to beat weeds, understanding of ecosystem resilience to improve protection of biodiversity, molecular ecology to increase resilience and understanding biodiversity change and its implications to kia tiakina ngā taonga tuku iho (better protect tonga species).
- **Biota – identification and understanding of plants, anthropoids and fungi, and bacteria** – enable understanding of plants, arthropods, fungi and bacteria, manage and improve collections and databases that underpin Aotearoa New Zealand's biodiversity and biosecurity systems and develop and promote environmental information management and computing technologies.
- **Managing land and water** – integrate the management of carbon, water and nutrients, protect and improve soil and ecosystem health, understand erosion processes and manage sediment, and integrate land and water management, including catchment-scale policy implementation that reflects climate change.
- **Characterising land resources** – characterise and monitor soil attributes and their spatial variability, generate credible spatiotemporal land-cover and land-use data, map and characterise ecosystem services, and enable scenario analysis, integrated modelling of land use information and providing online multi-platform access for stakeholders to Aotearoa New Zealand's land resource data (S-map, etc).
- **Climate change adaptation and mitigation** – accurate quantification of and changes in terrestrial GHGs and carbon stocks, develop and evaluate cost-effective technologies to mitigate terrestrial GHG emissions, determine the biophysical and socio-economic consequences of climate change and develop and evaluate climate change responses/options.
- **Society, culture and policy** – enable integrated policy and management across landscapes and people, rangahau mō te kaitiaki (research for the kaitiaki), understand environmental preferences, attitudes and behaviours, enable better-informed and more transparent resource management decisions to enhance system resilience, understanding incentives for and barriers to improved environmental policy and governance, and understand and harness dynamic inter-relations between people and the environment, including climate change adaptation.

Strategic Science Investment Fund platforms

- Land-based ecosystems
- Enhancing land use

Unique infrastructure

- **Nationally significant collections/databases** e.g. National Vegetation Survey Databank, Allen Herbarium and associated databases, NZ Arthropod Collection, Fungarium, International Collection of Microorganisms from Plants, Nga Tipu Whakaoranga (ethnobiology & NZ flax collection), and Land Resource Information Systems (including NZLRI and NSD).
- **Other databases and collections of national importance** e.g. New Zealand Organisms Register (NZOR), S-map online, Land Cover Database, and NZ National Soil Archive.

Core government contributions

- **Informing policy/regulation** – DoC's conservation policy and operations, regional council policy development and operations, and MPI and MfE policy for land, water and spatial planning and operations.
- **National biosecurity** – prediction, response and Pacific biosecurity, MPI biosecurity planning and response.
- **Sustainability and resilience of Aotearoa New Zealand** – social licence to operate, underpinning a zero-carbon economy, GHG inventory, understanding society, and mechanisms of change for the resilience & sustainability of landscapes of the motu.
- **Te Ao Māori** underpinning government policy and decision making.

Public good contributions

- **Protection of Aotearoa New Zealand** – taonga species and mahinga kai, Predator Free NZ, Aotearoa New Zealand's biodiversity heritage.
- **Resilience and sustainability** – landscapes for livelihood and leisure, Aotearoa New Zealand's society, understanding the resilience and sustainability of landscapes, optimising agricultural development within environmental limits, and community resilience to climate change.
- **Māori are more able to practice kaitiakitanga** – working with Māori to evaluate and implement options that enhance the mauri of te Taiao.

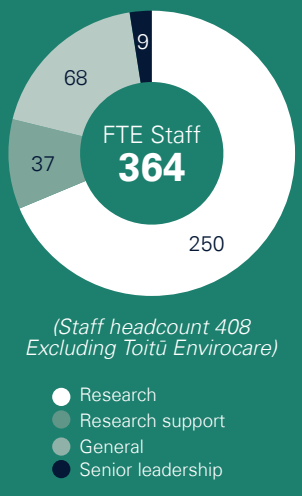
Industry contributions

- **Social license to operat**e – primary sector.
- **Market access** – via product, provenance, cadence and attributes.
- **Enabling Māori agri-business and kaitiakitanga.**
- **Environmental** – enhanced biosecurity, optimising agricultural development within environmental limits, and moving to a zero carbon economy.

Future direction and investment

- **Increase capability** – close relationships with Māori, te ao Māori and Treaty-informed approaches, integrated, transdisciplinary approaches, data science, analytics and associated tools, molecular tools and big data approaches, AI support in all forms of sensing (predators to landscapes) landscape scale change and social resilience for climate change adaptation.

Staff and locations



(Staff headcount 408 Excluding Toitū Envirocare)

APPENDIX 3

NIWA

NIWA's mission is to conduct leading environmental science to enable the sustainable management of natural resources for Aotearoa New Zealand and the planet. This page provides a snapshot of the key contributions and unique capabilities of NIWA.

Core unique capabilities

- **Climate, atmosphere and hazards** – Measuring atmospheric/ocean change, verify emissions (GHG) & calibrate satellites, determining future weather, climate and related hazard risk, including the Pacific, weather/climate/hazard predictions & forecasts, tools for adapting to climate variability & change, and transitioning to a low carbon economy.
- **Freshwater** – cause and effects on water quality degradation, including estuaries, modelling to predict water quantity and quality change/degradation, mitigation of land-use impacts on freshwater resources, pest incursion risk and control, and tools for restoration and protection of freshwater ecosystems.
- **Coasts and oceans** – understanding of ocean environment, resources and dynamics, measuring and forecasting marine environmental change and uncertainty, tools to avoid, remedy or mitigate impacts and restore degraded systems, ecosystem based approaches to marine resource use and management, identify and characterise Aotearoa New Zealand's marine biodiversity, and pest incursion risk and control.
- **Fisheries** – measurement and modelling of fish stock to inform management, identify and reduce impacts of fishing on the environment, and science to support Aotearoa New Zealand's access to international fisheries.
- **Aquaculture** – pilot commercial scale kingfish aquaculture, develop hāpuku as a high value culture species, economic land-base aquaculture, sustainable production from sea-based aquaculture.
- **Te Kūwaha, National Centre for Māori Environmental Research** - partnering with Māori communities/businesses and aligning NIWA research with kaupapa Māori research to meet Māori priorities and aspirations, research capacity of whanau, hapū and iwi to manage natural resource, and co-develop approaches & tools from combined knowledge systems for sustainable resource use.
- **Technology and innovation** – development of sensor technologies, network designs for environmental monitoring, big data analytics, high resolution environmental data, delivery of environmental data, information and user products based on enterprise data and databases.
- **Marine vessels** – platform for fisheries and ocean science, biannual voyages to the Ross Sea, support local sector/international research surveys.

Strategic Science Investment Fund platforms

- Marine Environment
- Freshwater Environment
- Climate and weather

Unique infrastructure

- **Databases and collections:** National Marine Invertebrate Collection, Water Resources Archive & Network, Climate Database & Network, Freshwater Fish Database.
- **Databases:** greenhouse gases, atmospheric constituents, ocean variables, NZ River Environment Classification, natural hazards.
- **RV Tangaroa, RV Kaharoa, RV Ikatere.**
- **High Performance Super-computer Facility.**
- **Northland Marine Research Centre.**

Core government contributions

- **Climate change** – GHG emissions mitigation and national adaptation to climate change.
- **Risk management** – hazard and risk management and Pacific island aid.
- **Environmental protection** – conservation, ecosystem management, global ocean management, invasive species management and eradication, international fisheries management, and resource management.
- **Māori** – resource management and Māori economic development.
- **Policy** – climate change policy, UN Law of the Sea/Antarctic Treaty obligations.

Public good contributions

- **Resilience/preparedness for change** – hazard risk management, community/iwi weather/climate adaptation and resilience, and community resilience to environmental change.
- **Sustainability and environmental health** – water quality, freshwater ecosystems, recreation, kaitiakitanga, ocean health, and Māori resource management.
- **Growth** – regional development research platform for Aotearoa New Zealand science providers and customary and recreational fisheries.

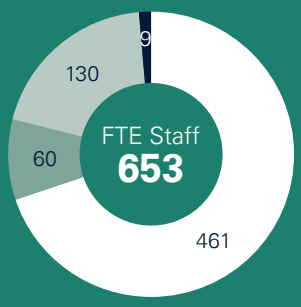
Industry contributions

- **Primary sector** – productivity, mining, safety at sea, marine access sustainable fisheries, primary production productivity, marine resource use, high-value species, and increased sea-based production.
- **Climate change** – mitigation solutions and adaptation strategies.
- **Freshwater** – primary sector productivity, energy generation, water treatment technology.
- Hazard response and reduction.

Future direction and investment

- Modelling and data analysis.
- HPC and research vessels.
- New remote sensing technologies.
- Recirculating Aquaculture systems.
- Building Māori research capacity.

Staff and locations



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APPENDIX 3

PLANT & FOOD RESEARCH

Plant & Food™ Research
Rangahau Ahumāra Kai

Plant & Food Research's purpose is to enhance the value and productivity of Aotearoa New Zealand's horticultural, arable, seafood and food and beverage industries to contribute to economic growth and the environmental and social prosperity of Aotearoa New Zealand. This page provides a snapshot of the key contributions and unique capabilities of Plant & Food Research.

Core unique capabilities

- **New cultivar innovation** – cultivars with improved economic, social and cultural traits and molecular and digital tools and technologies for better and faster cultivar breeding.
- **Sustainable production** – production systems that improve economic, environmental, social and cultural sustainability for Aotearoa New Zealand's plant-based food industries, data collection, manipulation, analysis, visualisation and interpretation to increase quality insights and impacts from data streams, bioengineering for supply chain management, quality assurance systems, postharvest management for sustainable and profitable growth of Aotearoa New Zealand's plant-based industries and their manufacturing and exporting activity.
- **Bioprotection** – low/no residue pest and disease control to minimise environmental and social impacts of invasive species, maintain/increase market access and protect ecosystem services of Aotearoa New Zealand's plant-based food industries, new phytosanitary technologies for improved market access and reduce the rate of establishment of invasive species.
- **Food innovation** – plant-based foods, ingredients and supply chains with better economic, environmental, social and cultural sustainability, new functional food products and health claims, new insights into consumer behaviour, preferences and food choices, indigenous plant extracts and foods, seafood technologies, and international development.
- **Seafood technologies** – efficient and effective production, harvest, and on-board handling of wild-caught finfish based on understanding finfish behaviour, physiology, nutrition and genetics; – quality and productivity increase, open ocean aquaculture systems suited to the Aotearoa New Zealand EEZ, processing technologies for unique marine extracts for bioactive and biomaterials; – added-value products, waste reduction, use of whole of seafood resource and understanding and managing risks to seafood safety.
- **International development** – support sustainable development to reduce poverty and improve lives in Pacific and other nations.

Strategic Science Investment Fund platforms

- Plant-Based food and seafood production
- Premium plant-based and seafood products

Unique infrastructure

- National Collections of Fruit and Crop Germplasm.
- New Zealand Food Composition Database (jointly with MoH).
- Consumer sensory facilities.
- PC3 for plant pathogens (one of two in the country).
- Electrospinning Unit.
- Graders and storage facilities at industrial standard for kiwifruit and apples.
- Disinfestation Unit & Fumigation facility (unique in Australasia).
- Insect rearing facility.
- Marine finfish facility & hatchery (one of three in the country).
- Finfish facility at sea (unique in the country).
- Marine products and extracts processing pilot plant (unique in the country).

Core government contributions

- **Sustainable production** – environmental impacts for regulations, standards, and government policy regulation.
- **Food** – nutrition and health climate regulations, Aotearoa New Zealand food reputation, market insights to contribute to government strategy, and data use in govt nutrition survey.
- **Seafood** – reduced energy use of natural resource and support for regional communities.
- Contribute to Aotearoa New Zealand's Pacific and other international development commitments.

Public good contributions

- **Environment and sustainability** – safeguard water quality, resilience to climate change, ecosystem service and natural estate protection, reduce environmental and social risks of pesticide use, responsible use of natural resources, sustainable solutions to global challenges.
- **Economic** – diversified economic base supporting regional communities and diversified value-added economic base.
- **Education and support** – public informed on food composition, supporting regional communities, and safe seafood.

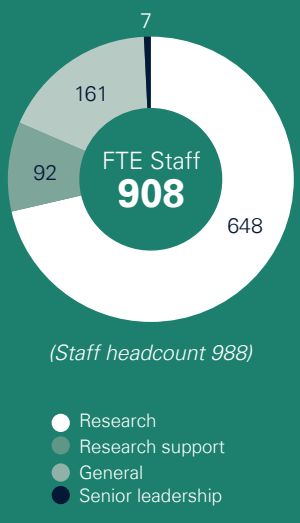
Industry contributions

- **Innovation and sustainable production** – resilient, sustainable, profitable sectors, social licence to operate and a sustainable seafood sector.
- **Economic** – market access, resilient, sustainable and profitable plant-based industries and economic sustainability of the seafood sector.
- **Social and cultural sustainability** of plant-based industries and the seafood sector.

Future direction and investment

- Social science – capacity for social implications of new technologies, public engagement, community perceptions, and social science methodologies
- Mātauranga Māori – capacity for effective partnership between science and Mātauranga Māori.
- Skills for international development – new and additional capability needed to address increasing demands from government.
- Data science – additional capacity needed in data management, data analytics and machine learning to speed innovation and insights from data.

Staff and locations



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APPENDIX 3

SCION

Scion's vision is "Prosperity from trees. Mai i te ngahere oranga". This page provides a snapshot of the key contributions and unique capabilities of Scion.

Core unique capabilities

- **Plant science, forest species** – breeding forest plant species for genetic improvement, resilience and desired traits, propagating forest plant species for seedlings/clones to be grown at pace and cost effectively to increase survival rates, whole plant physiology from understanding whole plant performance.
- **Understanding forest ecosystems** – biotic forest dynamics such as interactions between soil, trees and other species to improve growth and forest productivity, abiotic forest dynamics to understand the role of trees in carbon sequestration and water management, remote sensing for management of trees at scale, silviculture to improve management and increase forest productivity, improving tree health and wood quality, forest resilience, social and cultural benefits of forests and the non-monetary value of forests for decision making, integrating forestry for optimised management linking all part of the value chain.
- **Materials and manufacturing from trees and biomass (timber, biomaterials)** – wood science, wood modification and timber engineering to meet modern demands of architectural and engineering uses, novel and functional biomaterials, sustainable packaging that is durable and fit-for-purpose, manufacturing processes for biomaterials, waste processing and recycling for recovering waste to create value and reduce environmental impacts.
- **Enabling capabilities** – Māori co-innovation including cultural and social connections to forests, critical for breeding and propagation of indigenous trees, management of Māori land, development of value-add industry using Māori owned forestry resources, data science including size of trees, genomes and scale of remote sensing data, techno-economics for pathways to add value and identify and address commercial challenges, and molecular and biological chemistry to analyse materials and align to metabolic pathways and plant and microbial materials.

Strategic Science Investment Fund platforms

- Forest Systems
- Manufactured Products from Trees

Unique infrastructure

- National Herbarium (indigenous tree species and seed)(Nationally Significant Collection/Database).
- Soil database (plantation forestry).
- Research sites (Permanent forestry sample plots, Puruki Research Forest, Tree archive, Durability trials).
- Pilot Scale Mechanical pulping plant.
- Testing facilities (box, biodegradation, disintegration).
- Super critical fluid extraction facility.
- National Forestry Library.
- Xylarium.
- GMO Field Trial and glasshouse facilities.
- Biosecurity - Insect rearing and containment facility.

Core government contributions

- **Climate change and sustainability** – carbon sequestration understanding and management, carbon and ETS management, and support for resource understanding.
- **Biosecurity** – resistance to pests and diseases and building resilient forest ecosystems.
- **Standard and regulation** – health and safety, RMA and environment regulatory decisions, materials and manufacturing regulations and standards, and building code support.
- **Te Tiriti o Waitangi, economic development, waste management.**

Public good contributions

- **Climate change** – support a zero-carbon economy, building resilience to climate change, supporting adoption and mitigation, developing concrete/steel and fossil fuel substitutes.
- **Environmental sustainability** – water quality, protection of ecosystem services, optimised land use (economic and non-economic), and supporting resource understanding.

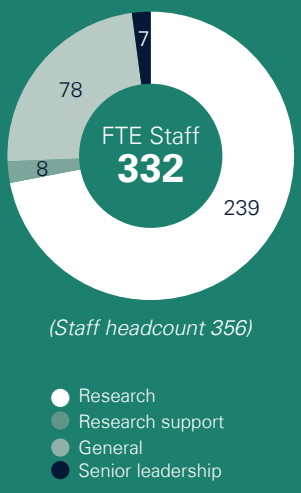
Industry contributions

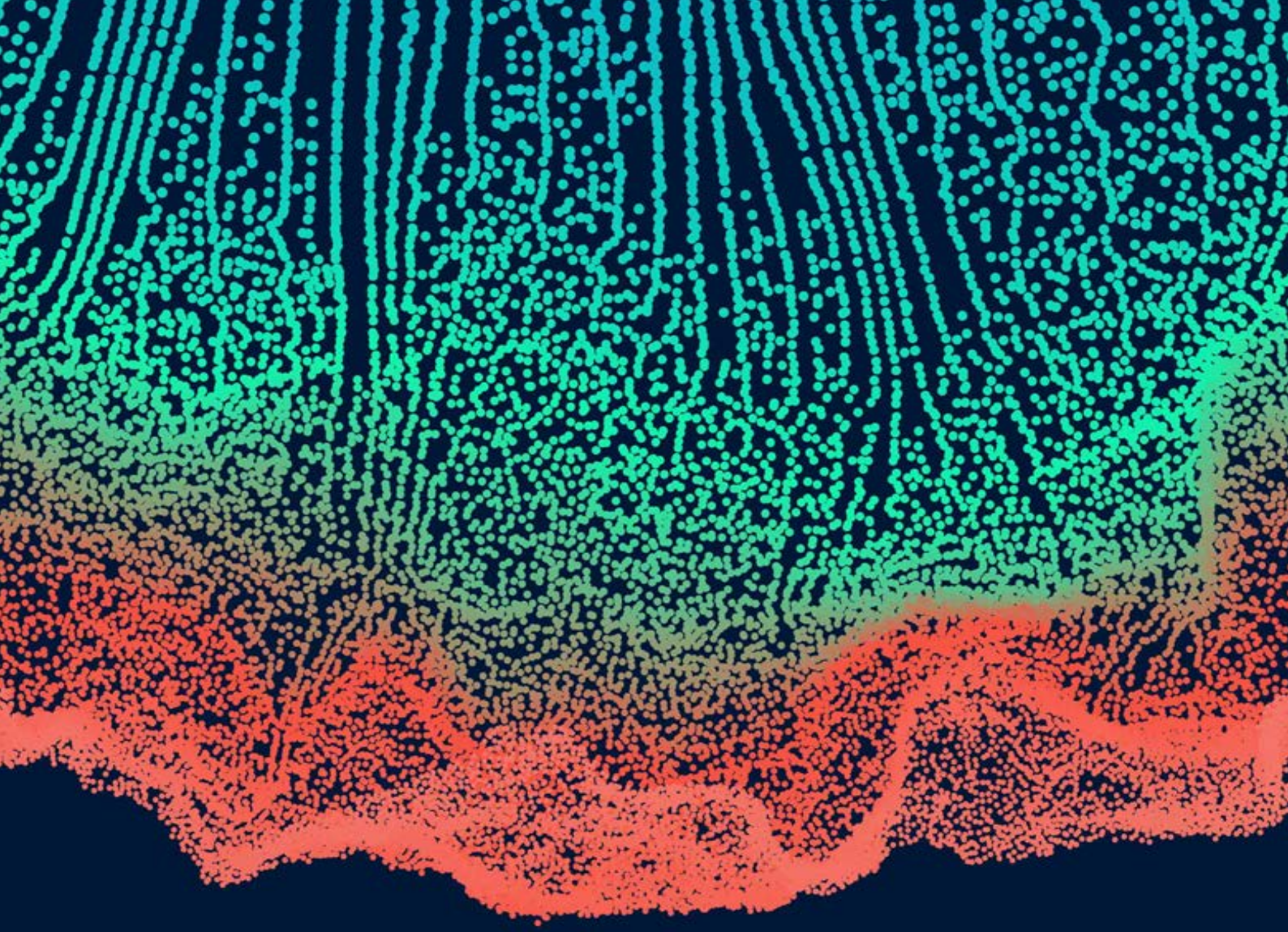
- **Environment** – improved fit-for-purpose trees, tree and forest health and productivity, improved tree survival and quality, forest understanding and management, improved sustainability, support resource understanding, and provide more sustainable products.
- **Economic** – cost efficiency and effectiveness, improved forest productivity and management, efficient and effective value chains, value recovery, and development of new knowledge.
- **Health and Safety.**
- **Māori business development.**

Future direction and investment

- **Plant species** – breeding and propagating.
- Whole plant physiology, biotic forest dynamics, remote sensing technologies including artificial intelligence, silviculture, forest resilience, novel and functional biomaterials, manufacturing processes for biomaterials.
- Redirect capability in wood science, modification and timber engineering and water processing and recycling.

Staff and locations





Science New Zealand

agresearch
āta mātai, mātai whetū

E/S/R
Science for Communities

GNS SCIENCE
TE PŪ AO

Manaaki Whenua
Landcare Research

NIWA
Taihoro Nukurangi

Plant & Food™ Research
Rangahau Ahumāra Kai

SCION™
FORESTS • PRODUCTS • INNOVATION