Conservation and Environment Science Roadmap

New Zealand Government

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Ministry for the Environment
Manatū Mō Te Taiao

Department of Conservation
Te Papa Atawhai

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This Conservation and Environment Science Roadmap is an important part of the Government's Bluegreen agenda. We view innovative science as critical to achieving our ambitious programme of goals like our 30 per cent reduction in greenhouse gas emissions by 2030, being predator-free by 2050, and having 90 per cent of rivers and lakes being swimmable by 2040. We are also waging war on invasive weeds through our 'War on Weeds' campaign and fighting for our native wildlife through our 'Battle for our Birds' pest control programme. The Roadmap will ensure our science investment across agencies is more strategic and better coordinated.

New Zealand is blessed with a unique and diverse biological, geographical, and environmental heritage, including a vast ocean domain extending from the sub-tropics to the sub-Antarctic. Tourism, agriculture and other primary industries are based on the use of our distinctive environmental heritage and natural resources.

New Zealanders want to see our environment preserved and protected. Tāngata whenua refer to our natural environment as a 'taonga' (treasure), which warrants special care and attention through intergenerational kaitiakitanga (guardianship). We aspire to continuing improvement in our economic and social well-being, which means sustainable use of our natural resources.

That means we must address a number of challenges facing our natural heritage including:

- increased pressure on fresh water and our most productive soils from our flourishing agricultural sector and expanding cities
- contaminants in our environment, invasive species of plant and animals, and other biosecurity threats
- the rapidly evolving threat of climate change
- accumulated effects of centuries of human impact on our environment and ecosystems.

Such challenges require complex policy and management decisions which must be informed by sound science and data. Forward-looking, coordinated and interdisciplinary research will ensure we have the knowledge we need. Collaboration between scientists and policy makers is crucial for delivering better environmental, economic and social outcomes.

The Government set out its long-term vision for the science system in the National Statement of Science Investment, including continued investment in our environmental research strengths. The Conservation and Environment Science Roadmap adds considerably more detail to signal the direction of future science investment in this area.

We all have a stake in New Zealand's environmental well-being and economic prosperity so it is up to all of us to take this Roadmap forward and make it a success.

Tō tātou taiāo. Tō tātou hītori. He tāonga tūturu nō Aotearoa. Maioha rawatia. Poipoia rawatia. Tukua!

Our nature. Our history. It's New Zealand's unique legacy. Enjoy it. Enrich it. Pass it on.

Hon Maggie Barry, ONZM
Minister of Conservation

Hon Dr Nick Smith
Minister for the Environment

The Roadmap at a glance

The scientific and technological world is vastly different in 2017 than it was 20 years ago. We have seen exponential advances in science and technology, and we are now facing issues and questions we never imagined in 1997.

This tells us that we need to be thinking strategically and creatively today about the kind of place New Zealand will be, and the world we will exist in, 20 years from now.

Parts of it will be beyond our imaginings, but other advances are almost upon us. In 2037 and beyond, it is likely that we'll be monitoring the water quality in our rivers remotely, in real time, from our desks rather than in waterproof waders by the side of a stream. Every household will have an app to measure and reduce its carbon footprint. We'll have access to affordable, large scale pest and weed control that is widely accepted by communities, and that doesn't threaten our treasured native species or waterways. And, the system-wide world view of mātauranga Māori will be an integral and constructive component of all scientific investigation and endeavour.

The Conservation and Environment Science Roadmap has thought about all of this, and more. It asked about the kind of world we want to live in 20 years from now and the kind of place New Zealand will be. It has asked what we will need to know, what choices we will face, and what tools and technologies we will need at our fingertips to alleviate the pressures on our environment and harness the potential of our natural world.

The Roadmap's key purpose has been to map out a shared vision of New Zealand's future science priorities and capability needs.

By drawing together thinking and advice across government agencies, science providers, and science users, it puts everyone 'on the same page' in terms of the big environmental issues we face in New Zealand. This will enable us to align our resources for scientific research and leverage our science funding. When the future arrives, the Roadmap will have ensured we have access to the critical science we need to be sure our economic, social and cultural well-being is sustained by a healthy environment.

The Roadmap does not choose, identify or develop policies or management decisions – that's the job of governments and communities. Instead, it tells us what we will want to know over the next 20 years to ensure we have robust and timely evidence to inform policy development, legislation, and conservation management.

The 20-year timeframe enables long-term strategic decisions by government agencies, researchers and funders about investment and developing research capabilities and infrastructure. We recommend that this 20-year vision be updated every four years, since we cannot have perfect foresight. We also identify clear priorities for the shorter term, to start us down the Roadmap route.

The Roadmap identifies six broad themes for our areas of scientific endeavour over the next 20 years. The themes are outlined in section 2.2.

The themes are supported by overarching principles that are particularly critical to conservation and environmental research. These include national and international collaboration; consideration of mātauranga Māori; gathering, maintaining or improving important environmental data sets and species collections; and national coordination of environmental monitoring efforts. These research principles are outlined in more detail in section 2.3.

The indicative research priorities for the next five years are:

Environmental monitoring

- New and improved tools for gathering and reporting data on condition and trends for our land, freshwater, air and marine environments.

Climate change

- Adaptation and mitigation scenarios that test and demonstrate the sensitivity of New Zealand's environment, economy, and society to climate-related impacts and extreme events.
- Technologies and practices for reducing greenhouse gas emissions.
- Models that help us better understand how changes to land-based activities that affect greenhouse gas emissions also influence freshwater quality and quantity and biodiversity.

Biosecurity

- Widely accepted and affordable solutions to invasive pests, weeds and diseases that have high-risk conservation, economic or health implications.

Integrated ecosystems

- Models that assess the effectiveness of interventions, particularly freshwater restoration programmes, including whitebait fisheries.
- Improved understanding of how our use of land affects freshwater quality and ecosystems.
- Predicting environmental thresholds and tipping points so we can look after our natural ecosystems better.
- Models and data that help communities make resource management decisions that have implications across our land, freshwater and marine ecosystems.

Freshwater

- A better understanding of how contaminants, including excess sediment, affect ecosystems, human health, and recreation to inform how we manage urban and rural land and water use.

Coasts and oceans

- Identifying key marine habitats that provide for the values we hold for biodiversity, traditional food gathering (kaimoana), recreation, and commercial fisheries.
- Understanding present and future threats to these habitats, including from climate change, and assessing management options.

Species and populations

- Cost-effective technologies to manage the threats to native species, particularly to help achieve the ‘predator-free New Zealand 2050’ goal.
- Improved tools for completing taxonomic inventories of coastal and oceanic species and land-based invertebrates.

Social and economic factors

- How to build social and cultural capital to manage the environment more effectively (including the acceptance of new technologies).
- Comprehensive models of New Zealanders’ values, beliefs and understanding of conservation and the environment.

Section 1: Introduction

1.1 What is the Roadmap and where did it come from?

A research roadmap provides a high-level, long-term view of research priorities, enabling a shared understanding of priorities and responsibilities between government, research institutions, and other stakeholders.

The Conservation and Environment Science Roadmap (the Roadmap) identifies the areas of scientific knowledge that will be needed over the next 20 years to support long-term decision-making for conservation and environmental management. This Roadmap covers the realm of New Zealand's influence, from the tropical Pacific to the Antarctic.[1] The Roadmap will help guide us toward a future where our country's well-being is supported by a healthy environment, allowing us to harness the potential of our biophysical resources to meet our economic, social and cultural aspirations.

For background on how the Roadmap began, see Appendix 1: The road to the Roadmap.

1.2 The purpose of the Roadmap

Purpose of the Roadmap

The Roadmap provides a 20-year outlook on the science knowledge, tools and capability that New Zealand requires to maintain and restore our natural systems and to optimise the benefits derived from them. Its key purpose has been to map out a shared vision of New Zealand's future science priorities and capability needs.

The Roadmap identifies research needs across the full spectrum of science disciplines. It will enhance collaboration between scientists and researchers by putting everyone 'on the same page' in terms of the big environmental issues in New Zealand now and in the future. It will build a more strategic direction for the science needed to inform key strategic areas and will eliminate existing gaps and overlaps.

Goals and objectives

- Provide a guide to New Zealand's future conservation and environmental science research needs and priorities for funders, research providers, and end users.
- Provide a framework for aligning research funding across government and research providers by identifying links between existing strategies.
- Identify current and future capability and infrastructure needs to ensure long-term research goals can be met, including international obligations.

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[1] The geographical scope of the Roadmap is New Zealand's sovereign domain in addition to the islands in the tropics (the Tokelaus); the Chatham Islands; outlying islands in the subtropics (eg, the Kermadecs) and the sub-Antarctic; New Zealand's Exclusive Economic Zone (EEZ) and Southern Ocean and the Ross Dependency in Antarctica.

Expected intermediate outcomes

- More coordinated and optimised science funding and delivery both within and between agencies and through external funders for conservation and environment issues.
- Long-term options for databases, collections and environmental monitoring.
- Stronger integration of mātauranga Māori (Māori knowledge systems) in environmental management, and greater recognition of a partnership with Māori.

Expected long-term outcomes for New Zealand

- New Zealand has a dynamic and adaptive science system that enriches New Zealand, making a more visible and measurable contribution to our productivity and well-being through excellent science.
- The capacity for the environment to sustain itself is safeguarded and the use of natural resources is optimised for the betterment of society and the economy into the future.
- New Zealanders gain environmental, social and economic benefits from healthy functioning ecosystems.
- The primary sector is agile, resilient and operates within sustainable environmental limits while maintaining and improving productivity and enhancing value of the sector and its products.

1.3 Who will use the Roadmap and how?

The Roadmap is designed to provide strategic direction to organisations which fund, resource and undertake environmental and conservation research, to ensure information will be available when it is needed to guide policy and management decisions over the long term.

Government agencies, regional councils, territorial authorities, non-government organisations (NGOs), and the private sector invest in environmental and conservation research. See Appendix 2: Funding and resourcing for more information about the system for funding scientific research in New Zealand.

By developing a shared view of New Zealand's future conservation and environmental research needs and priorities, the Roadmap will help these organisations to:

- establish or clarify their agency's long-term science strategy
- identify and guide investment in long-term capability needs
- coordinate with other agencies and providers to remove duplication and build synergies between research
- establish a framework to monitor priorities and outcomes, linking to government domain plans.

The Roadmap will also provide more clarity for directing investment in long-term science 'infrastructure' such as collections, monitoring and data management.

The Roadmap is intended to be used by research providers to identify priority areas for research bidding that meet the 'impact criteria' used by the Ministry of Business, Innovation and Employment in their funding decisions. The information in the Roadmap will also inform the private sector, non-governmental organisations, and citizens with knowledge to inform their own decision-making.

1.4 Links with other strategies and policies

The National Statement of Science Investment (NSSI) describes the Government's long-term strategy for the science system. It outlines the Government's vision of "*a highly dynamic science system that enriches New Zealand, making a more visible, measurable contribution to our productivity and well-being through excellent science*". The NSSI notes the importance of environmental research for New Zealand and that government is the main funder of this.

The Conservation and Environment Science Roadmap affirms the Government's commitment to this type of research and will help give effect to the NSSI's vision by guiding researchers towards specific research priorities with the highest contribution to well-being.

The Roadmap takes into account a number of other strategy documents and policies that set out the research goals and priorities of various institutions and agencies.

Each section relating to a theme has detailed information about links to other strategies and policies and further information is in Appendix 3: More on links to other strategies and policies.

A separate but aligned roadmap[2] is being developed by the Ministry for Primary Industries, focussing on key science and technology needs and opportunities for protecting and growing our primary industries and improving the associated environmental outcomes. The independencies between these two roadmaps are also explained in Appendix 3.

New Zealand has a strong conservation and environment legal framework that provides the mandate for what various government agencies do, and how and where they operate. The legislation that is most relevant to this Roadmap can be found in Appendix 4.

1.5 Using the Roadmap to connect

Building stronger connections between scientists and with communities

To be effective in achieving the goals in the Roadmap, government agencies and the scientific community need to improve how we integrate research efforts and information from a range of sources and disciplines including mātauranga Māori, biophysical and social sciences, engineering, and economics. New, more integrated ways of thinking are being used alongside the more discipline-specific approaches, which remain necessary in many areas. We are thinking and working at larger scales – of both time and space – and across ecosystem boundaries.

In doing this, science itself is changing to engage better in co-design and co-production models. Traditional science is increasingly linking to citizen science and indigenous world views.

Some new technologies are likely to challenge predominant or strongly held values and views in society. Researchers need to engage early with communities to understand any prevalent concerns and develop research and operational principles and rules in response. As new technologies are tested and used, our understanding of their costs and benefits will grow. In the meantime we must be careful to avoid unscientific regulations which would give the impression that there is undue risk when there is not. Systems and processes will need to

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[2] The *Primary Sector Science Roadmap* (Ministry for Primary Industries, in progress).

be adaptable and responsive to changes and externalities for social licence to emerge and take hold.

These are exciting developments that are challenging to science and society, and are an important focus for this Roadmap. As part of addressing these challenges, the Roadmap sets another challenge: for government agencies to work together on the science requirements to answer the big questions, and for the research community to respond collaboratively, innovatively and creatively to these questions.

Building stronger global connections

An important part of this Roadmap is identifying opportunities for international collaboration on research. Many of the problems identified are shared with other nations. For instance, New Zealand has committed, along with other countries, to work towards meeting the United Nations Sustainable Development Goals for 2016–2030, which recognise environmental limits and over-consumption as impediments to sustainable development. New Zealand is also a signatory to a large number of international environmental treaties. Many multilateral environmental agreements, such as the Convention on Biological Diversity, the Stockholm Convention on Persistent Organic Pollutants, and the Montreal Protocol on Substances that Deplete the Ozone Layer are directly related to how we manage our natural environment, and their implementation requires evidence-based policy.

The Convention on Biological Diversity, for example, has a strategic plan which outlines a set of strategic international targets (known as the Aichi Targets) to be referenced when developing national and regional targets. The Ramsar Convention provides international direction on how we manage out wetlands, while the United Nations Framework Convention on Climate Change (UNFCCC) agreements set global policy direction on global warming and how to mitigate it. Under the UNFCCC, New Zealand has committed to promote and cooperate in research, systematic observation, and development of data archives related to the climate system.

New Zealand is a member of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), which assesses the state of the planet's biodiversity and ecosystem services to inform decision-making. New Zealand is also a member of the Global Biodiversity Information Facility, a collaborative open data platform that enables data sharing to inform better decisions on conservation and sustainable use of biological resources globally.

Other nations are also very interested in the signals provided by the Pacific/Southern Ocean/Antarctica region on how the environment is changing and why, and in the conservation of the region's species and ecosystems. Our global science connections need to be nurtured and expanded so the best solutions can be found both for New Zealand and globally.

Section 2: Overview of the Roadmap

2.1 Introduction

Managing our natural assets in a way that sustains both environmental health and economic growth is complex, and we have many challenges. Our marine, land and freshwater ecosystems show the cumulative effects of centuries of resource use and other human impacts, beginning with hunting, whaling and sealing, widespread deforestation and wetland drainage, through to the more recent effects of agricultural intensification and expanding urban areas.

Many exotic plant and animal pest species and diseases have been introduced into New Zealand and threaten our native species and ecosystems and our primary sector. Many more could arrive and add to our biosecurity burden. Managing the risks they pose to our economy and environment presents an opportunity – to move towards a 'predator-free New Zealand' – an aspirational but achievable vision, if the best science can be used to its full potential.

The cumulative impact of human-made (anthropogenic) substances is also becoming increasingly evident in the environment. Industrial chemicals and toxic metals have long been a concern, but we are now facing the effects of the accumulation of substances, including micro-plastics, nanoparticles, and other waste from the products we use. Scientific research is essential to assess the risks, and ensure we have the right tools to monitor and mitigate them.

A range of land uses, including the recent expansion of dairy farming and urbanisation, has resulted in additional pressures on our freshwater systems – in terms of both extractive use and discharges – leading to the degradation of many rivers and streams, lakes, wetlands, aquifers, and other water bodies.

Climate change is also having a significant impact on our environment, and emissions of greenhouse gases from human activities will continue to accelerate these changes, placing increasing pressure on our marine, freshwater and terrestrial ecosystems, as well as our primary sector. We will need to understand impacts and thresholds and develop ways to mitigate these effects as well as help our ecosystems adapt where possible. Our national targets for reducing our greenhouse gas emissions are also challenging – but there are many opportunities for innovation to enable a transition to a low-carbon economy.

Research needs to identify where adverse effects are occurring and why, predict future changes, guide options for intervention, identify and develop the technologies required, and support the evaluation of effectiveness of interventions.

Restoration of an environment that has been degraded over many decades – even centuries – can be slow and complex, and needs to be informed by research. Solutions must draw on environmental knowledge developed by tāngata whenua over many generations, as well as the biophysical, social and economic sciences and developments in technology. Long-term, strategic planning of research will be required. In some cases, a shift in thinking (both within the scientific and wider community) may be required. For example, new developments in genetic and other technologies provide opportunities for tackling pest animals and plants. We need to understand the factors that influence public decision-making about utilising some of these techniques. Input from social and economic sciences will be needed to understand how people value the environment, and to inform the development and evaluation of socially acceptable interventions.

The Roadmap identifies that we need robust biophysical, social and economic science, observations and data to:

- identify where adverse effects are occurring and why
- predict future changes
- provide guidance for interventions
- identify and develop the required technologies
- enable evaluation of policies and management interventions.

The Roadmap identifies key research areas that are particularly critical for sustaining New Zealand's environment and the future prosperity and well-being of New Zealanders. It does this in a framework of six main themes and five sub-themes.

2.2 Major themes for future research

The themes can be organised into four groupings as shown below:

Process themes

The process themes support all areas of research and are interwoven into all other themes, but also stand as themes in their own right.

Theme 1: Environmental monitoring and data management

Developing, improving and integrating systematic observations, tools, databases, modelling and monitoring technologies for understanding and reporting on natural resource management. Includes issues of data access, sharing and management, and integration of environmental, economic, social and regulatory data.

Theme 2: Mātauranga Māori

Recognising, developing and utilising mātauranga Māori both alongside and integrated with other science approaches, to improve environmental outcomes and support Māori to exercise kaitiakitanga (stewardship) and other traditional roles. Mātauranga Māori encompasses traditional and contemporary knowledge, wisdom, and understanding of human-environment relationships.

Pressure themes

These are cross-cutting issues across the biophysical domains. Pressures such as population growth, resource consumption, increasing tourism and environmental contaminants are not dealt with as separate themes but are incorporated into research questions within the themes.

Theme 3: Climate change

Improved monitoring and modelling of observed and expected changes and their environmental, social and economic impacts; development of mitigation and adaptation options; tools and approaches to reduce emissions.

Theme 4: Biosecurity

Data, understanding, and tools to help achieve effective and efficient management of risks posed by pests and diseases, including eradication of invasive species.

Domain theme

The domain theme relates to the interactions between ecosystems and processes across all domains – land, fresh water, coasts and oceans, urban – as well as species and populations.

Theme 5: Integrated ecosystems and processes

Data, understanding and tools to inform integrated management of the environment as a whole, involving complex interactions between land, fresh water, coasts and oceans, urban environments, and species and populations, which also represent sub-themes under this theme.

Land

Data, understanding and tools to guide policy and management approaches to improve conservation and environmental outcomes, including mitigating the potential impacts and/or threats from disturbance, climate change, land use, and natural hazards.

Fresh water

Data, understanding and tools to support policy and management approaches that achieve healthy and resilient ecosystems and habitats, meet cultural and recreational needs and avoid adverse human health impacts, while enabling the efficient, equitable and productive use of water.

Coasts and oceans

Data, understanding and tools to support policy and management approaches that enable coastal and oceanic species, ecosystems and processes to be sustained or recovered, and which support biodiversity and the contribution of our coasts and ocean[3] to the prosperity and well-being of New Zealanders.

Urban

Identifying ways to achieve more resilient and liveable urban environments, maximising their value for people and biodiversity and environmental quality while minimising negative impacts on public health, and on land, fresh water and coastal and marine environments.

Species and populations

Data, understanding and tools to inform management and policy to protect our native biodiversity and habitat quality in the face of multiple and increasing cumulative pressures, such as habitat degradation and reduction, pests and climate change.

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[3] Covers New Zealand's Exclusive Economic Zone (EEZ), as well as waters over which New Zealand has a defined and agreed management interest, such as the extended continental shelf, the southwest Pacific Ocean and the Ross Sea, Antarctica.

Human dimensions theme

The human dimensions theme relates to the 'human' factors affecting the environment, including links between values, beliefs and environmental attitudes, environmental knowledge, social licence issues, and engagement in governance and decision-making.

Theme 6: Social and economic factors

Identifying societal values for the environment, and developing effective methods to assess the value of natural capital and ecosystem services to inform environmental and economic decision-making. Also encompasses mechanisms to encourage New Zealanders to make more sustainable choices, and factors relating to engagement in decision-making about the environment. This theme also includes economic factors including the effect of changes in international market forces.

2.3 Overarching research principles

While all of the research questions listed in the themes are considered to be strategically important for informing future decision-making, there are some overarching research requirements that are particularly critical for protecting New Zealand's environment and the future prosperity and well-being of its people. These are outlined below.

Collaboration

A culture of collaboration and interdisciplinary research partnerships is a key to success in providing policy-relevant conservation and environmental science. New Zealand is an extensive island archipelago with a large surrounding Exclusive Economic Zone, but with limited resources and huge challenges, we can only meet our research needs by working collaboratively with international partners. Such work is needed on mainland New Zealand but also in Antarctica, the sub Antarctic islands, the Pacific territories in the realm of New Zealand,[4] and elsewhere.

Collaboration between researchers nationally, facilitated by improved data-sharing practices and data infrastructure, as well as more and better use of citizen science.

Mātauranga Māori

Treaty settlements and increased emphasis on collaborative approaches – especially in freshwater management – have highlighted the benefit of using mātauranga Māori for informing conservation and environmental policy and management. The Roadmap supports the integration of mātauranga concepts across all themes to provide more system-wide solutions to environmental sustainability, as well as supporting mātauranga Māori in its own right.

Taxonomic collections and expertise

Many gaps remain in our knowledge of New Zealand's native flora and fauna. The lack of knowledge reduces conservation, environmental and economic opportunities – it is not

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4 The 'Realm of New Zealand' is the area in which the Queen of New Zealand is head of state. The Realm of New Zealand includes one Antarctic territorial claim, the Ross Dependency; one dependent territory, Tokelau; and two associated states, the Cook Islands and Niue.

possible to protect, or benefit from, what we don't know about. Continued resourcing for discovery, documentation, and improving our knowledge of biota is critical, particularly in the marine domain.

Up-to-date taxonomic collections and taxonomic expertise are vital to produce the evidence base for conservation and environmental management, as well as having broader cultural and scientific importance. The Roadmap strongly supports the recommendations of the Royal Society Report on National Taxonomic Collections in New Zealand that a strategic and more tailored approach to investment in this area is needed, and that urgent attention should be given to maintenance of taxonomic expertise and services (Royal Society of New Zealand, 2015).

Environmental monitoring, data sharing and infrastructure coordination

National data coordination and information exchange needs to be established for all types of environmental data, including taxonomic collections. This requires investment in data infrastructure and management, and establishing protocols for open data access, including to the public to encourage uptake of citizen science.

Ongoing environmental monitoring is imperative, facilitated by technical innovation in areas of big data and remote sensing. This will provide enormous opportunities to grow research and its influence on policy.

2.4 Research priorities for the next 5 years

The Roadmap sets out research goals and objectives for a 20-year timeframe. This is critical for long-sighted decision-making about research needs. However, it is also necessary to have clear priorities over the shorter term. Owing to limited funding and capability, not all research can be given the same weighting, and critical choices need to be made.

Through in-depth discussion with science and policy experts from the natural resource sector government agencies,[5] regional councils, and other research organisations, the following areas of research from within this Roadmap have been identified as indicative priorities for the next 5 years. These priorities are intended to provide clear direction, but will be refreshed as issues evolve and change.

Environmental monitoring

- New and improved tools for gathering and reporting data on condition and trends for our land, freshwater, air and marine environments.

Climate change

- Adaptation and mitigation scenarios that test and demonstrate the sensitivity of New Zealand's environment, economy, and society to climate-related impacts and extreme events.
- Technologies and practices for reducing greenhouse gas emissions.

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[5] The Natural Resources Sector agencies are the Ministry for the Environment, Department of Conservation, Ministry for Primary Industries, Ministry for Business, Innovation and Employment, Te Puni Kōkori, Land Information New Zealand, Department of Internal Affairs, and Ministry of Transport.

- Models that help us better understand how changes to land-based activities that affect greenhouse gas emissions also influence freshwater quality and quantity and biodiversity.

Biosecurity

- Widely accepted and affordable solutions to invasive pests, weeds and diseases that have high-risk conservation, economic or health implications.

Integrated ecosystems

- Models that assess the effectiveness of interventions, particularly freshwater restoration programmes, including whitebait fisheries.
- Improved understanding of how our use of land affects freshwater quality and ecosystems.
- Predicting environmental thresholds and tipping points so we can look after our natural ecosystems better.
- Models and data that help communities make resource management decisions that have implications across our land, freshwater and marine ecosystems.

Freshwater

- A better understanding of how contaminants, including excess sediment, affect ecosystems, human health, and recreation to inform how we manage urban and rural land and water use.

Coasts and oceans

- Identifying key marine habitats that provide for the values we hold for biodiversity, traditional food gathering (kaimoana), recreation, and commercial fisheries.
- Understanding present and future threats to these habitats, including from climate change, and assessing management options.

Species and populations

- Cost-effective technologies to manage the threats to native species, particularly to help achieve the 'predator-free New Zealand 2050' goal.
- Improved tools for completing taxonomic inventories of coastal and oceanic species and land-based invertebrates.

Social and economic factors

- How to build social and cultural capital to manage the environment more effectively (including the acceptance of new technologies).
- Comprehensive models of New Zealanders' values, beliefs and understanding of conservation and the environment.

Section 3: The Roadmap themes

3.1 Introduction

The Roadmap sets out the high-level policy-related science questions that will need to be answered to provide the evidence base to inform environmental and conservation policy across a broad range of areas. These questions and their associated research topics are organised into six major themes and five sub-themes. The themes provide a broad framework for the research that will be required – they should not be viewed as silos for research, but rather as interconnected and cross-cutting thematic areas.

In this section, each theme subsection begins with a description of the theme, followed by the strategic question or questions that will guide future research. This is followed by an outline of the 20-year priority research areas for each theme, which responds to the strategic questions, followed by a table presenting examples of the needs, opportunities and outcomes for each research topic within the theme. An outline of current capability and strategic needs for each theme follows, and finally, the links to other strategies and policies are set out.

3.2 Process themes

Photo courtesy of H Christophers, Department of Conservation

Theme 1: Environmental monitoring and data management

About this theme

This theme encompasses the development and use of tools, databases, data infrastructure, data and modelling to inform environmental monitoring and associated decision-making. It includes issues of data access, sharing and management, as well as integration of environmental, economic and social data.

Key question

How can we develop, improve and integrate the systematic observations, tools, databases, modelling and monitoring technologies for reporting on environmental management and its outcomes, leading to improved management practices and policy?

What are the priorities?

- New and improved tools for cost-effecting gathering of data on condition and trend.
- End-to-end automated process to support reporting on New Zealand's environment (eg, instantaneous and integrated process from data collection, data analysis, through to reporting).
- Development of new statistical areas, in particular relating to ecosystem services, environmental information gathered by and relevant to Māori, and linked environmental-economic information.

Examples of needs, opportunities and outcomes for research topics

Research topics	**Needs** Basic knowledge	**Opportunities** Practical application	**Outcomes** Translation into policy and management
	Examples of types of knowledge needed to populate models, develop tools, and inform policy	Examples of models, research approaches, or technologies that build on basic knowledge	Examples of possible outcomes when knowledge needs and innovation opportunities are achieved to inform management and policy
Ongoing monitoring of natural and managed ecosystems and their services to track changes in physical conditions over time • Integrating data and metadata to generate high-level, ecosystem-wide monitoring and reporting • Delivery of user-friendly data to stakeholders	• Developing and deploying innovative tools for efficient and cost-effective gathering of data • Integrated, multi-purpose remote sensing technology	• Citizen science provides opportunities for data collection and engagement	• New technological developments will provide user-friendly, linked science/policy response data for improved policy and management
Using mātauranga Māori-based monitoring to inform research and citizen science to generate new insights into trends	• Defining indicators and monitoring variables to capture mātauranga Māori and the state of mauri	• Developing data products, delivery systems, and tools that incorporate mātauranga indicators	• Ability to assess the significance of the environment from a Māori perspective • Mātauranga indicators support kaitiakitanga and help improve environmental outcomes overall

Research topics	**Needs** Basic knowledge	**Opportunities** Practical application	**Outcomes** Translation into policy and management
Land-use data, classifications, and management	• Developing an official dataset with an appropriate level of detail for both local and national coverage, using standard land-use classifications	• Linking data on farm practice and environmental impact to financial and other relevant data, such as GIS and census data included through the integrated data infrastructure.	• Resource management applications facilitate optimal use of land to achieve environmental and economic objectives, including water quality and climate change
Improved tools and methods for **data gathering and management in the marine domain**	• Access and availability of data and metadata • New tools and data infrastructure for marine data monitoring including: – ocean acidification and warming – native marine birds and mammals – coastal habitats and species – deep-water habitats and species	• Large scale datasets with spatial granularity utilising multi-dimensional forms of mapping and interpretation	• More timely, robust and comprehensive data is available to quantify the state of the marine environment at a national level • Data allows improved assessment of impacts of fishing and other activities on coastal and open ocean ecosystems
Monitoring data to support New Zealand international obligations on climate change	• Making data on emissions and sequestration (collected through the Emissions Trading Scheme) available for research • Data on socio-economic responses, pressures, adaptation, and mitigation	• A comprehensive set of indicators that show the environmental, social and economic implications of climate change for New Zealand • Cost-benefit analysis, computable general equilibrium models	• Integrated data and models are used to assess extent to which targets are met, the impact of policy interventions, and to identify barriers to the change required to meet targets

Current capability and strategic needs

The capabilities, infrastructure and responsibilities for undertaking systematic environmental monitoring are spread across many organisations, reflecting the many purposes and requirements for such data. Collaboration, standardisation of methodology, and sharing of data will help support the best outcomes for New Zealand as a whole. Improved capability and capacity will be required in taxonomy, bioinformatics, data management, and analysis.

Availability and quality of data varies across topics and between regions of New Zealand. There is an essential need for further and ongoing work to improve monitoring technologies and data storage, management and exchange. This includes building on the Environmental Monitoring and Reporting (EMaR) initiative supported by the Ministry for the Environment, Statistics NZ, and Local Government New Zealand, which is exploring standardisation of methods and sharing of collection, management and exchange protocols to allow national-scale interpretation of regional data. New cost-effective approaches are required for management to occur at the integrated ecosystems and processes scale. Further developments in modelling applications are required to provide information in unmonitored areas. The growth in data science techniques, such as machine learning, will help facilitate this.

Baseline data is insufficient in many areas. Fortunately, new techniques are being developed that offer the potential to greatly improve how we gather baseline data, analyse and interpret these data, and increase monitoring efficiency and effectiveness. It is important to ensure observation locations and times are truly representative – that is, covering a full range of environment types and conditions.

The ability to fully utilise and benefit from mātauranga Māori-based approaches to environmental monitoring and data management requires capability development in central, regional and local government and within Māori groups and organisations – supported by research providers and by partnerships with iwi/hapū/whānau and Māori researchers.

Regional councils will continue to undertake and support monitoring to address management and public information needs for their region. Government departments have a role in supporting data programmes that improve the availability of quality national data to support their reporting and policy development requirements. Science funding administered by the Ministry of Business, Innovation and Employment supports important long-term observation programmes which provide information vital to understanding changes across the themes identified in this Roadmap. However, the responsibility for these programmes has mostly been devolved to Crown research institutes and there is poor national oversight, as well as critically declining funding levels.

Links with other strategies and policies

Under the Environment Reporting Act 2015, the Ministry for the Environment and Statistics New Zealand are responsible for regular reporting of the state of the environment in New Zealand. Regional councils also report on the state of the environment in their regions. Underpinning some of this work and related needs is the Environment Domain Plan (Statistics New Zealand, 2013). The Plan is the result of a collaborative effort between Statistics NZ, the Ministry for the Environment, and the Department of Conservation to examine official information and provide insights about the state of New Zealand's environment.

The data used for state of the environment reporting and for environmental decision-making comes from monitoring and data collection undertaken by many agencies, organisations and science providers. For many environmental parameters, detecting change is important, so a continued programme of monitoring, meeting international standards for measurements and data assurance (where relevant) is vital. We also have responsibilities for sharing some data internationally – for example, under the United Nations Framework Convention for Climate Change, and as a member of the World Meteorological Organization.

Data are only useful if they can be accessed, and it is government policy that government data should be open, readily available, well managed, reasonably priced, and re-usable (unless there are necessary reasons to protect data). Thus it is vital to provide user-friendly access, good metadata (describing the data and the way it has been collected), and displays and analyses of data that are straightforward for policy analysts and resource managers to understand. Approaches to doing this include collaborative initiatives across government departments, councils, research providers, NGOs and the philanthropic sector. A good example is LAWA (Land, Air, Water Aotearoa), a user-friendly website which shares regional council environmental data with the public.

The research needs identified here, when addressed, will help provide the information required to inform policy development and initiatives, consistent with the following examples of strategic policy initiatives and legislation:

- **Ministry for the Environment and Statistics New Zealand:** *Environmental Reporting Act 2015* – Mandatory reporting on the New Zealand environment
- **Statistics New Zealand, Ministry for the Environment and Department of Conservation:** *Environment Domain Plan 2013: Initiatives to Address our Environmental Information Needs* (Statistics New Zealand, 2013) – Examines information requirements for insights on the state of our natural environment
- **Ministry of Business, Innovation and Employment**: *Environmental Data Management Policy Statement* (2010) (Ministry of Research, 2010) – More and better domestic and international collaboration, greater use of e-research services and applications, better use of large scale research infrastructure, and greater connectedness to end users (empowering Crown research institutes to drive better data management)
- **Environmental Protection Authority (EPA)**: *Hazardous Substances and New Organisms Act 1996* and *Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012*– EPA has responsibility for consent decisions and monitoring.
- **Regional councils** – *Research for Resource Management: Regional Council Research, Science & Technology Strategy 2016* refers to the need to retain and build scientific capability critical to state of the environment monitoring (New Zealand Regional and Unitary Councils, 2016).

Theme 2: Mātauranga Māori

About this theme

This theme relates to the use of mātauranga Māori (Māori knowledge systems, worldview and values) for improving environmental and conservation management. It encompasses traditional and contemporary knowledge, wisdom, and understanding of human-environment relationships. The research needs identified in this theme focus on understanding the distinctive contribution that mātauranga Māori can make to environmental and conservation research, science and technology for the benefit of Māori and New Zealand as a whole.

Mātauranga Māori is a means to interpret and explain the world, anchored by whakapapa (interconnected genealogy and kinship) that draws connections between iwi, hapū and whānau, ancestors, and the natural world. In parallel with science, it is an evolving body of knowledge that enables people to understand and form meaningful relationships with their environment.

Traditionally mātauranga Māori was key to resolving tensions inherent in natural resource use, based on tikanga (customary system of values and practices). Iwi and hapū have the responsibility to exercise kaitiakitanga to sustainably manage natural resources within their area of mana whenua (authority). Underpinned by mātauranga Māori, iwi and hapū seek to protect and perpetuate the ability to practice Māori culture and retain their ancestral connection to the whenua through heritage protection, preservation of indigenous biodiversity, ecosystem restoration, sustainable resource management, and participation in urban and rural planning processes.

Linking science with mātauranga Māori and citizen science for improved ecosystem management

Te Waihora (Lake Ellesmere) is a taonga to Ngāi Tahu. It is New Zealand's single most diverse bird habitat and has considerable botanical diversity. It is also valued for fishing and duck shooting. As New Zealand's largest single commercial eel (tuna) fishery, it is also important economically. Yet the lake is also a sink for a large area of agricultural land and has become hypertrophic – rich in nutrients (especially nitrogen and phosphorus).

Environment Canterbury, Ngāi Tahu, Department of Conservation, and others are involved in improving the management of the lake, informed by scientific information and mātauranga. Ngāi Tahu is using the Cultural Health Index, the Waihora Ellesmere Trust is coordinating an annual citizen science bird census of the lake (alongside Birds New Zealand and others), and universities and the regional council are undertaking extensive research into aspects of the lake and its catchment.

All of this information is integrated within decision forums (the Selwyn-Waihora Zone Committee and the Joint Officials Group comprising Ngāi Tahu, Environment Canterbury, Selwyn District Council, and Christchurch City Council), which treat the evidence as valid within the constraints and limitations of the collection of data and its interpretation. The information is then used to inform management interventions.

This approach is all about science – it works by treating all sources of information and knowledge with respect, and by testing it against the same criteria of validity and reliability.

Photo courtesy of Peter Langlands, Department of Conservation

Key question

How can mātauranga Māori be recognised, developed and utilised in new ways, both alongside and integrated with other science approaches, to improve environmental outcomes and to support Māori to exercise traditional roles such as kaitiakitanga and rangatiratanga?

What are the priorities?

- Exploring the circumstances to exercise kaitiakitanga on culturally appropriate spatial and temporal (eg, intergenerational) scales.
- Identifying opportunities to incorporate the concept of mauri (life force) and other mātauranga-based concepts into land-use and other environmental decisions.
- Using both Western science and mātauranga approaches to provide effective solutions for the restoration of taonga, such as lakes, rivers and streams.

Examples of needs, opportunities and outcomes for research topics

Research topics	Needs Basic knowledge	Opportunities Practical application	Outcomes Translation for policy and management
	Examples of types of knowledge needed to populate models, develop tools, and inform policy	Examples of models, research approaches, or technologies that build on basic knowledge	Examples of possible outcomes when knowledge needs and innovation opportunities are achieved to inform management and policy
• Understanding/learning from mātauranga Māori and other **Māori frameworks for valuing, monitoring and managing natural resources** • Translating and integrating these learnings for practical application in different contexts	• Understanding social and cultural values • Understanding Māori views of the relationship between ecosystems and human well-being • Understanding the basis of mauri	• Support framework to utilise Māori knowledge in land management and productive systems • Integration of Mauri Model, Mauri Compass	• Cultural values and mātauranga Māori included in environmental and land-use management decisions • System-wide planning to meet economic goals for New Zealand • Restoring and increasing the mauri of land, fresh water and marine environments
• Assessing the **barriers to and opportunities for integration or coexistence of mātauranga Māori and other science frameworks** in a policy or management context	• Understanding the basis of the two knowledge systems • Identifying the place of mātauranga Māori in current policies	• Co-design of policies acknowledging knowledge systems	• Integrated policy design informed by mātauranga reflecting Treaty obligations
• Exploring **use of scientific tools and approaches to support Māori functions and powers, duties and roles** (eg, power to exercise rangatiratanga, the duties as kaitiaki, the role of tāngata whenua)	• Monitoring data and observations on mahinga kai species, kaimoana, taonga species • Exploring minimum standards of ecological integrity to meet cultural values and aspirations	• Incorporating mātauranga values into GIS tools for environmental planning and management	• Māori values and indicators are used in conjunction with science tools and technologies to support Māori functions, powers, duties and roles in managing the natural environment

Capability and strategic needs

Current understanding and appreciation of mātauranga Māori and language and culture is variable across agencies, industries and individuals. In addition, there is limited capability and/or capacity of people in some government and research organisations and communities to identify the opportunities arising from mātauranga Māori. This continues to cause a disconnect in policy, regulatory design, and implementation and ultimately effective partnerships.

Support for Māori researchers to strengthen technical skills and science literacy, and for both Māori and non-Māori to better understand the interface between mātauranga Māori and other science is a priority. Equally, more emphasis within the research funding environment needs to be placed on development of Māori leadership within key research programmes.

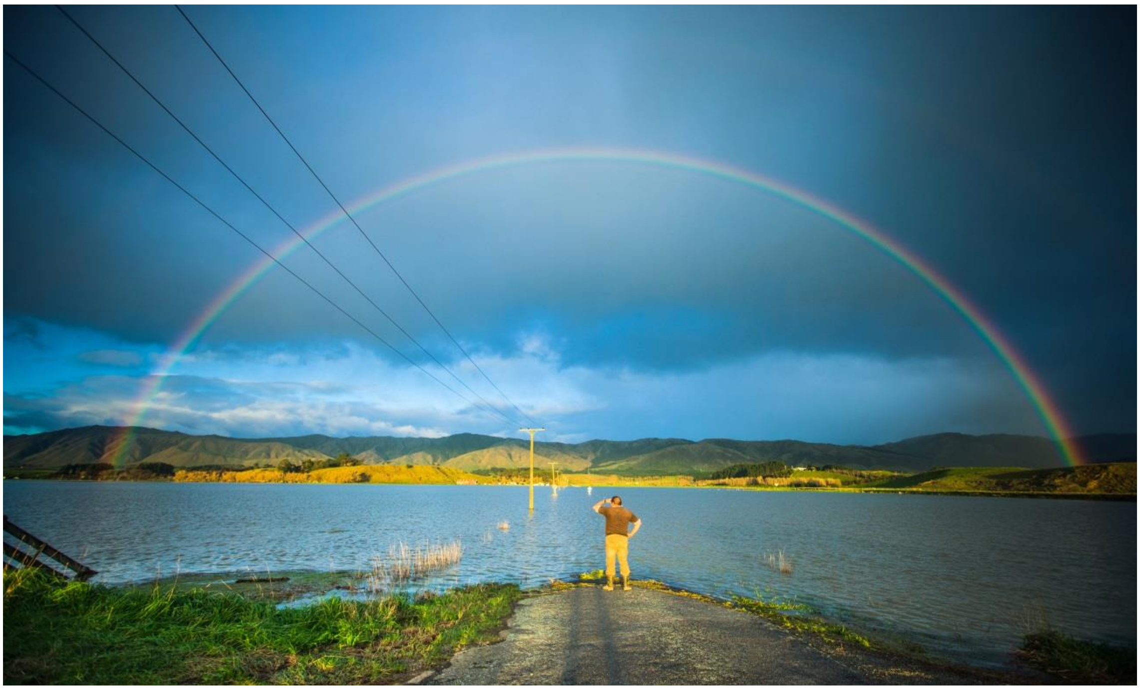
While there is considerable 'basic knowledge' around mātauranga Māori knowledge systems, development of models is *ad hoc* and the translation of science into policy and management approaches is limited, especially in marine, estuarine and freshwater environments, and more limited still is the development of complementary policy and management tools. More effort is needed to strengthen capability in these areas.

Links with other strategies and policies

The research needs identified here, when undertaken, will help provide the information required to inform policy development consistent with the following examples of strategic policy initiatives.

- **Ministry for Business, Innovation and Employment**: *Vision Mātauranga* (Ministry of Business, Innovation and Employment; Ministry of Research, Science and Technology, 2007) – Goal: Unlock the innovation potential of Māori knowledge, resources and people to assist New Zealanders to create a better future
- **Statistics New Zealand, Ministry for the Environment and Department of Conservation:** *Environment Domain Plan 2013: Initiatives to Address our Environmental Information Needs* (Statistics New Zealand, 2013) – Māori environmental statistics; environmental monitoring from a Māori perspective; developing indicators reflecting Māori values.

3.3 Pressure themes



Theme 3: Climate change

About this theme

This theme relates to measuring and predicting changes in the climate system and the environmental, social and economic impacts of these changes, technologies and practices to reduce net greenhouse gas emissions and support adaptation to climate change.

Future risks for New Zealand from climate change include sea-level rise and its impacts on our coasts and urban areas (which are largely coastal), increased likelihood of floods, fire and drought, increased competition for fresh water, impacts on terrestrial, freshwater and marine ecosystems, and flow-on effects from climate change impacts and responses elsewhere in the world. Ongoing monitoring, research and modelling for climate changes and impacts, as well as improved social and economic knowledge and modelling and research into effective public engagement and governance processes, are needed to inform policy and adaptation management.

New Zealand’s target under the 2015 Paris Climate Agreement is to reduce greenhouse gas emissions to 30 per cent below 2005 levels by 2030. Further data gathering and analysis is required to fully understand the benefits, risks and trade-offs associated with specific interventions, including new technologies (Royal Society of New Zealand, 2016). 2030 is only a little over a decade away, so the need for progress is urgent. The need is also ongoing, as the Paris Agreement targets of limiting global temperature increase to 2°C or less will require substantially more stringent targets as the century progresses.

Climate change is also a cross-cutting issue relevant to all of the themes in this Roadmap, since the biological, physical and social systems these themes relate to are all expected to be influenced by changes in climate.

Key questions

- What are the potential risks from climate change for New Zealand's environment, economy and society, and what options exist or can be developed to manage and reduce the risks, and/or adapt to the expected impacts?
- What options and technologies exist or can be developed to reduce New Zealand's net greenhouse gas emissions, and what are their economic, environmental and social costs and benefits?

What are the research priorities?

- Adaptation and mitigation scenarios that test and demonstrate the sensitivity of New Zealand's economy, environment and society to climate-related impacts and extreme events.
- Integrated land-use models that capture interactions between greenhouse gas mitigation, water quality/quantity and biodiversity outcomes.
- Emerging technologies and practices for reducing greenhouse gas emissions across different sectors, such as agriculture, waste management, and transport.
- Improving monitoring and modelling of the impacts of climate extremes and sea-level rise on the New Zealand coast, developed in conjunction with a response system based on adaptive management practices.
- Understanding how to transition New Zealand to a low-carbon economy through strategic changes in land-use patterns, minimising emissions of greenhouse gases, and optimising our marine and land carbon sinks.

Examples of needs, opportunities and outcomes for research topics

Research topics	**Needs** Basic knowledge	**Opportunities** Practical application	**Outcomes** Translation for policy and management
	Examples of types of knowledge needed to populate models, develop tools, and inform policy	Examples of models, research approaches, or technologies that build on basic knowledge	Examples of possible outcomes when knowledge needs and innovation opportunities are achieved to inform management and policy
Monitoring and interpreting observed changes to New Zealand's climate, and their environmental, social and economic impacts	• Ongoing tracking of characteristics, location and rate of change; expansion of databases (including provision of public access) • Understanding the interaction between natural variability and climate change as drivers of any observed changes • Impacts monitoring	• Exploiting growth in internet-connected sensors, statistical and model-based evaluation to detect deviations from historical patterns and attribute changes • Modelling to understand impact attribution – eg, earth system modelling	• Information tools available to policy makers and private sector decision-makers that track social and economic impacts as well as biophysical impacts • Case studies that test and demonstrate the sensitivity of New Zealand's economy, environment and society to climate-related impacts and extreme events

Research topics	Needs Basic knowledge	Opportunities Practical application	Outcomes Translation for policy and management
• **Projections** of how, where and when New Zealand's climate, including its extremes and variability, will change as a result of a range of plausible emission scenarios • **Impacts** on New Zealand's natural and built environment, society and economy in conjunction with other observed and possible trends/ changes for different scenarios	• Regional/local climate modelling • Build on and expand existing knowledge of physical systems through models and observational and time series data • Expand limited knowledge of biophysical, economic and social impacts and risks under a wide range of climate and socio-economic scenarios	• Use of plausible scenarios to understand individual and societal risk, perceptions and responses to climate change, including consideration of compound and indirect consequences • Expanding modelling and data analysis tools to assess implications of climate-related off-shore driven changes in trade, migration and security on New Zealand	• Improved risk management and communication tools utilise decision-relevant data on: – projected/potential changes in extremes – thresholds at species and system level linked to changes in climate – critical adaptation deficits and systems at regional and local scales requiring priority intervention at multiple levels
Climate-related changes to oceans – effects on our natural and managed coastal and marine systems	• Understanding vulnerabilities of New Zealand marine ecosystems and key species to ocean acidification and warming • Improving projections for New Zealand and understanding the drivers and impacts of sea-level rise • Understanding potential changes in the Southern Ocean	• Modelling changes in ocean circulation and wave heights affecting the New Zealand coastal environment and offshore ecosystems and fishing activities • Interaction with international groups undertaking modelling to understand how climate change will affect Antarctic ice sheets • Tools to estimate coastal inundation and erosion to support planning processes	• Tools that integrate climate change effects on coastal and offshore ecosystems and physical processes (eg, shifts in water masses and water mass temperatures) are available to support ecosystem-based management, enable cultural and recreational harvesting, and foster sustainable fisheries • Robust models to support coastal urban planning
Adapting to and mitigating climate change including reducing its impacts and risks	• Options for mitigation, adaptation and risk management, along with costs and benefits • Strengthened use of social science to characterise societal preferences and values in adaptation and mitigation pathways	• Theory and tools to develop dynamic adaptive pathways that overcome fixed, time-bound adaptation responses • Systematic mapping of adaptation pathways for most vulnerable systems and locations	• Risk management tools enable adaptive management methodologies that promote resilience and continued prosperity in the face of ongoing change • Strengthened links between climate change research and its utility for decision-making practice in the private and public sector

Research topics	Needs Basic knowledge	Opportunities Practical application	Outcomes Translation for policy and management
Emerging technologies and practices for reducing greenhouse gas emissions across different sectors[6]	• Analysis of emission reduction potential and cost/benefit of different options and their contribution to low-carbon pathways in different sectors (transport, urban planning, renewable energy, energy efficiency) • Understanding the contribution of different systems to carbon sequestration (eg, oceans, forests, soils) including forest sinks and restoration of indigenous vegetation, and their associated co-benefits	• Integrated land-use models that capture interactions between greenhouse gas mitigation, water quality/quantity, biodiversity and other environmental outcomes • Global integrated assessment models to understand implications of global changes on New Zealand's mitigation opportunities and risks • Developing alternative low-carbon development pathways within sectors and across the economy	• Ability to model trade-offs between deferred near-term and enhanced long-term actions to meet long-term goals • Identification and support for business and market opportunities arising from greenhouse gas mitigation approaches

Current capability and strategic needs

New Zealand research providers have internationally recognised strengths in climate change science, but this capability needs to be maintained, and improved in some areas. Specifically, there is a need to build capability in model development, science translation, and policy and management tools. Other needs include strengthened partnerships between researchers and iwi, to identify knowledge gaps and develop adaptation pathways and mitigation opportunities that recognise the particular needs of iwi. Continued investment in climate change science and monitoring is vital to test predictions and inform ongoing adaptive management to changes.

Collaboration across a range of disciplines, including social science, economics and engineering is required. We need to continue to collaborate internationally, including on Antarctic and Southern Ocean research, and on social and economic sciences as well as biophysical sciences.

Links with other strategies and policies

Reflecting the importance of international collaboration on research, under the United Nations Framework Convention on Climate Change New Zealand has a commitment to promote and cooperate in research and systematic observations and to exchange scientific knowledge. Observations from the tropical Pacific to Antarctica are of importance internationally, and there will continue to be opportunities to collaborate with other countries on research in this region. Pacific Island nations will continue to seek support from New Zealand in relation to science and technology for adaptation and emissions reduction.

The research needs identified here, when addressed, will help provide the information required to inform policy development and initiatives, consistent with the following examples of strategic policy initiatives and government direction:

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6 Research on mitigation options for the primary sectors will also be covered in the *Primary Sector Science Roadmap* (Ministry for Primary Industries, in progress).

- **Ministry for the Environment:** *Statement of Intent 2016–2020* – New Zealand has an innovative and productive economy, with fewer greenhouse gas emissions, and is resilient to the physical and economic impacts of climate change and adverse climatic events (Ministry for the Environment, 2016).
- **Natural Resource Sector; Ministry of Business, Innovation and Employment:** *Business Growth Agenda – Building Natural Resources 2015* (Ministry of Business, Innovation and Employment, 2015) – Reduce and mitigate greenhouse gas emissions in agriculture and transport
- **Local Government New Zealand:** *Local Government Leaders Climate Change Declaration* (2015) (Local Government New Zealand, 2015) – Give support to the New Zealand Government for developing and implementing, in collaboration with councils, communities and businesses, an ambitious transition plan toward a low carbon and resilient New Zealand.

Theme 4: Biosecurity

About this theme

This theme relates to developing tools and methods to support the effective management of risks posed by pests and diseases to the environment, economy, and human health, including activities off-shore, at the border, and within New Zealand.[7]

Invasive plants and animals (including invertebrates) and pathogens pose one of the greatest threats to global biodiversity (Secretariat of the Convention on Biological Diversity, 2014). They threaten land, fresh water and marine systems through competition, predation, disease, and by altering landscapes, habitats and biophysical processes. New Zealand is particularly vulnerable, owing to our long evolutionary isolation, and some consider invasive species to be the greatest single threat to our remaining natural ecosystems and habitats and threatened species. Examples include:

- extinctions and dramatically reduced populations of native bird species caused by mammalian predators such as rats, cats and mustelids
- incursions of wilding conifers over large areas of the South Island
- the impacts of kauri dieback on kauri forest (including kauri-dependent species)
- alteration of marine benthic environments caused by *Undaria* and other marine pests
- the potential risk of widespread impacts on pohutakawa, rata, manuka, kanuka and other native Myrtaceous species from myrtle rust if introduced to New Zealand (currently present in Australia).

Over the next 20 years, increased international travel, tourism and trade, changing global distributions of pests, a changing climate, and other accumulating environmental pressures will increase this threat significantly. The management of biosecurity risks will remain an enduring issue, both for preventing new pests and diseases becoming established and reducing or eliminating the impacts of established pests and diseases.

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[7] Research on technological developments for biosecurity will also be covered in the Primary Sector Science Roadmap (Ministry for Primary Industries, in progress).

Climate change will likely increase the likelihood of new incursions, and potentially increase the impacts from established species such as mosquitoes as vectors for human diseases because they will be able to survive in previously uninhabitable areas, due to a warming climate. It will be necessary to anticipate and manage these changes.

New technologies are rapidly being developed. For example, the male contraceptive idea, currently in trials in humans (Behre et al, 2016) is also being developed for rats (Senestech, 2016) and could have broad application to many mammalian pest species in New Zealand (mice, stoats etc). Gene-based technologies such as gene editing (eg, CRISPR/Cas9) and the use of transgenerational techniques such as meiotic gene drive manipulation are some of the many evolving biotechnologies that may be key to pest management. However, the pace of change comes with its own challenges, as the ability to deploy these technologies is dependent on the public being comfortable with the implications of their use. A question that will need to be addressed is whether we have the systems of education, engagement, management and regulation that will assure people of the safeguards, including ethical considerations, necessary to employ these new technologies.

Key question

What evidence, processes and procedures are needed to guide future policy and management options to achieve efficient and effective national-level prevention or management (including eradication) of invasive species to protect our environment, prosperity and well-being?

What are the research priorities?

- Improved and integrated detection and eradication/suppression tools and management systems for a range of current and potential biosecurity risks in terrestrial, freshwater and marine environments.
- Disruptive tools, technologies or approaches that have the potential to radically change the paradigm for managing biosecurity risks.
- Improved understanding of the behaviour of mammalian pests at low densities, to enhance success of eradication efforts and increase the success rate of early detection/prevention programmes.

Examples of needs, opportunities and outcomes for research topics

Research topics	**Needs** Basic knowledge	**Opportunities** Practical application	**Outcomes** Translation for policy and management
	Examples of types of knowledge needed to populate models, develop tools, and inform policy	Examples of models, research approaches, or technologies that build on basic knowledge	Examples of possible outcomes when knowledge needs and innovation opportunities are achieved to inform management and policy
Improved and integrated detection and eradication/suppression tools and management systems for a range of current and potential biosecurity risks in terrestrial, freshwater and marine environments	• Identifying species-specific biological traits to exploit in high-priority pests • Identifying the risk of emerging pathogen and 'sleeper pests' (highly localised species and/or in a quiescent phase) and weeds • Understanding effects of climate change on species ranges and habitats of species of interest	• Exploit species-specific weaknesses for incursion response and suppression • Novel methods for meta-genomics to characterise endemic and non-native pathogenic agents • Risk models that capture incremental climate change implications • Quantifying role of host phylogeny and host range on likelihood of extent/scale of impact	• The efficiency and effectiveness of current management regimes are significantly increased, are publicly acceptable, and work at a range of scales • Policy guidance links to risk models of change • Better targeted profiling of imported products that pose a biosecurity risk and pathways
Disruptive tools, technologies or approaches that have the potential to radically change the paradigm for managing biosecurity risks	• Understanding climatic, population and environmental influences on disease expression	• Species-specific, targeted technological approaches to pest and weed control on large scales • Novel technologies for reducing biofouling risk on vessels (particularly large merchant vessels)	• Cost-efficient delivery systems are available for suppression that can detect and control diffuse populations over large areas
Institutional arrangements for integrating the aspirations of community stakeholders, whānau, iwi and hapū, and business interests to deliver enduring biosecurity outcomes that work at increased scales	• Understanding the drivers for behaviour change	• Assessment of the value of different engagement/governan ce models	• Identification of institutional arrangements that best deliver conservation and environmental outcomes in a range of contexts

Research topics	Needs Basic knowledge	Opportunities Practical application	Outcomes Translation for policy and management
Understanding the drivers of social acceptability for use of biosecurity tools and management options, which considers: • views of Māori, iwi and hapū • different worldviews to manage future biosecurity activities or in developing/refining management tools	• Improved understanding of the social acceptability of novel control methods (biological control, mating suppression, lethal genes, targeted biocides) in natural and modified ecosystems	• Management approaches to achieve maximum community support for achieving biosecurity outcomes with acceptable tools	• Input into policies that incorporate arrangements to safeguard community, ethical and other requirements

Current capability and strategic needs

Skills in biosystematics, (comparative) risk analysis, and environmental impact assessment are inadequate. We also have a poor track record of bringing engineering, information technology, biotechnology, and genetics disciplines to bear on these problems in integrated ways. Nationally integrated databases are needed to enable timely access to critical information. Much could be gained from international collaborations in these areas. New ways of working collaboratively with stakeholders, including iwi/Māori, are being developed and trialled for incursion response and pest management. There will be immediate needs for social and policy science inputs into social licence to help with operational considerations.

Biosecurity risks to New Zealand have been recognised as a high priority for science investment for many years. Despite this, few transformative tools and approaches have emerged in recent times and, of those that have, a significant number have come from outside the science sector (eg, self-resetting traps and wireless monitoring technology). Significant research and development investment is required in getting tools and approaches application-ready, utilising a broader range of disciplines and underpinned by basic knowledge improvements (especially in biosystematics), new technology, better models, and improved translation of science into policy and management approaches.

Overall, there is a high public awareness of the threats posed by invasive species. However, we are hampered by the scarcity of effective tools for detection of low-density pest populations and large-scale suppression/eradication. Impact prediction is complex due to the yet-unknown ways in which new potential pest species interact with native ones, but new approaches to predicting the outcomes of these interactions may improve our targeting of effort. The issues surrounding social acceptability and community buy-in (social licence) and support of new technologies are a significant knowledge gap.

Links with other strategies and policies

New collaborations between government agencies, regional and district councils, industry groups, NGOs, philanthropists and community groups are leading to major landscape-scale initiatives. Predator Free NZ 2050 (see Species and populations sub-theme) is the latest example of these initiatives.

The research needs identified here, when undertaken, will help provide the information required for policy development, consistent with the following examples of strategic policy initiatives, legislation, and government functions:

- **Ministry for Primary Industries:** *Biosecurity 2025* (Ministry for Primary Industries, 2016) –The Ministry for Primary Industries has the greatest degree of responsibility for this thematic area. The strategy aims to ensure New Zealand's biosecurity system remains effective and resilient in the face of changing risks and pressures, and can take advantage of new opportunities
- **Regional councils:** *Regional Pest Management strategies.* Councils have a high degree of strategic and on-the-ground responsibility at regional and local levels
- **Department of Conservation:** *The New Zealand Biodiversity Action Plan 2016–2020* (Department of Conservation, 2016b) – Mainstreaming biodiversity across government and society; reducing pressures on biodiversity and promoting sustainable use; safeguarding ecosystems, species and genetic diversity
- **Department of Conservation:** *Wild Animal Control Act (1977)* – the Department of Conservation has direct responsibilities under the Act.
- **Environmental Protection Authority:** *Hazardous Substances and New Organisms Act 1996* – the Environmental Protection Authority has responsibility for new organism approvals.

3.4 Domain themes

Theme 5: Integrated ecosystems and processes

About this theme

Theme 5, 'Integrated ecosystems and processes', is comprised of five sub-themes: land, fresh water, coastal and marine, urban, and species and populations. This section outlines the overarching theme and its sub-themes.

While these domains are dealt with separately in this document and often in practice, it is critical to recognise that they are interconnected and that an activity in one domain has effects in another. For example, land-use intensification has impacts on freshwater bodies including aquifers, as well as coastal and oceanic environments.

The effects of some pressures can be relatively immediate (eg, phosphorus runoff from fertiliser application, or sediment yield increases from land disturbance) and others take time for the full effect to be seen (known as 'lag effects') (eg, nitrogen losses to soils in the Lake Rotorua or Taupo catchments).

Understanding the system-wide effects of different types, patterns and intensities of land and water use and applying this knowledge for integrated management will be key to achieving conservation and environmental outcomes. An example is the relationship between sediment yield with land use, water flow and regulation, estuaries and harbours, and the coastal and marine environment. While we have knowledge of individual components and interactions, we do not have adequate systems approaches or tools to effectively manage the cumulative impacts created by multiple pressures. This will benefit from incorporating mātauranga Māori knowledge and approaches, which inherently recognise such connections.

Overlaying all of these considerations is climate change, the ultimate global challenge for integrated ecosystems management.

Key questions

- What information is needed to guide policy development and management, and integrate cross-domain interfaces involving complex interactions between land, fresh water, coasts and oceans, urban areas and socio-ecological systems, including cross-cutting species and populations considerations?
- How can decision-makers at all levels recognise, value, and manage 'mountains to the sea' as a single systems-based domain to improve the science-policy connection?

What are the research priorities?

- Develop integrated and interactive modelling frameworks and data 'ecosystems' that operate across a range of scales and ecosystem domains, which can be used by decision-makers and communities.
- Fully characterise 'cause and effect' relationships that link land use, and land-use change, to ecosystem responses over time and space, particularly for the role of multiple stressors on complex systems, and develop appropriate indicators for decision-makers and communities.
- Investigate how institutional arrangements can help improve ecosystems outcomes.

Examples of needs, opportunities and outcomes for research topics

Research topics	**Needs** Basic knowledge	**Opportunities** Practical application	**Outcomes** Translation for policy and management
	Examples of types of knowledge needed to populate models, develop tools, and inform policy	Examples of models, research approaches, or technologies that build on basic knowledge	Examples of possible outcomes when knowledge needs and innovation opportunities are achieved to inform management and policy
• **Baseline information, models and tools** to enable sustainable management of land, fresh water and marine domains, and interface environments such as estuaries • Interactive and integrated systems models to inform policy across domains	• Quantifying key relationships between land, fresh water, and marine domains • Identifying key integrated model parameters	• Developing integrated models that link desired marine and coastal outcomes to land-use changes	• RMA instruments such as plans and national policy statements utilise integrated data and tools for optimal outcomes across all ecosystem domains • Visualisation tools provide communities with the means to consider plausible future scenarios
Ecosystem services valuation to inform decision-making across ecosystem domains and in interface environments	• Identifying ecosystem services most relevant to communities in relation to resource use, conservation and development • Understanding the demands on and capacity of ecosystems to provide services	• Mapping ecosystem services for communicating value of nature, trade-offs, and win-wins	• Valuation frameworks integrate community values across all well-beings in a way that usefully informs choice- making • Using an ecosystem services framework for environmental reporting gives a comprehensive view of the system and inter-connections • Scenario analysis can test policy or community-driven options to improve ecosystem services

Research topics	Needs Basic knowledge	Opportunities Practical application	Outcomes Translation for policy and management
Approaches to ensure ecosystem integrity and endangered ecosystems and species (including genetic resources) are protected • at a national scale • within a matrix of competing land and water (fresh and marine) uses	• Understanding relationships between endangered ecosystems and land and water use and surrounding ecosystems • Developing a credible methodology for prioritising ecosystems for protection at both national and local scales	• Identification of key management response points, with a focus on identifying where management can make the biggest difference for multiple benefits	• The community has improved tools for risk analysis and the design and implementation of management strategies • Integrated threat/stress management is used to maximise ecosystem services values (initially at catchment scale)
Mitigating impacts of natural hazards, including geological hazards	• Data and monitoring of extreme rainfall events and flooding • Rationalisation of natural hazards data and information into a single platform • Considering climate change effects	• Models to inform how natural hazards can be managed to both avoid and mitigate adverse effects, while also capturing potential benefits (eg, flushing and storage)	• Natural hazards management is well informed by defensible tools to quantify hazards, interpret risk, and adopt effective interventions and appropriate scales
Institutional and social arrangements and structures that best promote integrated ecosystem management across systems-relevant scales	• Identifying mechanisms that best promote systemic changes in behaviour • Understanding of the relationship between environmental decision-making processes and community 'buy-in' • Identifying governance arrangements (rules and structures) that recognise and give priority to integrated ecosystems and processes in decision-making	• Decision-making frameworks within which institutions support behaviour change at individual and collective scales and address the interconnectedness of ecosystems and processes	• Planning instruments, resource management policy and decisions at central, regional and local levels and the decisions of land managers and resources users reflect ecosystem integration principles

Current capability and strategic needs

Mātauranga Māori is based on whole-of-ecosystem thinking. However, integrated ecosystem-based management is complex, and is still not common practice in New Zealand. Examples of whole-of-system research and management are rare, except perhaps in some case of focused integrated catchment management such as the Motueka Integrated Catchment Management project.[8] While we have considerable basic knowledge, we do not have models and policy/management tools that cover the total landscape. More research is required, perhaps beginning with case studies such as the catchments of Kaipara Harbour or Te Waihora/Lake Ellesmere.

[8] Integrated Catchment Management for the Motueka River – see http://icm.landcareresearch.co.nz.

Integrated system modellers are necessary – people who can access and understand systems dynamics, and who can work with specialists to develop the interactive system models needed to work across domains. Researchers who are experienced in data interoperability techniques and developing new data standards are also required, as are people at the science/policy interface who have the skills to take into account all environmental domains, human interactions with those domains, and their inter-relationships.

Linked strategies and policies

The research needs identified here, when undertaken, will help provide the information required to inform policy development and restoration initiatives, consistent with the following examples of strategic policy initiatives:

- **Ministry for the Environment:** *National Policy Statement for Freshwater Management 2014* (Ministry for the Environment, 2014) – Directs regional councils to set objectives for the state their communities want for their water bodies in the future and to set limits on resource use or allocation to meet these objectives.
- **Department of Conservation:** *New Zealand Coastal Policy Statement 2010* (Department of Conservation, 2010) – Guides local authorities in their day-to-day management of the coastal environment.
- **Department of Conservation:** *The New Zealand Biodiversity Action Plan 2016–2020* (Department of Conservation, 2016b) – Mainstreaming biodiversity across government and society; reducing pressures on biodiversity and promoting sustainable use; safeguarding ecosystems, species and genetic diversity
- **Statistics New Zealand, Ministry for the Environment and Department of Conservation:** *Environment Domain Plan 2013: Initiatives to Address our Environmental Information Needs* (Statistics New Zealand, 2013) – Examining information that provides insights on the state of our natural environment.

Theme 5: Integrated ecosystems and processes – land

About this sub-theme

This sub-theme encompasses all land environments including soil structure and chemical processes, the underlying rock, its formation and movement, soil biota (ie, animals, plants and fungi found in the soil), weathering and soil formation processes, as well as what is on the land surface, such as vegetation and human-made structures. It also includes relevant volcanic and tectonic processes.

The area of New Zealand's forests and wetlands has been reduced drastically since human arrival. Today, about one-third of the pre-human forest extent remains, concentrated mainly in upland and mountainous areas. Wetlands have been reduced to about 10 per cent of their original extent. These reduced ecosystems are important habitat for most of our native terrestrial fauna and flora. There are also many uncommon or rare ecosystems or components of ecosystems (ecosystems that have always been relatively limited in their extent), which are strongholds for rare and threatened species. Examples include the salt pans in Central Otago and the remnant dry kanuka shrublands on the Canterbury Plains.

There is a continuing need to increase our baseline knowledge of native biodiversity and ecosystems and develop the necessary tools for their protection. This will help us identify and manage risks, more effectively manage ecosystem vulnerability and resilience, and manage the potential impacts and/or threats from disturbance, climate change, land use, fire, animal and plant pests and natural hazards. Trends in the agricultural sector to introduce 'farm environment plans' and other codes of practice and certification schemes will require ongoing and more sophisticated environmental and conservation data sources and management intervention advice.

Particular areas needing ongoing attention include:

- changing land use and land cover, and pressures from these changes on freshwater, estuarine and coastal environments
- quality and quantity of soils
- biodiversity and biosecurity knowledge in terrestrial ecosystems
- impacts of anthropogenic substances, including pesticides and herbicides
- socio-cultural perspectives and impacts (such as landscape values)
- climate change and natural hazards
- cost-effective management interventions and systems that will achieve conservation and environmental outcomes.

Key question

What evidence do we need to guide policy development and management on how to effectively manage land to sustain and improve conservation and environmental outcomes, including restoration and regeneration of native ecosystems, while continuing to foster social and cultural prosperity and well-being?

What are the research priorities?

- Discovery and documentation of biota in land environments – it is estimated that less than 50 per cent of New Zealand's native terrestrial biota has been discovered and documented (see also the Species and populations sub-theme).
- Understanding impacts and interactions (eg, of land use, biodiversity and climate change) and identifying thresholds/tipping points to inform proactive management for productive landscapes.
- Understanding the full range of cross-domain landscape values to incorporate into decision-making.
- Better tools and prioritisation approaches for ecosystem restoration.
- Improved data infrastructure for long-term land management and use of new technologies (remote sensing, sensors, 'big data') to better monitor soil health and resilience and natural disaster risk.

Examples of needs, opportunities and outcomes for research topics

Research topics	**Needs** Basic knowledge	**Opportunities** Practical application	**Outcomes** Translation for policy and management
	Examples of types of knowledge needed to populate models, develop tools, and inform policy	Examples of models, research approaches, or technologies that build on basic knowledge	Examples of possible outcomes when knowledge needs and innovation opportunities are achieved to inform management and policy
Real-time information platforms so end-users can take a more system-wide approach to land-use management. Includes activities intended to remediate past land-use impacts.	• Baseline and monitoring data on species and ecosystems • Land ecosystem service valuation • Understanding and predicting responses of land systems to land management changes	• Advances in remote-sensing technology and mapping systems • Innovative species and ecosystem assessment tools • Real-time data incorporated into system management models, eg, farm management plans	• Ecosystem-based management tools/platforms – methods and software incorporate scientific and socio-economic information into decision-making. • New tools and management systems enable land users to understand property-level impacts (eg, OVERSEER® and audited self-management)
Information, tools and models to understand, predict and manage hazards including fire, tectonic and volcanic activities and climate extremes, where these have an impact on species and ecosystems.	• Baseline and monitoring data on species and ecosystems in response to natural hazard events	• Developing reliable and timely ecological response models	• Ecological response models are used for rapid design of mitigation actions (including for infrastructure)
Managing threatened biodiversity on the public conservation estate and private land at regional and national scales • including through integration into production and urban landscapes • taking into account expanding matrix of competing land uses	• Improved knowledge of systematics and evolution of native biota to underpin documentation and analysis of species, and their distribution • Knowledge of synergies (win-wins) with, or competition between, different land uses and biodiversity	• Scenarios/models of land-use impacts on biodiversity at extensive (choice of land cover) and intensive (production methods) margins	• New tools and management systems that integrate biodiversity into land-use systems
Understanding and utilisation of mātauranga Māori values and practices for land ecosystem management alongside science-based approaches to ensure optimal outcomes	• Cultural monitoring methods and indicators • Knowledge of mātauranga Māori practices	• Modelling outcomes from mātauranga Māori and scientific practices and combinations of approaches	• Co-knowledge generation processes to enable more effective partnering when implementing management actions

Research topics	Needs Basic knowledge	Opportunities Practical application	Outcomes Translation for policy and management
Reducing fragmentation and improving the health and resilience of soil and terrestrial ecosystems	• Baseline data and monitoring of soils and ecosystem health • Baseline data on current and anticipated land-management practices • Knowledge of tipping points and impacts on soils in response to agricultural and other land-use practices	• Scenarios/models of impacts of use of pesticides, herbicides, fertilisers and new technologies • Predictive models of how soils are affected by land-use change, land management practices, and mitigation options	• Soil sustainability models used as a core component in farm environment planning and overall land-use planning
Options for remediation of legacy 'non-sustainable' land-use practices that: • are cost-effective • maintain the productive potential of land within defined environmental constraints	• Identifying alternative/modified practices that are cost-effective to implement • Understanding behaviours and values of the farming sector to enable and influence a shift towards more sustainable practices	• Developing sustainable land-use models that are context-specific and identifying non-sustainable practices for which they provide an alternative	• Farm environment plans and similar initiatives implement sustainable land-use practice changes

Current capability and strategic needs

A range of research activities underpin this theme, including taxonomic capability, systems and databases, modelling and scenario analysis, capability in community engagement and collaboration processes, mātauranga Māori, and knowledge transfer and translation. Particular requirements are:

- the commitment to ongoing monitoring of state/condition of ecosystems
- Department of Conservation and other government agencies working with councils on land-use issues at boundary interfaces (eg, between conservation land and privately-owned farmland), including on weed and pest control
- science capability to understand and critique new tools and technologies
- building research connections with the private sector so they can take advantage of new tools and land uses and accelerate economic and environmental gains.

While overall we do have substantial basic knowledge and a number of useable models in the land domain, there are significant knowledge gaps around the cumulative impacts and legacy effects of historic and current land-use activities, particularly for soil and water microorganisms and invertebrates, and the flow-on impact on higher species in the biological web. While there has been some effort to develop mātauranga Māori indicators, monitoring tools and engagement processes, significant effort is still needed in mainstreaming and implementing mātauranga Māori in the management of land and ecosystems. New approaches to land and ecosystems management require ongoing research effort, as does the translation of science into best practice. Innovative policy and management tools are being trialled for some applications and places, however broad-scale, integrated use remains a gap.

Links to other strategies and policies

The research needs identified here, when undertaken, will help provide the information required to inform policy development consistent with the following examples of strategic policy initiatives:

- **Statistics New Zealand, Ministry for the Environment and Department of Conservation:** *Environment Domain Plan 2013: Initiatives to Address our Environmental Information Needs* (Statistics New Zealand, 2013) – examining information that provides insights on the state of our natural environment
- **Ministry for Primary Industries:** *Biosecurity 2025* (Ministry for Primary Industries, 2016)– ensuring New Zealand's biosecurity system remains effective and resilient in the face of changing risks and pressures, and can take advantage of new opportunities
- **Department of Conservation:** *The New Zealand Biodiversity Action Plan 2016–2020* (Department of Conservation, 2016b) – mainstreaming biodiversity across government and society; reducing pressures on biodiversity and promoting sustainable use; safeguarding ecosystems, species and genetic diversity.

Theme 5: Integrated ecosystems and processes – fresh water

About this sub-theme

This sub-theme covers the biota, ecosystems and processes in ice, snow, lakes, rivers, wetlands (estuaries and lagoons as appropriate), and groundwater.

Fresh water, in our lakes and wetlands, rivers, streams and in our aquifers is one of New Zealand's most abundant resources – yet, especially in many lowland agricultural and urban areas, it is not in a healthy state. This is mainly the result of land use over many decades – primarily agriculture, forestry and urban settlements. Many of our freshwater fish species and species of birds, invertebrates and plants associated with freshwater environments are threatened or at risk. Invasive plants have colonised many rivers and lakes, negatively affecting native species and their habitats as well as interfering with water use such as irrigation. Enabling further water resource development, while dealing with the legacy effects of historic land use, is an enormous challenge.

Given the range of values held for fresh water – economic, ecological, recreational, and cultural – it is not surprising that extractive use and discharges from land can conflict with instream values. Social and biophysical science can help resolve this tension.

Climate change will undoubtedly alter our freshwater bodies. The east is expected to get drier, the frequency of heavy rainfall and flood events is predicted to increase and effects on snow pack and glaciers will accelerate. There are also expected to be flow-on effects on river flows, groundwater, and the entire hydrological cycle. These effects will require us to adapt and to mitigate – they will have effects on both the quantity of water and its quality, which in turn will have ecological, environmental and economic implications.

Key questions

What tools, systems and processes can be put in place to inform policy development and aid protective and restoration activities to ensure the following conditions while enabling the efficient, equitable and productive use of water:

- freshwater ecosystems and habitats are healthy and resilient
- adverse human health impacts are avoided
- cultural needs are met
- recreational needs are met?

What are the research priorities?

- Better understanding the impacts of contaminants and excess sediment on ecosystems and – where relevant – human health, particularly in sensitive or hydrologically complex catchments, to inform allocation processes and land-use practices
- Understanding impacts (eg, of land use and climate change) and identifying thresholds/tipping points to inform proactive management
- Understanding the full range of freshwater values to inform policy in an adaptive manner
- Better tools for the restoration of freshwater bodies
- Improved data infrastructure for long-term freshwater management.

Examples of needs, opportunities and outcomes for research topics

Research topics	**Needs** Basic knowledge	**Opportunities** Practical application	**Outcomes** Translation for policy and management
	Examples of types of knowledge needed to populate models, develop tools, and inform policy	Examples of models, research approaches, or technologies that build on basic knowledge	Examples of possible outcomes when knowledge needs and innovation opportunities are achieved to inform management and policy
Identification of emerging contaminants and their potential impacts to enable proactive management	• Categorising the chemicals and other contaminants of concern and their potential impacts on flora and fauna	• Developing and using transport, transformation and source-to-sink models • Tracking and forecasting the chemical environment	• Derivation of levels of emerging contaminants that represent concerns to ecosystem health and human health; their sources and sinks identified in district plans.
• **Understanding trajectories of change, thresholds and tipping points** to better predict the state of fresh water and its values • **Linking these data to models of terrestrial and freshwater production systems** and to desired environmental flow and water quality conditions in rivers, lakes, groundwater and wetlands	• Clear definition and examples of tipping points and thresholds at the single-species and ecosystem scales, so there is a consistent approach to avoidance of such occurrences	• Development, guidance and use of interoperable models within a multiple-stressor context	• Good time-series data and statistical analyses are used in a threshold response to inform policy and management

Research topics	**Needs** Basic knowledge	**Opportunities** Practical application	**Outcomes** Translation for policy and management
Tools, processes and policies to scale up freshwater ecosystem restoration that: • are cost-effective • address the range of pressures facing these systems (including land-use pressures) • deliver essential biodiversity outcomes (eg, habitat, taonga and threatened species) • enhance ecosystem services	• Improved knowledge of restoration trajectories in a range of scales in time and space, and the capability to measure change and responses to mitigation approaches	• Modelling consequences of restoration actions for ecosystems, species and economics	• Ecosystems are connected in policy and management approaches (ki uta ki tai)
Knowledge and tools for communities, iwi and hapū to best determine and achieve the environmental conditions that meet their aspirations at the catchment scale	• Identifying, classifying and prioritising ecological, cultural and social values (including mātauranga Māori) in freshwater bodies • Identify key drivers of change, eg, sedimentation, nutrients, climate change	• Use of tools (eg, Bayesian Knowledge Networks) and resulting visualisations within a collaborative community context to create and test management scenarios	• Successful models of restoration are adapted and refined according to community needs and aspirations and results incorporated into local/regional policy
Modelling, monitoring, data infrastructures, and data systems for fresh water that incorporate: • evaluation of environmental and conservation outcomes • economic cost • intangible values • policy effectiveness	• Identifying comparative sentinel sites and indicators across the range of freshwater habitat types	• Developing interoperable models that include economic consequences, indices of values, which can be adapted to meet evolving needs of freshwater management	• Management and policy are informed dynamically by use of a variety of models, which are documented in a national inventory (including case study approaches) and can be adapted to the questions being asked

Current capability and strategic needs

There are complex interactions both within the freshwater domain, but also between it and the other domains – and these are far from fully understood. The complex relationships between land-use and the quality and quantity of surface and groundwater need further attention – and this need will only increase with the effects of climate change. More research into the complementary approaches of mātauranga Māori and collaborative approaches to freshwater management are urgently needed.

Another challenge is in linking knowledge and using model outputs effectively to translate science into the policy process in ways that are meaningful for communities and decision-makers alike. Decision tools need to address community aspirations such as swimmability and take account of complex temporal and spatial issues, such as the lag time to clear some contaminants and nutrients from waterbodies, and ground and surface water interactions where sources and sinks and mixing zones are dynamic and difficult to identify.

There are knowledge gaps about some of our freshwater fish species and invertebrate fauna. There are also gaps in our knowledge about the full extent of biota in our freshwater environments (especially aquatic invertebrates), and about the specific habitat needs of some of our native fish species and their susceptibility to pollutants and exotic species. There is still much to be understood about groundwater. Pollutants such as bio-toxins, persistent organic pollutants, heavy metals, and micro/nano-particles, require urgent attention and the development of cost-effective solutions for preventing, minimising or reversing impacts. There is considerable knowledge about nutrients and nutrient modelling but less is known about micro-pollutants (organic or mineral substances that have toxic, persistent and bioaccumulative properties that may have a negative effect on the environment).

Freshwater researchers have developed science-management models, and many tools are being implemented through a variety of policy, governance and management arrangements. Some of these tools are being challenged and new approaches promoted, including those that take account of mātauranga Māori (Harmsworth, Awatere, & Pauling, 2013). Further development of these approaches is supported, but requires research to determine effectiveness and ascertain which work best across the full range of needs expressed by water resource users (including aspects of resource 'ownership' and incentive structures).

Links to other strategies and policies

The research needs identified here, when undertaken, will help provide the information required to inform policy development and restoration initiatives, consistent with the following examples of strategic policy initiatives and direction:

- **Ministry for the Environment:** *National Policy Statement for Freshwater Management 2014* (Ministry for the Environment, 2014) – Directs regional councils to set objectives for the state their communities want for their water bodies in the future and to set limits to meet these objectives
- **Department of Conservation:** *The New Zealand Biodiversity Action Plan 2016–2020* (Department of Conservation, 2016b) – Mainstreaming biodiversity across government and society; reducing pressures on biodiversity and promoting sustainable use; safeguarding ecosystems, species and genetic diversity.

Theme 5: Integrated ecosystems and processes – coasts and oceans

About this sub-theme

This sub-theme encompasses ecosystems and biota in the coastal and oceanic environment.[9]

New Zealand's oceans are facing multiple and cumulative pressures, including:

- global greenhouse gas emissions, which are causing ocean acidification and warming and sea-level rise
- modification of food webs through fishing and other activities

[9] This includes New Zealand's Exclusive Economic Zone, as well as waters over which New Zealand has a defined and agreed management interest, such as the extended continental shelf, the southwest Pacific Ocean and the Ross Sea, Antarctica.

- destruction of benthic habitats as a result of extractive activities and impacts of land use
- build-up of pollutants
- invasive species.

Of these pressures, the most serious from a long-term perspective are the pressures associated with climate change. Coastal sea levels and long-term sea-surface temperatures around New Zealand have risen over the last century, and our oceans are now displaying similar rates of change in acidification experienced elsewhere in the world. However, the most serious immediate pressures on threatened species and the estuarine and coastal environment are caused by land-use intensification, sedimentation, shoreline and shallow seabed modification (typically resulting from reclamation), infrastructure development, commercial fishing and invasive species. These pressures are affecting marine ecosystems in ways that will not be easily reversed. We need to find ways to more effectively protect, manage and/or restore coastal and marine ecosystem resilience.

New Zealand has a relatively large Exclusive Economic Zone (EEZ) which stretches from the Kermadec Islands in the north, to the Campbell Plateau in the south. Beyond the EEZ, New Zealand has responsibilities over a broader area that encompasses the Tokelaus in the tropics, the sub-Antarctic and the Southern Ocean and the Ross Dependency in Antarctica.

Ocean observations and research require expensive facilities and logistics, so international collaboration on research across this region is critical. Other nations are also very interested in the conservation of the region's species and ecosystems, and in the signals provided by the Pacific/Southern Ocean/Antarctica region on how the environment is changing and why. This interest leads to good opportunities for collaboration, which we must continue to foster.

Key question

What evidence do we need to inform the management and policy choices to enable the coastal and marine species/ecosystems and essential processes (eg, sea grass breeding grounds for snapper) to recover or be sustained at a level sufficient to provide for the conservation and environmental values of coasts and oceans and their contribution to the economic, social and cultural well-being of New Zealanders?

What are the research priorities?

- Identifying marine habitats that provide biodiversity, social, traditional food gathering (kaimoana), recreational, primary production, and commercial production (fisheries) values.
- Understanding present and future threats to these habitats, including from climate change.
- Accessing high-quality data to characterise the marine domain, establish environmental baselines, and track changes over time and space.

Examples of needs, opportunities and outcomes for research topics

Research topics	Needs Basic knowledge	Opportunities Practical application	Outcomes Translation for policy and management
	Examples of types of knowledge needed to populate models, develop tools, and inform policy	Examples of models, research approaches, or technologies that build on basic knowledge	Examples of possible outcomes when knowledge needs and innovation opportunities are achieved to inform management and policy
Future-proofing New Zealand's marine domain • includes biodiversity conservation efforts to maximise resilience of species/ecosystems and communities • takes into account increasing anthropogenic environmental pressures • addresses issues such as food security, spatial competition, and regional and global connectivity	• Ongoing emphasis on basic surveys to determine the nature and state of marine resources • New tools to complete rapid inventories – need for broad coverage • Identifying an agreed set of indicator species	• Integrating new survey tools with citizen science capability, both domestic and international	• Spatial planning tool refinement linked to policy process • Ecosystem-based management tools are used to evaluate and manage competing interests affecting marine biodiversity and sustainability
Identifying key coastal and oceanic habitats that drive production and recruitment of fish and other species, and **how to sustainably manage these species' habitats** in the face of increasing pressures on oceans and the coastal environment (including estuaries)	• New rapidly deployable sensing tools for habitat mapping • Long-term collection of basic biophysical data at appropriate spatial and temporal scales • Establishing open access to monitoring data and a metadata catalogue • Spatial expansion of habitat characterisation across Coastal Marine Area/EEZ • Integrating regional, national and global datasets	• Remote-sensing and other verified monitoring technologies and tools that can identify and catalogue key habitats • Establishing environmental baselines and tracking changes in the coastal marine area and wider EEZ • Novel tools for habitat characterisation	• New habitat maps used as a basis for policy • Dynamic resource management through tools, models and processes for describing ecosystem health • Knowledge that underpins environmental reporting, impact assessments, and prioritisation of restoration efforts
Improved utilisation of hazard and climate change science and modelling to manage the interfaces between land, freshwater and marine domains	• Research on tolerance ranges of habitats and species to changing sea levels, ocean acidification, and sediment and contaminants from land and rivers	• Demonstrate effects of changing sea levels, ocean acidification etc on habitat, species' life cycles and species' distributions	• Better informed decision-making benefits biodiversity conservation, environmental management, and relevant communities

Research topics	Needs Basic knowledge	Opportunities Practical application	Outcomes Translation for policy and management
• **Understanding and utilising mātauranga Māori/cultural monitoring methods, indicators and management tools** for the coastal/marine environment in association with science-based approaches to ensure optimal environmental outcomes • **Co-knowledge generation processes** for more effective partnering when implementing management actions	• Recognition and understanding of both existing and new tools and how they can be used in complementary ways	• Use of citizen science to collect data, including collaboration with mātauranga Māori/cultural monitoring methods	• Frameworks to link cultural health indices with management and policy-setting
Tools and processes to rapidly identify existing and emerging contaminants, measure and track their spatial extent, and rapidly identify their implications for the coastal-marine environment	• Data on the types, sources, and quantities of contaminants in our waterways • Improved understanding of pathways and impacts of contaminants on the marine environment	• Technologies for quantifying inputs (eg, passive samplers) • Novel ecotoxicology bioassays tailored to New Zealand	• Improved tools and processes allow effective management of emerging contaminants to prevent/minimise negative impacts
Understanding ecological impacts of activities, including land use and fishing, on coastal and open ocean ecosystems	• Tools for measuring land-use impacts, eg, sediment flow • Better tools for measuring all fish takes and impacts of fishing - commercial, recreational and customary	• Developing sediment flow models to limit impacts • Modelling sustainable harvest with complete range of data on harvests and impacts	• Reliable data used for setting and managing limits • New harvest technologies prevent impacts • Decision tools for land use prevent sediment flow impacts

Current capability and strategic needs

There are significant information gaps across all components of this sub-theme, from basic information on species and ecosystems, through to the physical and chemical system and processes. While some relevant models exist (eg, the Quota Management System and fishery stock models, models for sea-level rise, erosion and deposition rates), reviews and improvements are needed to enable more joined-up systems analysis. Communicating and translating science effectively is a significant gap and this is reflected in gaps in effective policy and management tools.

There is still considerable need to survey and catalogue the biodiversity throughout our marine environment. We need to make better use of the diversity of datasets we currently have. Informatics will become increasingly important to leverage national benefit from this data. Although we are well-connected through international networks of biosystematists, there is an urgent need to address capability in New Zealand, which is insufficient for organisms other than marine birds and mammals. Citizen science can play a major role here also, in basic data-gathering and monitoring, and integrating science and mātauranga Māori.

Links to other strategies and policies

The research needs identified here, when undertaken, will help provide the information required to inform monitoring assessments and policy development, consistent with the following examples of strategic policy initiatives and direction, legislation, and government functions:

- **Ministry for Primary Industries:** *Fisheries Act 1996* – the Ministry for Primary Industries has wide ranging responsibilities for managing fishing practices and their effect on the aquatic environment
- **Ministry for Primary Industries:** *Biosecurity 2025* (Ministry for Primary Industries, 2016)
- **Department of Conservation:** New Zealand Coastal Policy Statement 2010 (Department of Conservation, 2010)
- **Department of Conservation:** *The New Zealand Biodiversity Action Plan 2016–2020* (Department of Conservation, 2016b)
- **Ministry for the Environment and Environmental Protection Authority:** *Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (the EEZ Act)* – the Environmental Protection Authority has responsibilities for consents and monitoring in the EEZ
- **Ministry for the Environment and Statistics New Zealand:** *Environmental Reporting Act 2015* – Mandatory reporting on the New Zealand environment
- **Regional councils:** *Regional coastal plans* (Department of Conservation) – councils have a high degree of strategic and on-the-ground responsibility at regional and local levels aiming to achieve sustainable management of the coastal environment.

Theme 5: Integrated ecosystems and processes – urban

About this sub-theme

This sub-theme relates to urban ecosystems including the urban built environment and blue/green infrastructure (urban design features that incorporate building with nature), and their interactions with the biophysical environment, biodiversity, and human health and well-being.

New Zealand is one of the world's most urbanised nations, with more than 86 per cent of our population living in urban areas. Our towns and cities are important expressions of New Zealand's cultural identity and sources of social capital, including our unique Māori heritage. However, urban intensification and sprawl, and increasing resource use and consumption are putting pressure on the environment – for example, on fresh water and 'versatile soils' (our most fertile, lowland soils).

Because most of our urban areas are coastal, they will be directly affected by climate change and the accompanying sea-level rise. Increasing population density in cities exposed to natural hazards poses challenges in terms of the resilience of communities and the built environment. In fact, one of the things that sets many New Zealand towns and cities apart is their exposure to multiple geological and weather-related hazards. The complexity associated with multi-hazard management is an issue which we have not yet fully grasped.

Urban and natural ecosystems are intrinsically linked and require integrated management to improve the sustainability of both environments. There are opportunities for innovation to improve outcomes for both our natural and built environments – for example, improving efficiencies in the use of energy, water and other resources, and enhancing natural environments and biodiversity within the urban domain.

The challenges are as much social as they are biophysical – many urban dwellers have limited opportunities to interact with the natural environment. We need to understand the consequences of changes such as increasing urbanisation, find effective ways to manage these increasing pressures, and create biodiversity-rich and sustainable towns and cities where New Zealanders can live healthy, productive and prosperous lives.

Particular areas needing ongoing attention include:

- resilience to natural hazards, increased frequency of extreme weather and climate variability in urban areas – societal resilience and environmental resilience (natural and built environments)
- energy efficiency to meet the growing demand for energy in a sustainable manner
- health and well-being – making cities more 'liveable'
- transport efficiency and impact reduction
- air pollution
- fresh water, stormwater and wastewater – in particular, understanding and responding to immediate and lag effects from the built environment (eg, zinc-coated rooves, poorly designed roads that channel pollutant-loaded runoff directly into waterways, sewage overflows)
- understanding the drivers and motivations of individual and organisational choices and behaviours – so New Zealanders recognise and take advantage of opportunities for realising environmental gains, for example, through more sustainable urban design and urban ecosystems
- the potential impacts of coastal developments on connectivity and health of marine habitats.

Key question

How can we develop our urban environments to make them more resilient and liveable, maximising their value for people and biodiversity while minimising negative impacts on public health, and on adjacent land, fresh water and coastal and marine environments?

What are the research priorities?

- Understanding how to design and build urban green space and natural habitat, which maximises indigenous biodiversity and is resilient to climate change in the longer term.
- Better tools for community engagement and participation in planning and regeneration processes.
- Improved data infrastructure for long-term infrastructure management and transition to smart cities (low carbon and low pollution).

Examples of needs, opportunities and outcomes for research topics

Research topics	Needs Basic knowledge	Opportunities Practical application	Outcomes Translation for policy and management
	Examples of types of knowledge needed to populate models, develop tools, and inform policy	Examples of models, research approaches, or technologies that build on basic knowledge	Examples of possible outcomes when knowledge needs and innovation opportunities are achieved to inform management and policy
Understanding urban design features required to: • enhance human health, well-being, cultural and social values • improve urban biodiversity and ecosystem function • ensure minimal impacts on the wider natural environment	• Understanding social and cultural values • Knowledge of urban biodiversity and habitat needs – identification and assessment of key remnant ecosystems and associated populations • Environmental monitoring using common metadata standards for urban data • Human health monitoring linked to environmental drivers, eg, air pollution	• Urban planning models for climate resilience (eg, blue-green infrastructure) and healthy urban environment • Effective engagement and decision-making processes and tools to allow communities to effectively participate in planning and development • Impact assessment tools	• Incorporation of environmental protection, biodiversity management and risk overlays in council GIS and district plans • Baseline measures and ability to monitor progress, to set targets in district and regional plans • Communities actively participate in planning and related processes
Urban land-use ecosystem model/decision tools • to inform household, community, and industry-level responses to key drivers of ecosystem and water quality in urban areas	• Real-time remote data recorders that better track and demonstrate individual and community actions that are harming the environment	• Emerging contaminant prediction models and analysis tools • Contaminant load modelling in urban catchments (eg, OVERSEER®-type software)	• Data used to drive social and economic changes that incentivise more sustainable behaviours
Reconnecting urban dwellers with indigenous biodiversity and ecosystems • Identifying processes and ensuring they effectively partner with urban iwi, hapū and whānau	• Assessing community knowledge, understanding and environmental values for demographic, socio-economic and ethnic variables • Increasing citizen's understanding of native biodiversity and ecosystems, including threats and opportunities	• Utilising knowledge of gaps and opportunities to develop targeted environmental education resources • Identifying needs for effective community pest control and ecosystem restoration programmes	• Environmental education resources are freely accessible to urban-based iwi, community groups, schools, locals, and local government in a range of media • Urban communities actively initiate and support 'citizen-led' biodiversity and ecosystem restoration and enhancement programmes

Research topics	Needs Basic knowledge	Opportunities Practical application	Outcomes Translation for policy and management
Transitioning New Zealand towns and cities towards a low-emission and low-pollution society	• Technology and options that will improve energy efficiency without reducing service performance, eg, in the transport sector • Increasing understanding of people's motivations for choices and behaviours	• National community education programmes • New technology that provides efficiencies while performing at desired service levels	• Proven policy options implemented through district and regional plans and other pathways
Resilience to natural hazards and climate change – information, tools and processes to better predict impacts and enhance resilience in urban areas	• Integration tools that use natural ecosystem data to deliver messages, real time and for future scenarios that can be used to improve adaptive capacity and sustainable use of resources	• Impact modelling across all well-beings • Financial, legal and building solutions that optimise resilience and minimise adverse effects (eg, increased costs) • Technological and structural adaptations (solar energy, rainwater collection) to facilitate resilience in extreme events	• Cities and communities are more resilient and able to cope with shocks • The built environment is designed and adapted to be resilient and to better cope with the impact of natural hazards or extreme events
Modelling, monitoring, data infrastructures, and data systems for urban planning and management that: • take advantage of advances in data visualisation and processing • are as real-time as possible • integrate across different data types, eg, horizontal and vertical infrastructure, soil and geological data	• Metadata standards for cities and settlements; data from national to regional scale • Robust mechanisms and protocols to integrate and utilise private sector data for infrastructure planning	• Developing interoperative models and systems that integrate across scales and data types and allow scenario-testing and prediction	• Effective 'smart city' and community networks are established in New Zealand

Current capability and strategic needs

There is a growing need for more capability across disciplinary and functional divides within councils and other agencies involved in urban planning – in particular, between engineering and freshwater quality and habitat. These divides also need to address mātauranga Māori concerns and their research needs.

Knowledge and models of 'liveable cities' exist internationally and are being studied in New Zealand, though more work is needed, particularly in how to translate science into policy and management tools. These models will be important if we are to transform cities into lower carbon environments, to improve water and air quality, and to restore biodiversity. At the policy and management tools level, more work is required in the area of urban transport, biodiversity and low-carbon options. Better geospatial urban planning tools and improved use of data are needed.

Links to other strategies and policies

The research needs identified here, when undertaken, will help provide the information required to inform policy development consistent with the following examples of strategic policy initiatives and direction:

- **Ministry for the Environment:** *National Policy Statement of Urban Development Capacity* (Ministry for the Environment and Ministry of Business, Innovation and Employment, 2016)
- **Ministry for the Environment:** *New Zealand Urban Design Protocol* (Ministry for the Environment, 2005) – custodianship: ensuring design is environmentally sustainable, safe and healthy
- **Ministry for Social Development:** *Sustainable Development Programme of Action* (Department of Prime Minister and Cabinet, 2003) – includes a goal for sustainable cities
- **Ministry of Transport:** *New Zealand Transport Strategy* (Ministry of Transport, 2008) – providing a transport system that ensures environmental sustainability while assisting economic development and protecting and promoting public health
- **Ministry of Business, Innovation and Employment:** *New Zealand Energy Strategy 2011–2021* (Ministry of Business, Innovation and Employment, 2011) – environmentally-responsible development and efficient use of New Zealand's diverse energy resources that allows economic growth while recognising the environment for its importance to our way of life
- **Local and regional government:** urban development strategies
- **Land Information New Zealand:** *Smart Cities – Smart Nation project* (Land Information New Zealand, 2016) – utilising new technologies to make cities smarter and safer – including monitoring the city environment (eg, air and water quality).

Theme 5: Integrated ecosystems and processes – species and populations

About this sub-theme

This sub-theme relates to all populations of native species across all domains: land, fresh water, coastal and marine, and urban, including New Zealand's realm of influence from Tokelau and the Kermadecs to Antarctica.

Within this sub-theme there are three fundamental areas for research:

1. continuing the urgent task of cataloguing the data we have on species and their populations
2. habitat protection and restoration (see the Land sub-theme)
3. new technologies that will allow us to better control significant animal and plant pests and to consider the ecosystem-wide implications of the applications of these technologies.

A vital supporting area of science is that of taxonomic collections and taxonomy. Biological collections, supported by taxonomic expertise and research are critical for conservation, biosecurity, ecological assessment, human health, and sustainable ecosystem management.

The New Zealand archipelago has a diverse range of native plants and animals, including many endemic species that are found nowhere else on Earth. However, we have yet to catalogue most of our invertebrate species and microbiota, and little is known about many of our other flora, fauna and fungi. New Zealand is known as a global biodiversity hotspot, but it has been profoundly modified, mainly through land-use change and introduced animals and plants. Other threats include climate change, disease and chemicals, plastics and other human-made substances introduced into natural environments. New Zealand now has a large list of threatened and endangered plants and animals, including the quillwort (a critically endangered aquatic fern), the kiwi species, Maui's dolphin, the New Zealand sea lion, and the Canterbury knobbled weevil.

Managing endangered species, especially those with very small populations, is becoming increasingly complex. There is a need to invest heavily in population dynamics science to help avoid problems associated with inbreeding and to identify appropriate species recovery pathways, including in terms of habitat management.

Introduced mammalian pests such as rats and stoats have been directly responsible for extinctions and for ongoing pressure on our remaining species. Other pests and diseases (insects, fungi, bacteria, viruses and plants) present significant risks to our environment – both to productive land and the conservation estate. Wilding pines and invasive vines threaten ecosystems and species viability as well as productivity over large areas in both islands. The recently announced Predator Free New Zealand 2050[10] is an attempt to address these issues, but will require major research input.

Key question

What smarter, more innovative and cost-effective ways of cataloguing, understanding, managing and ultimately protecting our indigenous biodiversity in the face of multiple and increasing cumulative pressures can be developed to inform policy options to stop, and where possible reverse, the decline in populations of native species?

What are the research priorities?

- The development of sustainable and cost-effective technologies to support mitigation of threats to native species.
- New tools for the rapid completion of species/taxonomic inventories across all domains, especially coasts and oceans, and for terrestrial invertebrates (eg, through use of eDNA).
- Intervention-effectiveness modelling to assess the effectiveness of policy options and management scenarios in enhancing biodiversity across private (urban, production, Māori-owned) and public lands. Requires 'real-time' data on status of populations, communities and species in response to policy and management interventions.

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[10] Predator Free New Zealand (PFNZ) 2050 is an exceptional new initiative to be driven by a private company with central government seed funding. At least $1m per annum of that funding will be directed at research. In the short term the Board of PFNZ will work with the NZ Bioheritage National Science Challenge to produce a PFNZ research roadmap, essentially the building block of a prospectus of desired 'game changing' research, consistent also with key research questions in this Roadmap. The success or otherwise of this initiative should be monitored for key developments, learnings and capability needs.

Examples of needs, opportunities and outcomes for research topics

Research topics	**Needs** Basic knowledge	**Opportunities** Practical application	**Outcomes** Translation for policy and management
	Examples of types of knowledge needed to populate models, develop tools, and inform policy	Examples of models, research approaches, or technologies that build on basic knowledge	Examples of possible outcomes when knowledge needs and innovation opportunities are achieved to inform management and policy
Cost-effective tools to speed up the cataloguing and understanding of New Zealand's biodiversity resources	• Supporting national taxonomic expertise, collections and databases • Digitisation and DNA sequence characterisation of national collections • Genomic and transcriptomic approaches to identify evolutionary significant units in threatened and endangered species to inform management strategies	• National integrated database as a one-stop-shop for New Zealand's biodiversity, allowing public access • Spatial depiction of rare ecosystems	• Enhanced biodiversity across private (urban, production, Māori-owned) and public lands through assessment of integrated modelling frameworks on effectiveness of policy options and management scenarios • Fit-for-purpose knowledge that generates priorities for management irrespective of land tenure
Identifying species and community bottlenecks and tipping points to inform better system-wide management	• Standardised data required for management intervention and monitoring, chosen from combined analysis of exemplar studies • Improved knowledge of factors leading to tipping points – across various scales of time and space, different environments and ecosystems	• New, simple-to-apply population viability analysis tools • Guidelines for population management based on meta-analysis of exemplar studies in main taxon groups • A system to identify priorities for management and policy intervention	• Priority-setting for management and policy interventions increases success of maintaining or restoring habitats, populations and ecosystems to sustainable levels
Overlapping climate change and species tolerance models and maps to identify range effects and ongoing conservation needs for proactive management of species and populations	• Collection of agreed tolerance range monitoring data for susceptible indicator species • Improved knowledge of climate change, disease and contaminant interactions on susceptible indicator species	• Developing species tolerance range models linked to climate change predictions	• Mitigation strategies take account of tolerance change model predictions for at-risk species

Research topics	**Needs** Basic knowledge	**Opportunities** Practical application	**Outcomes** Translation for policy and management
Scaling up vertebrate, weed, pest and disease control to achieve eradication, using existing and new technologies in ways that are socially and culturally acceptable and cost-effective	• Understanding the behaviour and detectability of pests at low densities to prevent incursions and achieve eradication • Identifying technologies that could potentially be used, including consideration of social licence to operate • Information on acceptability of new technologies for pest control to inform policy choices	• Understanding how management actions interact with one another for synergy or adverse consequences, for example, control of one species might have positive or negative unintended consequences for others • Developing landscape-scale integrated threat management that avoids unexpected consequences	• A wider range of cost-effective and socially accepted tools and options is available for policy makers to consider for weed, pest and disease management • Biodiversity recovery and freedom from disease threats is achieved at landscape scale
Innovative institutional arrangements for co-producing conservation, social, cultural and economic value, including within production and urban landscapes	• Catalogue of new approaches evaluated against a range of cost-effectiveness performance criteria	• Evaluate existing and new approaches and apply lessons to co-production of policy • Examine the 'leverage' potential of treasured species to the communities that support them	• Incentives to support these new institutional arrangements that encourage protection and enhancement of biodiversity on private land while respecting private property rights
Utilising combinations of mātauranga Māori and interdisciplinary science approaches to identify new ways of managing species within production and other land- and water-scapes: • including 'farming' to increase numbers • ultimately allowing for sustainable customary harvest	• Document existing management approaches, eg, of tītī (muttonbirds), and identify lessons and new opportunities • Identifying culturally appropriate indicators to assess biodiversity	• Co-governance approaches utilising bicultural indicators to achieve intergenerational aspirations • Developing and extending existing models and frameworks to enable inclusion of intrinsic values and cultural benefits for system-wide management outcomes	• Conservation/ sustainable use models increase the range of conservation outcomes

Current capability and strategic needs

It is well-recognised that New Zealand faces major challenges in the conservation of its native species. This recognition is generating new approaches such as the Predator Free New Zealand 2050 strategy.

Biological collections, supported by taxonomic expertise and research, provide a vital evidence base. But there has been a decline in specialised taxonomic expertise and in funding support for collections, and investment and capabilities are fragmented across organisations (Royal Society of New Zealand, 2015). A strategic and more tailored approach to investment in this area is needed, and immediate investment needs to maintain critical taxonomic expertise and services should be addressed.

The application of new and improved technologies to address issues such as pests may require regulation, linked also to the need for social licence to operate – these challenges need to be addressed and will require dedicated social science input, policy and legal consideration (see Theme 4 – Biosecurity).

Strengthened iwi interests in natural resources that have emerged from Treaty settlements raise some important challenges. For instance, is it feasible to farm threatened species and increase range and numbers to a point where sustainable traditional harvest is possible? And how would New Zealanders view such developments? Complementary mātauranga Māori and interdisciplinary science research and new collaborative arrangements are necessary to address such questions.

Links to other strategies and policies

The research needs identified here, when undertaken, will help provide the information required to inform policy development and restoration initiatives, consistent with the following examples of strategic policy direction and recommendations:

- **Department of Conservation:** *The New Zealand Biodiversity Action Plan 2016–2020* (Department of Conservation, 2016b) – mainstreaming biodiversity across government and society; reducing pressures on biodiversity and promoting sustainable use; safeguarding ecosystems, species and genetic diversity
- **Royal Society of New Zealand:** *National Taxonomic Collections in New Zealand* (Royal Society of New Zealand, 2015) – identifies strategic directions, capacity, and investment needs for the management of New Zealand's taxonomic collections.

3.5 Human dimensions theme

Theme 6: Social and economic factors

About the social and economic factors theme

This theme relates to social/human factors affecting conservation and the environment, including links between values, beliefs and environmental attitudes and knowledge, social licence for technology and development, ethnic background and associated cultural beliefs and practices, community involvement, degree of community involvement, and engagement in governance and decision-making. It also addresses the economics factors effecting environmental management, including the effect of changes in international market forces.

Legislation, policy decisions, and plans guiding environmental management are produced by central and local government to reflect societal values and aspirations, but sometimes also with the intention of changing behaviour in socially desirable ways. Therefore, partnerships between social scientists, economists, and biophysical scientists are needed to provide valuable information and data to help develop and evaluate targeted environmental governance and policy and approaches to conservation management.

Key questions

- What do New Zealanders – individually and as a society – desire as a 'liveable' environment, and how can they be encouraged to make and implement long-term sustainable decisions that draw on robust science and which are beneficial for society, the economy and the environment?
- How can the economic, social and cultural benefits we derive from ecosystems ('ecosystem services') and intergenerational benefits and costs to the environment be identified and built into decision-making?

What are the priority research areas?

- Investigate power and trust in institutional arrangements to build social and cultural capital to manage the environment more effectively (including acceptability of new tools and technologies).
- Develop comprehensive models of New Zealanders' values and beliefs (eg, psychographics and behaviour economic characteristics).
- Understand the dimensions of social and cultural capital and their relationship with natural capital.
- Move towards integrating mātauranga Māori within interdisciplinary science approaches for long-term environmental management with synergistic benefits for society and the environment.

Examples of needs, opportunities and outcomes for research topics

Research topics	Needs Basic knowledge	Opportunities Practical application	Outcomes Translation for policy and management
	Examples of types of knowledge needed to populate models, develop tools, and inform policy	Examples of models, research approaches, or technologies that build on basic knowledge	Examples of possible outcomes when knowledge needs and innovation opportunities are achieved to inform management and policy
Understanding New Zealanders aspirations for the conservation estate and the environment • How do New Zealanders perceive risks and trade-offs, and how do these views affect individual and collective decisions and actions?	• Identifying the values and understanding that individuals, communities, businesses, and consumers at different locations (international, local, urban, rural) hold for the environment and conservation estate, and translating to policy relevant decision data • Understanding the factors (social, cultural, psychological, environmental, economic, institutional) and relationships that influence how individuals, businesses, and communities respond to interventions aimed at delivering environmental outcomes	• Traceability systems connect consumers and communities to environmental outcomes • Systemic models of behaviour are used to test assumptions and identify key leverage points to target interventions and focus on key relationships	• Policy makers have tools to guide impact of interventions across a suite of stakeholder values
Ecosystem services valuation • Understanding values and services (including economic, cultural, recreational, health and well-being, physical protection, and social) provided by ecosystems in New Zealand to inform	• Methodologies for dealing with comparison of differing values and accounting for intrinsic, spiritual and cultural values that communities and Māori do not wish to quantify • Framework for engagement with mātauranga Māori	• Developing models and associated social processes that can provide a basis for a fully integrated assessment of potential impacts from interventions • Improved tools that translate ecosystem services and natural	• Communities are able to equitably take into account the range of values derived from the environment and to use this to assess the impact of interventions • Land managers are able to fully cost their management impacts

Research topics	Needs Basic knowledge	Opportunities Practical application	Outcomes Translation for policy and management
conservation and environmental policy and management		capital applications into information used in conservation and environmental policy and management	
Identifying private actions and policies that can effectively improve environment related social outcomes	• Understanding the value proposition that private actions will be based on and understanding how that aligns with the anticipated outcomes	• A set of principles that can be applied to a range of contexts illustrating why, how and when private actions can be incentivised	• Incorporate principles into negotiations on public-private partnerships and design of policy that will target incentives that are aligned with private expectations
Factors, engagement processes and governance approaches for effective environmental decision-making and management?	• Understanding the mechanisms, arrangements and institutions that support innovation (collectively known as an 'innovation system') which deliver environmental outcomes, and the role and function of institutions (rules and norms) individuals and organisations in that system	• Roles, functions and characteristics of organisations and principles related to an effective innovation system documented and codified	• Organisations will have a clear idea of their role and that of others to collectively innovate, identify key gaps and misalignment and to design systemic solutions
Citizen science, co-development and co-design of research, and effective communication of science	• Understanding benefits to the individual of participating in these research activities, behaviours, tools and processes that are required	• Global case studies to compare across a diversity of cultures and contexts to identify behavioural characteristics and processes that deliver optimal outcomes • Allows for incentivising the types of behaviours that are best suited to co-development	• Findings facilitate informed citizen participation in environmental decision-making, and uptake of robust scientific knowledge and data for informing policy
Learning from Māori experience and values to promote a more system-wide and sustainable approach to management of New Zealand's environment	• Engagement with and inclusion of mātauranga Māori with an interdisciplinary science culture	• Align land management activities with the Māori principle of keeping/increasing the ora (vitality) of life	• System-wide, long-term, sustainable management and outcomes
Understanding pressures of increasing population and tourism numbers on the New Zealand environment including the conservation estate, and identifying effective responses	• Foresight studies that identify trends and potential related impacts. Scale and time need to be taken into account and address lag effects • Build on international literature on socio-ecological systems	• Modelling to develop plausible future scenarios that can be used to explore and test assumptions and interventions • Develop models of adaptive behaviour and associated institutions	• Robust information is available to test the validity of policy options and to identify key risks and build adaptive capacity to respond

Current capability and strategic needs

While human factors and economic dimensions are key factors in environment and conservation policy and management decisions, the capability in these areas is relatively weak. The number of researchers in New Zealand with experience and skills in socio-economic research on environmental issues is small compared to those with biophysical expertise. There is no Crown research institute dedicated to social science, and the current model of engaging a small number of social scientists within otherwise biophysical science-dominated Crown research institutes, and employing social scientists within government departments who have little control over their research agenda is not providing a complete solution.

The National Science Challenges are starting to build collaboration across institutions in socio-economic research, but this is a slow and challenging process. Given the policy-relevance and importance of such research, there is a need to attract and employ more researchers with relevant skills, and to find ways to build them into collaborative groups with enough critical mass so they can undertake and publish quality research.

Links with other strategies and policies

Funding from the Ministry of Business, Innovation and Employment through Strategic Science Investment Fund (SIFF) funding of Crown research institutes and other research institutes, support for National Science Challenges, and the Endeavour Fund can support the development of basic knowledge related to this theme. Government departments, including the Department of Conservation, Ministry for the Environment, Statistics NZ, and Treasury, along with the Envirolink Fund and regional councils, will need to play a role in funding and co-development work towards the ‘policy and management tools’ end of the research continuum, to support applications which support their particular policy needs. The philanthropic sector and NGOs can also play an important role in stimulating relevant work including citizen science and engagement between researchers and other stakeholders, including the public.

The research needs identified here, when addressed, will help provide the information required to inform policy development and initiatives, consistent with the following examples of strategic policy initiatives and direction:

- **Ministry for the Environment:** *Statement of Intent 2016–2020* (2016) – making New Zealand ‘liveable’ requires bringing together the environmental and economic bits of the jigsaw to support a strong and sustainable society, culture, economy, and environment (Ministry for the Environment, 2016).
- **Department of Conservation:** *Draft National Strategy for Environmental Education for Sustainability* (2016) – Vision: New Zealanders are innovative and motivated people who work together for social, economic and environmental sustainability (Department of Conservation, 2016a).
- **Regional councils:** *Research for Resource Management: Regional Council Research, Science & Technology Strategy* – identifies needs for (1) Research into and in support of decision- making systems, including community values-setting and accounting, and management policy design and evaluation, and (2) Research to develop operable approaches to assessments of resources or aspects of the environment as stocks and services, that explicitly address complexities and uncertainties including risk (New Zealand Regional and Unitary Councils, 2016).
- **New Zealand Treasury:** *Long term challenges and opportunities in the Natural Resource Sector – Three Case Studies* (2013) – New Zealand’s cultural, social, and economic prospects are inextricably intertwined with the health and sustenance of our natural capital (New Zealand Treasury, 2013).

Section 4: Implementing the Roadmap

This Roadmap document outlines, at a high level, the science that will be needed over the long term to support robust conservation and environmental policy making and management in New Zealand, and identifies capability and resource needs and desirable strategic directions. Government agencies and research organisations will use the Roadmap as the basis of more needs-specific, short-term decision-making.

The Roadmap will not achieve its purpose unless resources are effectively allocated by both funding agencies and research providers to address the research needs it identifies. Continued partnership between policy makers and research providers is also required so science is effectively translated into policy and management decisions. For this to happen, the Roadmap needs to be treated as a living document; its implementation needs to be monitored and effectiveness evaluated, feeding into periodic review and renewal. This will ensure it remains as relevant as possible.

The Roadmap highlights areas where capacity needs to be built and conceptual knowledge enhanced to inform decision-making. Investment to address these needs must be prioritised to the most critical areas identified in this Roadmap, and in a way that enables New Zealand to meet its environmental and conservation goals.

Decisions around the investment of new money in the science system are a matter for the Government to determine through the annual budget process. The priorities and any areas of under-investment identified in the Roadmap may provide a basis for a budget business case which would be progressed by the appropriate Natural Resources Sector agencies.

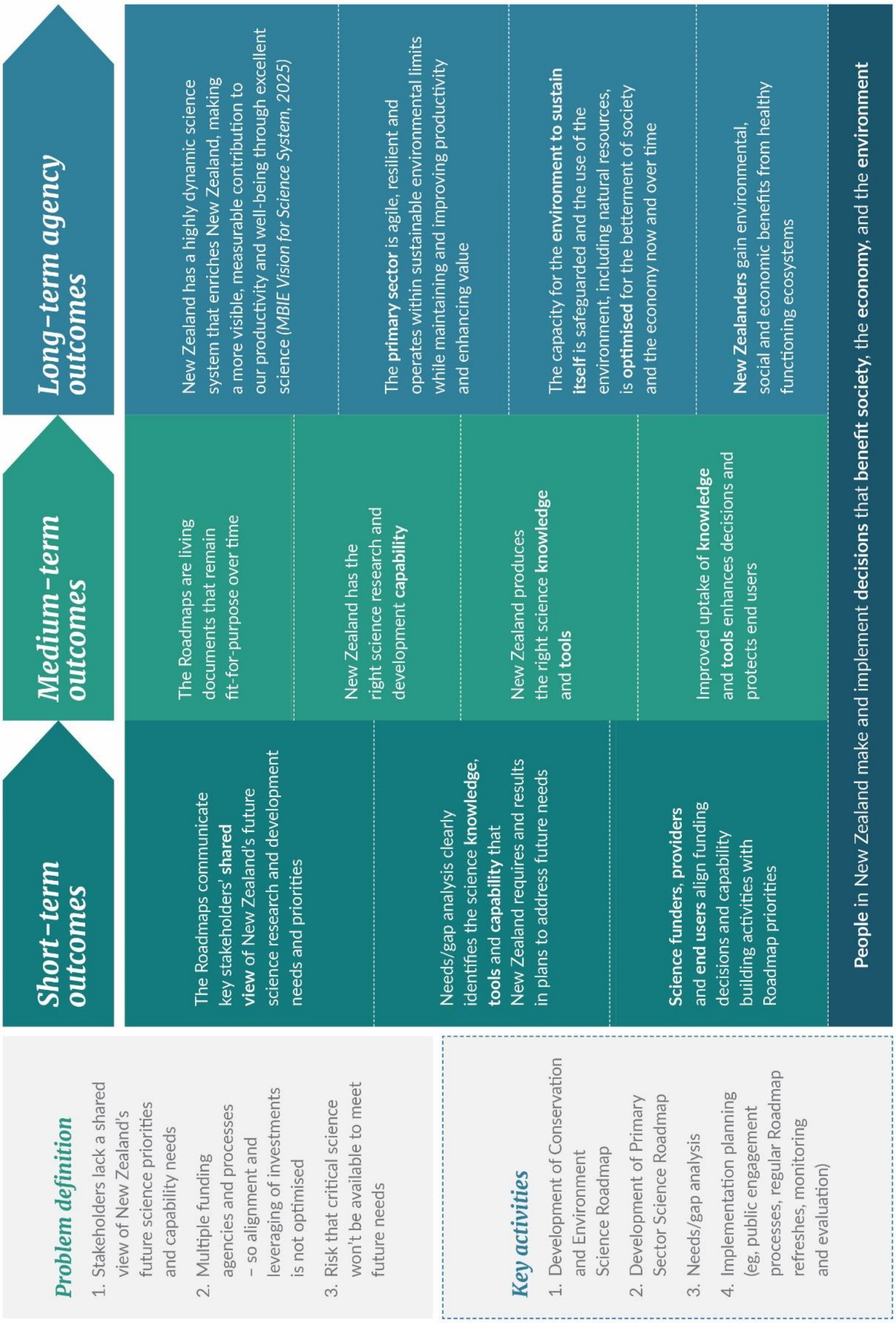
An overview of the current funding environment and the New Zealand science system is provided in Appendix 2. The allocation of science funding should continue to utilise existing funds and investment decision tools. The Ministry of Business, Innovation and Employment will need to factor the direction provided by the Roadmap into its future research investment plans.

A detailed implementation plan for this Roadmap identifying ongoing responsibilities and management priorities is being developed by government departments, led by the Department of Conservation and the Ministry for the Environment. The following matters will be addressed within the implementation plan:

- Working closely with the Ministry of Business, Innovation and Employment and the Ministry for Primary Industries, Department of Conservation, and Ministry for the Environment will take primary responsibility for ongoing governance and management of this Roadmap. The NRS secretariat should play a coordinating role in the implementation. The NRS coordinates planning across departments, including budget bids, so is well placed to identify resources to address areas of need.
- Government departments and agencies should take the Roadmap into account as they develop their own budgets, and their research and procurement plans.
- It is expected that the Ministry of Business, Innovation and Employment will integrate the Roadmap into its investment decision-making processes, and encourage providers to consider the Roadmap as an indicator of needs and of likely impact when they develop proposals for the Endeavour Fund, or negotiate ongoing funding from the Strategic Science Investment Fund.

- Ideally, there should be an annual review of progress, with evaluation metrics developed as part of the implementation plan (and including funds being allocated annually to each theme, compared to directional signals provided by the Roadmap).
- The Roadmap document itself should be periodically reviewed and updated, on a 4–5 yearly cycle. This is because environment and conservation research is a dynamic area of science, and because policy needs and priorities will change over time.

Figure 1: Outcomes from the Primary Sector Science and Conservation Environment Science Roadmaps



Glossary

Term	Definition
Anthropogenic	Created by people or caused by human activity.
Ahuatanga Māori	Māori tradition.
Big data	Very large data sets that can be analysed computationally to reveal patterns, trends, associations and interactions.
Biodiversity	Diversity among and within plant and animal species in an environment.
Biosecurity	The exclusion, eradication or effective management of risks posed by pests and diseases to the economy, environment and human health.
Biosystematics	Taxonomy based on the study of the genetic evolution of plant and animal populations.
Biota	The animal and plant life of a particular region, habitat, or geological period.
Blue/green infrastructure	Urban design features that incorporate building with nature to provide an ecological framework for social, economic and environmental health of the surroundings.
Co-design	Participatory design process – an interactive approach to design that actively involves all stakeholders in the design process.
Co-knowledge	Forms of knowledge that are typically complementary and at times overlapping and which are used together to inform in a variety of decision/policy fora, eg, Western science and traditional ecological knowledge.
Co-production	An approach to research that offers communities greater control over the research process and provides opportunities for researchers to learn and reflect from their experience and local knowledge, including working with those communities of interest.
Data infrastructures	Structures, systems and facilities that promote and facilitate the sharing and use of data.
Decision tool	Computer-based information system that supports organisational decision-making activities.
Ecosystem	A biological community of interacting organisms and their physical environment; a complex network or interconnected system.
Ecosystem-based management	An environmental management approach that recognises the full array of interactions within an ecosystem, including humans, rather than considering single issues, species, or ecosystem services in isolation.
Ecosystem services	The benefits provided by ecosystems that contribute to making human life both possible and worth living. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth.

Term	Definition
Estuarine	Relating to, or formed in an estuary – a partially enclosed coastal body of brackish water with one or more freshwater rivers or streams flowing into it, and with free connection to the open ocean, forming a transition zone between river and marine environments.
Exclusive Economic Zone (EEZ)	A sea zone prescribed by the United Nations Convention on the Law of the Sea over which a state has special rights regarding the exploration and use of marine resources. New Zealand's EEZ is one of the largest in the world, and is 15 times the size of its land mass.
Greenhouse gas emissions	Atmospheric gases that contribute to the greenhouse effect by absorbing infrared radiation produced by solar warming of Earth's surface. They include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), and water vapour.
Indigenous	Originating or occurring naturally in a particular place; native.
Informatics	Systems and processes used to collect, curate, manage and interrogate information.
Integrated catchment management	An approach that recognises the catchment or river basin as the organising unit for research on ecosystem processes for managing natural resources. Context includes social, cultural and economic considerations.
Kaitiakitanga	Guardianship, stewardship.
Mātauranga Māori	Māori knowledge systems, encompassing traditional and contemporary knowledge, wisdom, and understanding of human-environment relationships.
Mauri	Life force; the essential quality and vitality of a being or entity.
Multiple stressors	Simultaneous exposure of organisms or ecosystems to multiple environmental factors that have both individual and interactive adverse effects.
Natural capital	Stocks of natural assets, which include geology, soil, air, water and all living things. A wide range of services (see ecosystem services) that make human life possible are derived from natural capital.
Non-governmental organisation (NGO)	Not-for-profit organisation that is independent from national and international governmental organisations.
Natural Resources Sector (NRS)	The Natural Resources Sector is a grouping of government agencies, whose shared goal is to improve the productivity of New Zealand's resource-related industries while reducing their environmental impact. The NRS agencies are the Ministry for the Environment, Department of Conservation, Ministry for Primary Industries, Ministry for Business, Innovation and Employment, Te Puni Kōkori, Land Information New Zealand, Department of Internal Affairs and Ministry of Transport.
Ora	Well-being, vitality.
OVERSEER®	An agricultural management tool which helps farmers and their advisers examine nutrient use and movements within a farm to optimise production and environmental outcomes. OVERSEER® produces a nutrient budget which is a summary of all nutrient inputs and outputs from a farm or block within a farm.
Paris Climate Agreement	An agreement within the United Nations Framework Convention on Climate Change (UNFCCC) dealing with greenhouse gases emissions mitigation, adaptation and finance starting in the year 2020.

Term	Definition
Primary production (oceans)	The production of organic compounds from aquatic or atmospheric carbon dioxide through photosynthesis (using sunlight as energy) and/or chemosynthesis (using oxidation/reduction of chemical compounds as energy). Phytoplankton and sea grasses are the main primary producers in marine systems.
Rangatiratanga	Sovereignty; self-management.
Resilience	Process of adapting well in the face of adversity, disasters, threats or significant sources of stress.
Scenarios	Outlines or narratives that describe a plausible future situation.
Social capital	The networks of relationships among people who live and work in a particular society, enabling that society to function effectively.
Smart city	The collection and analysis of data from the physical environment and from the city's populace, and mapping the behaviour of the end users through intelligent analysis, to arrive at efficient and sustainable solutions for the future.
Taonga	Treasure.
Taxonomy	The branch of science concerned with classification, especially of organisms; systematics.
Tikanga	The customary system of values and practices that have developed over time and are deeply embedded in the social context; code, practice, protocol.
Tipping point	The point at which a series of small changes or incidents becomes significant enough to cause a larger, more important change.

Appendix 1: The road to the Roadmap

The Roadmap had its genesis in early 2016, in discussions between the Prime Minister's Chief Science Advisor and the Ministers of Conservation, Environment, and Science and Innovation, which identified the need for a long-term, strategic view of research needs for both the environment and the primary sector. The Conservation and Environment Science Roadmap was developed by the Department of Conservation and the Ministry for the Environment, taking into account existing policies and issues, government objectives and international obligations, and a horizon scan of future research priorities,[11] with valuable input from other government departments,[12] and guidance from a Strategic Advisory Group chaired by the Prime Minister's Chief Science Advisor, Sir Peter Gluckman.[13]

A discussion paper for the Conservation and Environment Science Roadmap was released on July 2016, with 88 submissions received from individuals and organisations including Crown research institutes, universities, government agencies, non-government organisations, and iwi. These submissions were considered and taken into account in the final Roadmap, which was approved for release by the Government in February 2017. Progress on the goals and objectives in the Roadmap will be monitored and feed into a 4-yearly refresh of the document (see Section 4: Implementing the Roadmap, for more information on the implementation of the Roadmap).

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11 Research roadmaps are common internationally, and also have precedent in New Zealand. Over the past decade a common 'horizon scan' method has developed, which was largely followed for the public discussion paper. It involved inviting ideas on the big research questions, evaluating those ideas through an expert panel, and reducing the large number of submitted questions to a set of themes and more specific questions.

12 Input from departments was received directly through consultation and through an Officials' Working Group, comprised of the Ministry for the Environment, Department of Conservation, Ministry of Primary Industries, Ministry of Business, Innovation and Employment, Te Puni Kokiri, Office of the Prime Minister's Chief Science Advisor, Statistics New Zealand, and the Environmental Protection Authority.

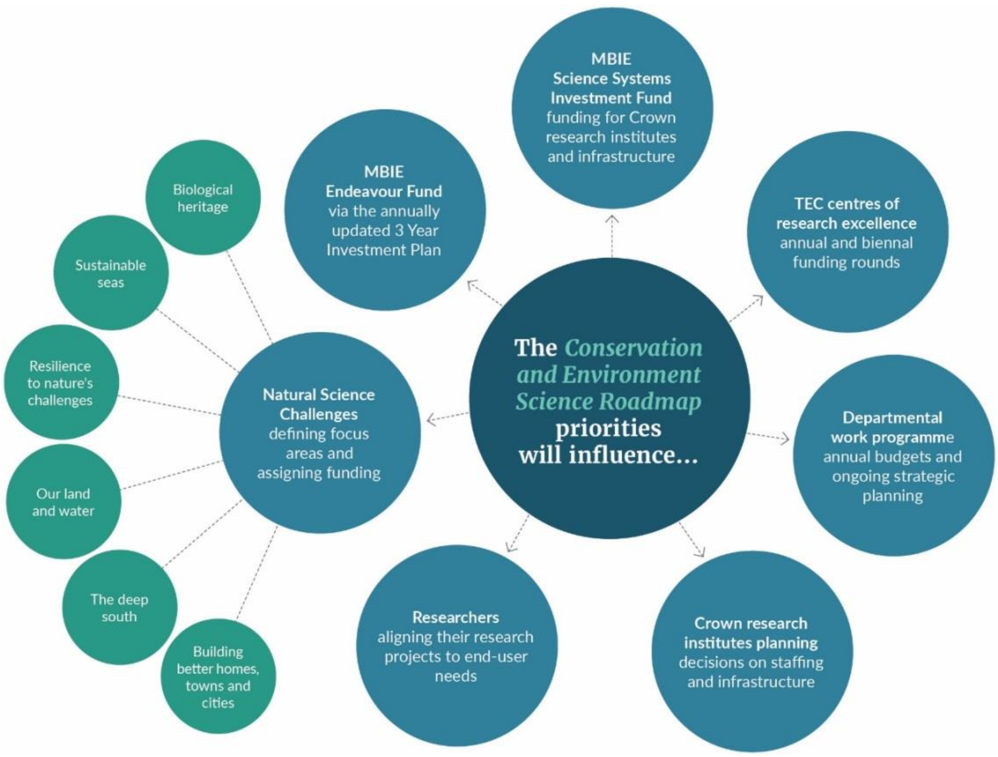
13 The Strategic Advisory Group members were Sir Peter Gluckman (Chair), Peter Bodeker, Sir Rob Fenwick, Wendy Nelson, Sir Chris Mace, Warren Parker, William Rolleston, Charlotte Severne, Janet Wilmshurst, Gillian Wratt, Gary Taylor, Suzi Kerr, Ken Hughey and David Wratt.

Appendix 2: Funding and resourcing

The Government is the primary funder and immediate end-user of much environmental science. Government funding of conservation and environment science is currently allocated by the Ministry of Business, Innovation and Employment (MBIE), the Tertiary Education Commission, or the government agency which manages the relevant fund. Decisions about the funding of research are either made by the individual agencies when they let contracts or provide grants, or by research providers such as Crown research institutes through their planning or through the science planning undertaken for the National Science Challenges and other MBIE-funded research streams. At a more local level, MBIE supports the Envirolink funding scheme for transferring scientific environmental knowledge to councils.[14]

Conservation and environment research is supported through departmental budgets (including those of the Ministry for the Environment, Department of Conservation, Land Information NZ, Ministry for Primary Industries, Ministry of Education, Ministry of Culture and Heritage, and Ministry of Health, Ministry of Foreign Affairs and Trade, and Te Puni Kōkori), but the bulk of research funding is through MBIE-administered core and contestable funding as outlined in the diagram below.

Figure 2: Science funding and the Conservation and Environment Science Roadmap



The National Statement on Science Investment (NSSI), released in October 2015, includes investment in science to enhance environmental quality and resilience, including:

- science to deliver effective safeguards and solutions against environmental impacts
- reduced or mitigated environmental risks
- improved condition of an environmental asset

14 See: http://www.envirolink.govt.nz.

- better understanding of the environment, and characterisation and management of natural capital.[15]

The NSSI focuses on measures of excellence and impact of research, as well as uptake by end-users and translation to policy.

There is also significant investment from the philanthropic sector. For example, the NEXT Foundation intends to commit $5–15 million per annum to environment and education projects over the next 10 years[16] – a level similar to funding by the Ministry for the Environment and the Department of Conservation. Other major donors to conservation and environmental research include the Tindall Foundation and the Morgan Foundation.

Stocktake of conservation and environment science funding

The figures in the table below provide a stocktake of current expenditure on conservation and environment science expenditure by government. It has been assembled from 2015/2016 funding provided through the main public science funding mechanisms; however, the figures are approximate because it is difficult to map across departmental expenditure using MBIE data.

The primary investment mechanisms in this area are Crown research institute core funding (now part of the Strategic Science Investment Fund), the Endeavour Fund, and the National Science Challenges– together these make up nearly 80 per cent of investment.

Investments have been tentatively mapped to Roadmap research themes. Due to inherent assumptions and uncertainties in this process, and because most projects cross multiple themes, this mapping is **indicative only**. This shows a fairly even spread of research funding across the themes, although the analysis suggests '**Coasts and oceans** and '**Species and populations'** receive less support than others.

The analysis of funding split by research objective is more reliable than the split by theme, as fewer assumptions are involved. Some findings of this which are consistent with previous anecdotal evidence are that there is relatively little:

- climate change mitigation research except for agricultural greenhouse gases
- air quality research.

National Science Challenges (NSCs) are still not fully established. Annual funding going forward across NSCs is likely to increase over future years.

Further caveats

- The analysis does not capture research conducted using general university funding. This is likely to be have a more basic (versus applied) focus in general than the research that is captured by this analysis.
- This analysis was not able to estimate the amount invested in the cross-cutting Mātauranga Māori and Social and economic factors themes.

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15 See: http://www.mbie.govt.nz/info-services/science-innovation/national-science-challenges/nz-biological-heritage.

16 See: http://www.nextfoundation.org.nz/about#vision.

Figure 3: Indicative current government spend relevant to each theme based on 2015/2016 funding

FUNDING SOURCES	Environmental monitoring	Climate change	Biosecurity	Land	Fresh water	Coastal and oceans	Urban	Species and populations	Social and economic dimensions	Unclassified	Total
Crown research institutes core funding/Science System Investment Fund	$11.9m	$9.5m	$6.6m	$6.6m	$7.3m	$4.1m	$8.0m	$2.8m	$1.5m	$4.4m	**$62.7m**
Department of Conservation	$0.0m	$0.2m	$4.7m	$1.1m	$1.1m	$1.1m	$1.1m	$1.2m	$0.0m	$0.4	**$10.9m**
Endeavour Fund	$5.4m	$4.4m	$7.0m	$6.7m	$6.7m	$1.9m	$2.8m	$1.4m	$0.0m	$1.0m	**$37.3m**
Ministry for the Environment	$0.5m	$0.2m	$0.0m	$1.2m	$1.3m	$0.5m	$0.6m	$0.4m	$0.0m	$0.2m	**$4.9m**
Ministry for Primary Industries – various	$0.4m	$7.6m	$2.4m	$0.5m	$0.4m	$4.7m	$0.0m	$0.0m	$0.4m	$0.0m	**$16.4m**
National Science Challenges	$3.5m	$5.3m	$0.8m	$2.2m	$2.4m	$2.5m	$1.3m	$2.3m	$3.2m	$1.5m	**$25.0m**
Natural Hazards Platform	$0.0m	$0.0m	$0.0m	$0.0m	$0.0m	$0.3m	$2.7m	$0.0m	$0.0m	$0.0m	**$3.0m**
Total	**$21.7m**	**$27.2m**	**$21.5m**	**$18.3m**	**$19.2m**	**$15.1m**	**$16.5m**	**$8.1m**	**$5.1m**	**$7.5m**	**$160.2m**

Estimated expenditure by each agency in each Roadmap theme

Estimated total expenditure by each agency and against each theme

Notes

1: 'Mātauranga Māori' and 'Social and economic factors' themes are cross-cutting. The amount invested in these cannot easily be split but they are embedded in many research projects. The Mātauranga Māori theme is excluded completely from this table, while Social and economic factors is included but almost certainly underestimated.

2: Ministry for Primary Industries (MPI) figures are a subset of MPI funding in areas that align to the scope of this Roadmap.

3: This includes marine environmental related research funded by MPI. It does not include fisheries stock assessments.

4: Based on 2015–16 funding.

The New Zealand science system

The New Zealand science system is complex. Investigator-led science is funded through several mechanisms, including:

- Performance-Based Research Fund allocations to tertiary education organisations
- centres of research excellence
- the Marsden Fund.

Mission-led science is directed towards a particular policy aim or goal, and is funded through:

- the Strategic Science Investment Fund allocations to Crown research institutes
- the MBIE Endeavour Fund
- National Science Challenges.

In the New Zealand tertiary education sector, science research capability is provided through eight universities, 16 institutions and polytechnics, and three wānanga. The latter focus in part on the application of knowledge regarding ahuatanga Māori (Māori tradition) according to tikanga Māori (Māori custom).

MBIE's Vision Mātauranga Capability Fund aims to unlock the science and innovation potential for Māori knowledge. This includes investment in developing people and organisations conducting research supporting taiao (environment), which focus on achieving environmental sustainability through iwi and hapū relationships with the land and sea.

While the Roadmap will be informed by current investment strategies and plans, it presents a longer-term view of government science needs. Over time, the Roadmap will guide and inform the shape of these strategies and plans as they are reviewed and updated.

Appendix 3: More on links to other strategies and policies

The Roadmap, the National Science Challenges, and other contestable funds are strongly linked, but the Roadmap provides a higher level, strategic view of research needs, while the latter have a more specific, shorter-term focus.

In addition, the Roadmap relates to, and has been informed by, other strategic documents, such as the New Zealand Biodiversity Action Plan 2016–2020, Predator-free New Zealand 2050, and the National Policy Statement for Freshwater Management 2014.

A separate but aligned roadmap – the Primary Sector Science Roadmap – is being prepared by the Ministry for Primary Industries. The focus of the Primary Sector Science Roadmap is on identifying key science and technology needs and opportunities for protecting and growing our land and aquatic-based industries, and improving environmental outcomes associated with these industries.

There are clear interdependencies between the two roadmaps. For example, production from agriculture, forestry and fisheries is dependent on natural capital and ecosystem services, and conservation and environmental management are in many cases closely linked to primary sector activities. Both roadmaps seek enhanced environmental outcomes and prosperity for New Zealand. They address shared pressures, such as biosecurity and climate change, and opportunities to improve policy development and management through better support for and utilisation of mātauranga Māori and investment in technology platforms that may benefit both sectors.

Appendix 4: New Zealand Legislation relevant to the Conservation and Environment Science Roadmap

Legislation	Lead agency	Purpose of the Act
Acts establishing the functions of the main agencies		
Environment Act 1986	Ministry for the Environment	Provide for functions and operation of the Ministry for the Environment
Conservation Act 1987	Department of Conservation	Provide for functions and operation of the Department of Conservation – to promote the conservation of New Zealand's natural and historic resources
Environmental Protection Authority Act 2011 (the EPA Act)	Environmental Protection Authority	Provide for functions and operation of the New Zealand Environmental Protection Authority
Other relevant acts (not an exhaustive list)		
Biosecurity Act 1993	Ministry for Primary Industries	Provide legal basis for exclusion, eradication, and effective management of pests and unwanted organisms
Conservation Law Reform Act 1990	New Zealand Conservation Authority	Establish New Zealand Conservation Authority with functions to: • review and approve conservation management strategies • investigate conservation matters of national importance • encourage participation in educational and publicity activities aimed to improve understanding of New Zealand nature conservation • Liaise with New Zealand Fish and Game Council
Energy Efficiency and Conservation Act 2000	Ministry for the Environment; Energy Efficiency and Conservation Authority	Prepare a national energy efficiency and conservation strategy
Environmental Reporting Act 2015	Ministry for the Environment; Statistics New Zealand	Mandatory reporting on the New Zealand environment
Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (the EEZ Act)	Ministry for the Environment; Environmental Protection Authority	Assist sustainable management of natural resources in the EEZ and continental shelf
Hazardous Substances and New Organisms Act 1996 (the HSNO Act)	Environmental Protection Authority	Protect the environment and public health/safety by preventing/managing adverse effects of hazardous substances and new organisms

Legislation	Lead agency	Purpose of the Act
Fisheries Act 1996	Ministry for Primary Industries	Provide for the utilisation of fisheries resources while ensuring sustainability – maintaining the potential to meet the needs of future generations and avoiding, remedying, or mitigating any adverse effects on the aquatic environment
Forest Amendments Act 1993	Ministry for Primary Industries	Promoting the sustainable management of New Zealand's indigenous forests
Marine and Coastal Areas (Takutai Moana) Act 2011	Department of Conservation	Provides for the special status of the common marine and coastal area that is incapable of ownership
Marine Mammals Protection Act 1978		Provide for protection, conservation and management of marine mammals within New Zealand and its fisheries' waters
Marine Reserves Act 1971	Department of Conservation	Marine reserves to be maintained in natural state, and public to have right of entry
National Parks Act 1980	Department of Conservation	Preservation of national parks in perpetuity for their intrinsic worth and for their use and enjoyment by the public
Reserves Act 1977	Department of Conservation	Acquisition, preservation and management or areas for their conservation values or public recreational and educational values
Resource Management Act 1991	Ministry for the Environment	Coordinated and comprehensive approach to environmental management
Trade in Endangered Species Act 1989	Department of Conservation	Further the protection and conservation of endangered species of wild fauna and flora by regulating the export and import of such species and any product derived from those species
Waste Minimisation Act 2008	Ministry for the Environment	Encourage reduction in waste generation and disposal to reduce environmental harm and provide economic, social and cultural benefits
Wild Animal Control Act 1977	Department of Conservation	Provision for the control of harmful species of introduced wild animals and the means of regulating the operations of recreational and commercial hunters
Wildlife Act 1953	Department of Conservation	Protection and control of wild animals and birds and the management of game

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