

New Zealand Government



# Conservation and Environment Science Roadmap

DISCUSSION PAPER

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**“New Zealand’s environment is a taonga of paramount importance. It sustains everything we depend on for healthy and prosperous lives: our economy, culture, and well-being.”**

Ministry for the Environment

**“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.”**

Department of Conservation

# Message from the Conservation and Environment Ministers

What is our vision for New Zealand in 20 years?

If you asked most New Zealanders what future they wanted for the New Zealand environment, it is likely that their answer would include having 1) a clean and healthy 'natural' environment with relatively intact natural ecosystems such as national parks, and coastal areas, and 2) a healthy and sustainable productive landscape that supports a sustainable economy.



How do we ensure that this vision is fulfilled in the long term? We create our future by what we do or do not do today. The decisions we make now and in the near future can have long-term effects on our environment. In the case of natural resources and biodiversity, for example, an ill-considered and environmentally-damaging decision today may take many years to reverse, if it is reversible at all. As a nation, we need to consider whether our current policies for resource use and environmental management are wise when viewed from a future perspective. We also need to ask ourselves what exactly our future policies might need to address. Scientific knowledge can help us make good policy decisions, and choose wise management practices for resource and environmental use. This roadmap is aimed at identifying research directions that can ensure that decisions by government, organisations and individuals are better informed.

Good scientific evidence and advice underpins good decision-making, whether those decisions are made by central, regional or local government. Evidence-based decision-making is particularly critical for big, cumulative issues relating to conservation and the environment. 'Science' in this respect includes not only biological and natural sciences, but also mathematical, engineering, and social sciences, economics and mātauranga Māori. Policy-makers at all levels of government, irrespective of political ideology, need to have access to high-quality, scientifically-derived evidence to inform regulatory and policy development, management practices, and evaluation.

Given the often long lead-time from scientific investigation to implementation, the evidence needed to inform government policy development and management practices today can only come from research that was initiated some time ago. The work that is being done today will only provide answers sometime in the future. This means that we need to be very thoughtful and forward-looking to ensure we are best placed to deal with future challenges, and have the capacity to take on opportunities – using scientific insight or innovative technologies – in a timely manner for the benefit of society, our environment, and our economy. We also need to ensure that our strategic planning for today aligns our research directions toward the future information needs of policy-makers. Funders of science will also need to think strategically in order to best align funded research with future needs.

The Conservation and Environment Science Roadmap takes a 20-year perspective on the research needed to achieve the most desirable future for New Zealand. It will take into account our long-term goals, asking questions about the science needed to work towards the goal, and to deal with the challenges and obstacles along the way.

Government funds research into conservation and environmental matters in many ways. Beyond academic investigator-led research funded through the Marsden and Endeavour Funds, the Ministry for the Environment, the Department of Conservation, the Crown research institutes, Te Papa, regional agencies, the National Science Challenges, the Ministry for Primary Industries, Land Information New Zealand and others, are all major funders of mission-led research using taxpayer and ratepayer funds. A roadmap ensures better prioritisation and coordination between these multiple agencies and authorities.

This discussion paper – developed by an Officials’ Working Group, with guidance from an external Strategic Advisory Group – includes input from earlier engagement with a wide range of stakeholder groups. It identifies some of the big issues and possible research directions New Zealand can take over the next 20 years, organised around a set of 12 proposed themes, and a series of possible key research questions that if answered will help government address the challenges and opportunities we will face.

The discussion paper is not a draft roadmap – the roadmap will be completed once we have considered your views as part of this consultation process. The consultation will determine whether the themes and research questions identified in this document are broadly the right themes and the right questions to consider, and what the more focussed priorities should be.

In making your input we wish to emphasise that responses can be both specific and generic – all will be valued and we look forward to wide and considered engagement occurring during this process, as it is your input that will help us shape the final roadmap.



Hon Maggie Barry, ONZM  
Minister of Conservation



Hon Dr Nick Smith  
Minister for the Environment

# Developing a Conservation and Environment Science Roadmap

## Setting the scene

In 20 years' time, Aotearoa New Zealand will be a different place. Our demographics, population and economy will all have changed markedly. Technology, and how we connect both locally and globally, will be radically different. Our environment, too, will have changed, some for the good, and other areas less so. Because of this, an enormous range of policy issues – many relating to conservation and the environment – will have been raised and addressed, and science will have helped us to understand these issues and find solutions.

It is likely that New Zealand will still be rich in natural resources, but as a society, we will probably be using these resources in very different ways. We will continue to face complex issues and trade-offs between conservation of our natural environment and using our natural resources to support our society's health, well-being and economy. To ensure that our natural resources can continue to support important aspects of our economy, our society and our culture, we will need to adapt to pressures such as climate change, rapid globalisation, and urban intensification. Innovative thinking and research will be necessary to enhance the sustainability of the primary sector and tourism. We must act now to improve our knowledge base if we are to maintain our quality of life and competitive advantage in the rapidly changing global landscape.

New Zealand has a unique and valued environment and conservation estate, which its people are determined to protect and, where possible, improve. There are many benefits to New Zealand having clean air, clean water, and unpolluted seas, and protecting its native biodiversity while using its resources sustainably. Not least of these is New Zealand's strategic economic advantage relating to our 'clean and green' brand, and to our key natural environment-based industries – agriculture, forestry, fishing, and tourism. The opportunity to secure 'premium' high prices for our exports based on brand is compelling. Protecting and enhancing this brand will enable sustained and value-added economic growth, and this will need to be linked to conservation and the environment in mutually reinforcing ways. It is already challenging to build and maintain this strategic advantage; it will become more so as customers become more discerning, and as product traceability becomes more widespread.

There are complex policy trade-offs between environmental protection and economic growth that current and future governments will have to address. New technologies will change the interaction between resource conservation and sustainable use, and will have implications for the primary sector. These will be addressed in a roadmap for primary sector science<sup>1</sup>, being developed in parallel, and aligning with, the Conservation and Environment Science Roadmap.

There are many challenges ahead. Pressures are unavoidably created by population growth, the need to continue to enhance our economy, and to reach the expectations of a high quality of life for all our citizens and residents. Central and local government, private sector, non-governmental organisations and individuals will need to make many decisions that affect our environment and natural heritage. The complexities of the interactions that now exist between human and natural ecosystems mean that scientific knowledge will be critical for making better informed decisions and evaluating their impact.

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1 The Primary Sector Science Direction: A roadmap for the primary sector's future science and technology needs (Ministry for Primary Industries, in development).



It is these future-focused issues and research opportunities that are at the heart of the proposed Conservation and Environment Science Roadmap addressed in this discussion paper. The discussion paper is deliberately broad-ranging, to encourage input. It is envisaged that the final roadmap will narrow and become more directional following the consultation phase.

## The goal for the roadmap

A key part of any roadmap is having a clear goal – a view of where we want to head. Not only is this goal about the type of New Zealand we want to live in, it is also about the role we want our science community to play in leading us there.

Science has a critical role in deciphering the links between environmental stressors, the actions that influence them, and possible long-term outcomes. Science is also key in finding innovative solutions to address the opportunities and to mitigate the risks we are likely to face in the future. New Zealand's science capabilities and relationship with the international science community need to be supported and grown, to help steer us toward our desired future.

The goal of the roadmap is therefore to identify the areas of scientific knowledge that will be needed to support decision-making for conservation and environmental policy and management. This will help us reach our national ambitions of having a healthier people and environment, and a robust economy, while also nurturing our environment and conservation estates and implementing our obligations under the Treaty of Waitangi.

To do this, the roadmap process will take into account existing policies and issues, government objectives and international obligations, and carry out a horizon scan of future research priorities based on a structured consultation process and public feedback.

## Scope of the roadmap

The roadmap will include the environmental areas of land, fresh water, and coastal/marine environments. Important elements across these are climate change, mātauranga Māori, biodiversity, biosecurity, anthropogenic (human-made) substances, introduced organisms, and new and emerging technologies.

The types of information needed will come from a wide range of disciplines including biological and physical sciences, economics, social sciences, and technology. It will include emerging trends in socio-ecological systems from multi-cultural perspectives.

Where the scope, themes and specific research questions clearly overlap with production (eg, in terms of agricultural sector greenhouse gas emission mitigation technologies), then it is expected that the Primary Sector Science Direction will capture these needs.

The geographic scope includes mainland New Zealand, the Tokelau islands, the Chatham Islands, outlying islands in the subtropics (eg, the Kermadecs) and the sub-Antarctic, and New Zealand's Exclusive Economic Zone (EEZ), as well as the three main islands. It also includes the Southern Ocean and the Ross Dependency in Antarctica.

## What the roadmap will be used for

The roadmap will be a tool to indicate environmental and conservation science research priorities to research funders and providers. Government funding of conservation and environmental science must be cohesive and strategic to get maximum value from research, and ensure the resulting data is fit-for-purpose for future decision-making.



The roadmap will not develop environment and conservation policy. It will take guidance from tāngata whenua, and policy-makers and decision-makers in stakeholder organisations, about policy areas that are likely to become important. This will help identify the research needed to support policy and regulatory development, implementation, monitoring and management.

The roadmap will take a 20-year strategic view to identify research and capability needs for a resilient, future-looking, integrated research system that can generate robust scientific evidence to guide New Zealand's future sustainability. It will help core government departments set their own research priorities, and integrate research priorities across Natural Resource Sector agencies. The roadmap will support the National Statement of Science Investment produced by the Ministry of Business, Innovation and Employment (MBIE) in 2015. This provides a framework for coordinating research resources nationally, and influencing how research providers respond in future bidding rounds for MBIE science funding. It will sit alongside, and over time give direction to, the high level objectives of both the National Science Challenges, and the future funding of the new Strategic Science Investment Fund. There will be additional benefits from better cross-agency coordination and leadership around contemporary issues, linked to collections and big data management and their ongoing accessibility. Ultimately we expect the roadmap to guide the science used to inform policy in 12 proposed themes outlined in this discussion paper.

Implementing the roadmap will also address key opportunities, including:

- helping to meet international obligations
- long-term options for databases, collections and monitoring
- stronger integration of mātauranga Māori, and greater recognition of our partnership with Māori going forward.

The roadmap is a living document, whose impact will be evaluated, reviewed and updated regularly. This will ensure that the roadmap remains responsive to future conservation and environmental policy and management needs.

## Looking ahead: challenges and opportunities

Change in our environment, and its speed, is driven by a number of factors. How these drivers progress, and how we can influence them, will impact the future of the New Zealand environment. As well as widely recognised changes to freshwater quality and species decline, there are other less observable but more pervasive drivers, such as climate change and the cumulative effect of land-use change. There are also much broader social, technological, economic and political drivers that impact conservation and the environment, both positively and negatively. These changes will also provide opportunities (eg, through new technologies), and we will want to take advantage of the opportunities as well as rising to the challenges.

### Climate change – mitigation and adaptation opportunities

Climate change is expected to have a very significant impact on our environment, with effects cutting across almost every aspect of environmental and conservation research. It is likely to influence species, habitats, ecosystems, biodiversity, biosecurity, water quality and availability, land use, and primary production.

Climate-related sea level rise will affect our coastlines, exposing communities and fragile coastal ecosystems to more frequent flooding, and accelerated erosion. Changes can be expected in the frequency and severity of natural hazard events, including extreme weather, drought, frosts, wild fires and flooding. Land-use pressure will increase as some areas become

less suitable for existing productive use, while other areas will experience changed opportunities (eg, with temperatures warming further south there will be new horticultural opportunities). Our rivers will be affected; floods may occur more often but, paradoxically, flows may become less reliable. These changes will impact hydro-power generation and water storage for irrigation, as well as the habitats of threatened and at-risk New Zealand species.

Scientists strongly agree that human activities, and in particular anthropogenic greenhouse gas emissions, contribute to global climate change. There are many actions we can take to reduce its future impacts, and to prepare for the impacts we cannot avoid. Research will play a key role in identifying and understanding these impacts and mitigation opportunities. For example, forests and soils can be used for carbon sequestration, which will work with conservation efforts and restoration of natural ecosystems. Our scientists will need to work across ecosystems (eg, land and water) to help policymakers address these issues and improve our resilience. The challenges, and often the associated opportunities, are enormous.

## Enhancing ecosystem services

Human well-being is dependent on ecosystems and their 'services,'<sup>2</sup> through which they provide resources, moderate climate, absorb pollutants, cycle nutrients, and confer cultural and other benefits. These services are all supported by biodiversity – the animals, plants and micro-organisms that have adapted to, and interact in, the ecosystem. While we also interact with ecosystems, our actions can transform them so their functioning, and ability to provide for us, is compromised. We need to strengthen our ability to assess the tipping points of ecosystems, so we can enhance, rather than disrupt, their functioning.

Ecosystems are often differentiated by their 'domains' – eg, land, fresh water, and marine – which each have unique characteristics, science questions, and management issues. But these domains also interact with each other, and activities or changes in one domain will have flow-on effects in others. Understanding how ecosystems and processes work with one another will improve our management and decision-making.

## Fresh water – a continuing challenge

Fresh water is vital to New Zealand's way of life and economy. Our rivers, lakes, wetlands, and groundwater support our economy through agriculture, horticulture, hydroelectricity generation, and tourism, and will continue to do so into the foreseeable future.

New Zealanders enjoy many forms of recreation in our lakes and rivers, including swimming, boating, and fishing. For Māori, fresh water is a taonga and essential to life and identity. Access to fresh water for food, materials, and customary practices is fundamental to Māori.

The quality of water in New Zealand's lakes, rivers, wetlands and aquifers varies, and depends largely on the main land use in the catchment. Many of our freshwater fish species are unique, and are threatened or at risk. Despite government, iwi and community investments in freshwater management and restoration, there are still some negative trends in freshwater health. There are enormous incentives to align the policy and the research at government, industry and community levels, but it will take time for the ecosystem to respond.

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2 Ecosystem services are the processes by which people obtain benefits from ecosystems, such as clean air, fresh water, and the pollination of crops. These benefits are commonly classified as being one of four types: provisioning (eg, food, fibre, water, fuel, genetic resources); regulating (eg, air quality, climate, water flow, pollination, erosion control, pest and disease control); cultural (eg, spiritual, aesthetic, recreational, educational); or supporting (eg, photosynthesis, soil formation, nutrient cycling).

## **Our land, coastlines and seas – supporting our economy**

Since arriving in New Zealand, humans have used its natural resources to support their lives and lifestyles. Over time we have profoundly altered the natural landscape to accommodate agriculture, forestry and urban settlements. Our economy continues to be based largely on land-based primary production and exports, and we are a high-value provider of protein to the world market. But looking out 20 years, will this continue to be the case? If we want to continue to support a primary sector-based economy, we need to consider what to do as environmental resources such as fresh water become limited, and our native biodiversity and ecosystems face increasing pressure.

Research into innovative technologies and processes, and their impacts, will help us make decisions on how to produce more primary goods on less land, while sustaining both the primary sector economy and our terrestrial ecosystem services.

In the marine domain, economically important activities in New Zealand's Exclusive Economic Zone affect oceanic flora and fauna. We rely on our coastal marine environment for economic growth and ecosystem services, but unlike terrestrial environments, changes in the ocean are difficult to observe, complex and highly variable. We are often aware of changes only after the fact. Decision-making is challenging, but research to understand environmental effects can help inform policy development to help sustain our economic, social and cultural connection to this environment.

## **The urban ecosystem**

New Zealand is one of the world's most urbanised nations. More than 86 per cent of our population live in urban areas, some with only minimal connection to the natural environment. Demographic and cultural changes mean our understanding of New Zealand's unique biological heritage has weakened. Social science and environmental education research is needed to understand and promote positive future conservation and environmental outcomes, and their relationship with our primary industry-driven export economy.

Urban intensification puts increasing demands on the natural resources (eg, fresh water) needed to support good economic, environmental, social and cultural outcomes. We need to understand the consequences of these changes, including the impact of urban development on conservation lands, and on coastlines where most of our cities are located. Our unique coastal environments and resources have immense cultural value to all New Zealanders, but the construction and expansion of ports, marinas and other coastal infrastructure has replaced large areas of natural habitat, and urban processes have introduced pollution and sediment to marine habitats. This has affected culturally important species in our delicate coastal and estuarine habitats, causing conflict with Māori and coastal communities. Coordinated research in hazard science (including hazardous substances), biophysical ecosystem science, and political ecology sciences could change the way we think and act with regard to urban areas.

## **Environmental contaminants**

The impact of human activity is becoming more visible, in contamination of the natural environment by human-made (anthropogenic) substances. Industrial chemicals and toxic metals have long been a concern, but we are now facing the effects of accumulation of persistent and new substances, including micro-plastics, nanoparticles, and other by-products of modern lifestyles.

Some contamination occurs through the intentional use of pesticides, herbicides and fertilisers, but also unintentionally through accidental spills, leaching, and flushing waste

(including cleaning products, cosmetics, building products and other consumer ‘necessities’) into water, or burying it in landfill. Chemicals and other contaminants from land-based activities accumulate in freshwater and marine sediments. When enough plants or animals are affected, contamination can change how ecosystems function.

With newer substances such as nanoparticles, little is known about impacts on the environment and human health. Their properties (eg, a tendency to aggregate and sediment) may cause them to react significantly differently from traditional contaminants. Scientific research is essential to assess the risks, and ensure we have the right instruments for monitoring and mitigating risks. We also need innovation in science to help identify opportunities for new environmentally-friendly products and processes.

## **Protecting New Zealand’s unique flora and fauna**

New Zealand’s native species face a number of threats, including habitat loss, disease, invasive species (both plant and animal), man-made substances (eg, chemicals, plastics), and impacts of climate change, which are increasing at an already dangerous rate of extinction. Tools and technologies need to be developed to manage and protect our biodiversity in the face of these challenges.

Introduced animal pests have been directly responsible for extinctions. Pest insects, fungi, bacteria, viruses and plants also present significant risks to our productive and natural environments. Large-scale challenges are also posed by introduced ‘woody’ plant pests, including wilding trees and invasive vines that threaten ecosystem structure, species viability, and cultural and economic values over both the South and North islands. This threat is becoming more pervasive as the cumulative and synergistic effects of these species incursions grow. While our scientists have led the world in the control of invasive species, and New Zealand continues to gain operational experience in both scale and efficiency, pest and pathogen management remains a challenge, and a substantial cost to society. We need to investigate long-term solutions, and consider some radical ideas that have been technically limited in the past, but may become feasible with time and technology.

Biotechnology is already offering potential genomic selection methods to increase resistance to kauri dieback, gene drives for eradicating invasive pest species, and biocontrol agents for weed control. Similar kinds of ‘radical’ thinking are needed in freshwater and marine environments, where introduced species are also increasingly threatening species, habitats and ecosystem processes. We have the opportunity to practice ecological restoration at a national level, but to take advantage of these tools, broad community discussion is needed, informed by science, and responsive to societal and cultural values.

## **Globalisation and biosecurity**

New Zealanders lives are intertwined with those of people around the world in ways unimaginable to previous generations. The integration of New Zealanders with global society, through the internet and the ease of international travel, has provided many benefits in information exchange, communication, commerce and tourism. But global travel and trade activities represent a constant concern for New Zealand’s biosecurity system. This system is key to protecting not only our indigenous species and taonga, but also the commercial species that underpin our primary industries. We need to investigate and utilise new and novel technologies, and find ways to stay ahead of the game as it continues to change at a rapid pace. This all needs to be done in a way that society can accept and support. A shared vision for the future is critical.

## **Mātauranga Māori and Treaty-related opportunities**

Perhaps one of the biggest and most positive drivers of change in New Zealand is cultural – new Treaty of Waitangi settlements and related law and lore are driving changes in the way we work, the way we manage, and the way we act. Western science and management systems are engaging and integrating with Māori ways of doing – it seems likely that this ‘mixing’ will provide more opportunities than would be available from either working in isolation.

The Māori economy is driving much of this progress and is adding new, world-leading multi-generational perspectives to the way we think about the environment and conservation. It is becoming increasingly clear around the world that including indigenous knowledge in conservation and environmental decision-making can significantly enhance the use of science research for making better choices.

Māori have a special relationship with the natural environment – culturally, scientifically and spiritually, and utilise mātauranga Māori (traditional and contemporary knowledge systems) in resolving complex resource management issues. Whanau, hapū and iwi have clear duties to exercise kaitiakitanga (guardianship) to sustainably manage resources throughout Aotearoa. Embracing the holistic view of the environment that underpins Māori culture, along with western scientific perspectives, creates the opportunity for a more integrated approach to environmental and conservation management in New Zealand. This approach can be applied across all environmental domains and conservation issues.

## **People matter**

People are at the heart of each and every major conservation and environmental issue discussed so far. As humans we both affect and are affected by the trends and changes in our environment. The importance of understanding the social dimensions of conservation, resource management, land use, and economic choices, and how they impact on long-term environmental health and sustainability, must not be underestimated.

Much of the response to environmental change may ultimately be attributed to us as consumers, and will reflect our values, culture, and social norms. But it is not only the environment that is changing. New Zealand’s population and underlying demographics are undergoing major change, and the values of our society are becoming increasingly diverse. The way we work is changing, as are our recreation activities and the way we think about and connect with the environment and conservation, and this will continue into the future.

Dealing with these changes will require new tools for engagement and for decision-making, particularly around the relationship between environment, conservation and development. Making science accessible to everyone will help feed the growing interest in ‘citizen science’, presenting opportunities for valuable contributions and public engagement.

Current debates and questions about ‘social license to operate’ need to be broadened and better informed by science, while at the same time acknowledging that perceptions and concerns are shaped often more by cultural worldview and experience than by the presentation of scientific evidence. Social scientists will need to work effectively with physical and biological scientists and science communicators on issues that require a change of behaviour. Solutions are needed across a wide range of public and private interests.

## **Underpinning science**

Aotearoa New Zealand is still not properly explored – there is much we don’t know about what inhabits our lands, let alone our vast coastal and marine environment. The need to keep exploring makes conservation and economic sense – we can neither manage nor benefit from

the unknown. The need for agencies to work together, share infrastructure, and manage big data for the benefit of New Zealand has never been stronger.

Monitoring our environmental state and trend is critical for conservation and resource management policies, and improved tools for collecting, managing and analysing data will be needed as we continue to explore and negotiate our rapidly changing environment. Thus, Environment Aotearoa 2015<sup>3</sup> represents the first state of the environment synthesis report for New Zealand as required three-yearly under the Environmental Reporting Act 2015. Long-term science projects and data recording, as well as taxonomic collections, are an essential resource for this, supporting science with information about our natural world, and informing our conservation and environmental monitoring and management. They need to be maintained and protected into the future.

Decision-making in the natural resources sector utilises approaches such as environmental economics, cost-benefit analysis, optimisation models, ecosystem services, and natural capital valuation. Decision-makers first reach for data and the latest scientific understanding for those models. If there are data gaps, inefficiencies and poor decision-making occur. For example, currently there are no systematic data on land use or management that can be connected to economic and social data to evaluate these relationships, which are critical to policy development. We need to consider what is needed in terms of data infrastructure systems in future, to provide a robust, accessible and sustainable supply of relevant data and information for these purposes.

## **Providing solutions through technology**

Many of our conservation and environmental challenges can probably be addressed, or at least mitigated, by innovative thinking, collective action and technology. The speed of technological advancement is enormous, outpacing our ability to deal with the social and political challenges that some of these technologies pose.

Biotechnology is an area where New Zealand needs to keep abreast of developments and their implications for our economy, society and environment. Biotechnological tools such as gene editing and new breeding technologies offer the potential for resistance to disease, ecosystem restoration, suppression or eradication of invasive species, and to reduce the environmental footprint for agriculture.

As a society we need informed debate about the benefits and risks of adopting biotechnological solutions that may be philosophically challenging in some areas. The potential benefits for the environment and conservation are significant. For example, possums are vectors of bovine tuberculosis (Tb), and predators of endangered bird species, and are currently controlled to some extent using the pesticide 1080. Developing existing and new genetic technologies could ultimately see these and other species controlled over the whole country.

The introduction of new technologies involves weighing the potential risks against the benefits that may be achieved. In the case of pest management, the risks associated with genetic technologies need to be weighed against the risks of alternative management strategies (eg, pesticides), and against the risks of uncontrolled pest invasion. Scientific evidence is key to such decisions, although society's values and perceptions of risk are also critical factors in the equation. Understanding the value that society places on various outcomes – for example being 'GM-free', pesticide-free, or retaining our native forests and birds – provides a basis for deliberation and constructive debate so acceptable solutions can be found.

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<sup>3</sup> Ministry for the Environment & Statistics New Zealand (2015).

We need to acknowledge that while science can provide information on potential effects – both positive and negative – it cannot prove any course of action to be totally safe. There is no such thing as zero risk. Science can help identify risks and ways to reduce or mitigate them, and also to inform strategies to prepare for possible unforeseen effects; debate and policy decisions are then informed by this information.

## Identifying enduring themes and questions

Given all of the above, the need to construct a roadmap for science to answer the most pressing questions, and lead us to constructive and innovative solutions, has become clear.

To produce this discussion paper, a ‘horizon scan’ exercise was undertaken, involving a Strategic Advisory Group of business, research and community leaders chaired by Sir Peter Gluckman, the Prime Minister’s Chief Science Advisor, and targeted engagement with a range of science and policy organisations, key stakeholders and tāngata whenua. This process identified 12 major themes and a number of enduring research questions relating to them. The themes and questions reflect the major trends, challenges and opportunities described above.

This discussion paper presents the results of this initial consultation, and seeks your feedback to guide development of the final Conservation and Environment Science Roadmap.



# Roadmap phase 1: The discussion paper

## Purpose

This discussion paper seeks your input into development of a Conservation and Environment Science Roadmap. Your feedback will be used to shape the final roadmap document.

## Methodology

This discussion paper has been developed by an Officials' Working Group,<sup>4</sup> with guidance from a Strategic Advisory Group.<sup>5</sup> The areas where future research is likely to be needed are outlined in the next section, and have been identified by taking into account:

- current government policy documents and strategies
- a review of international literature
- initial input from key stakeholder groups and tāngata whenua through a structured foresight-oriented questionnaire (see [Appendix tables A1 and A2](#)).

Research roadmaps are common internationally,<sup>6</sup> and have also been prepared in New Zealand.<sup>7</sup> Over the past decade a common 'horizon scan' method has developed, which we have largely followed for this discussion paper. It involves 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. This approach has been followed here with one significant difference: while most international examples were developed by the scientific community, this application has been driven by the Government and by two government agencies. As a consequence there has been a combination of a bottom-up (submission driven) approach and a top-down (policy question) approach. The two have met in the middle and the result is the 12 themes and associated science questions as presented in this discussion paper.

As part of identifying the proposed research questions, the following criteria, which have been used in other international applications (for example in Canada (Rudd et al, 2011)) were applied:

- Questions should be answerable by New Zealand research team(s), along with appropriate international collaboration.
- Questions should be answerable on the basis of fact rather than value judgements.
- Questions should not be answerable by just 'yes', 'no' or 'it all depends'.
- If related to effects and actions, questions should contain a subject of the action, an action, and a measurable outcome.

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<sup>4</sup> The agencies represented on the Officials' Working Group include 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.

<sup>5</sup> The Strategic Advisory Group members include 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.

<sup>6</sup> For example, Rudd et al (2011), Fleishman et al (2011), US Food and Drug Administration (2011), European Commission CORDIS (2016), FDA Office of Women's Health (2015).

<sup>7</sup> For example, Ministry for Research, Science and Technology (2006), Collins et al (2014).

- If answered, the question would increase the effectiveness of policy or management actions regarding the New Zealand environment, ecosystems, and ecological processes in the face of current or future stressors.

## The themes and questions

Using the ‘horizon scan’ method described above, we asked a range of science and policy organisations, key stakeholders, and tāngata whenua for their thoughts. We received 32 submissions that identified 211 enduring research questions that the submitters believed needed to be answered to inform future governmental policy. These questions were grouped into 12 thematic areas.

The key themes identified from the first round of submissions reflect the major trends and challenges identified above. They are:

1. climate change
2. integrated ecosystems and processes
3. freshwater ecosystems and processes
4. land ecosystems and processes
5. coastal and marine ecosystems and processes
6. urban ecosystems and processes
7. populations and species
8. biosecurity
9. mātauranga Māori
10. social and economic dimensions
11. informatics, modelling and monitoring
12. new and emerging technologies.

The explanation, or context, of each theme reflects their overlapping nature with other themes – in fact, no theme stands in isolation. The themes then have a number of specific research questions from the stakeholder and tāngata whenua input. The greatest challenge in posing these questions was to convey them at a level that was neither too specific nor too general. We also recognised that some elements cut across all of these, which could be themes in their own right (and some that are, eg, climate change) but because of the way they cut across the themes, we have chosen to weave them into specific themes as appropriate. The explicit cross-cutting elements identified were:

- partnership between the Crown and Māori, recognising and providing for mātauranga Māori (knowledge), te reo (language), and culture (values and custom), for example kaitiakitanga and rangatiratanga
- climate change
- biodiversity and biosecurity
- anthropogenic substances and introduced organisms
- new and emerging technologies.

## The question of priorities

In this discussion paper we have not attempted to prioritise the questions (which total 50), but some criteria have been suggested by the Strategic Advisory Group for establishing priorities in the final roadmap to be developed later this year:

1. irreversibility of issue (either damage or loss of opportunity)
2. the size of the impact on human (or natural) welfare
3. the probability of damage
4. the extent to which risk and impact can be mitigated – or opportunity enhanced
5. the extent to which research could contribute.

## Your input: consultation to inform development of the roadmap

We need you to provide your input to help shape the roadmap. This discussion paper presents initial thoughts on the way ahead. We welcome your feedback on the following questions:

- Have we identified the major drivers, trends and issues that Government will need to address over the next 20 years?
- Have we identified the most important key themes to address in the roadmap?
- For each of our themes do you agree with our:
  - proposed enduring question?
  - proposed vision and goals?
  - proposed research questions?
  - assessment of new or expanding capability needs?
  - do you have any other comments about the theme (eg, emerging ideas)?
- Do you agree with the proposed criteria for establishing research priorities?
- What benefits do you see being provided by a conservation and environment roadmap?
- Do you have any other comments you wish to make?

Further information on how you can provide your input is included in the final section of this discussion paper – [Roadmap phase 2: Where to from here?](#)

We look forward to considering your views.

## Related roadmaps

A separate but aligned roadmap – *The Primary Sector Science Direction: A roadmap for the primary sector's future science and technology needs* (Ministry for Primary Industries, in progress) – is being prepared in parallel with this roadmap. There are clear interdependencies between the two roadmaps, since conservation and the environment are affected by primary sector activities, and production from agriculture, forestry and fisheries is dependent on environmental services. These areas of overlap are being addressed through close liaison between the teams preparing the two roadmaps, including some common memberships of Advisory Panels and Officials' Working Groups.

# Science directions: Major themes and questions for future research

It is clear that New Zealand and the rest of the globe will face increasingly challenging questions as we attempt to respond to environmental change and the impact we have on it. We will need to use science effectively to tackle a range of enduring issues, and manage complex trade-offs that will have significant impact on our environment and conservation estate, including marine, terrestrial and freshwater domains.

The trends and drivers of change, and some of the opportunities we have to influence them in a positive way, are discussed in the section '[Looking ahead: challenges and opportunities](#)' of this discussion paper. These trends have led us to focus on key themes, and in turn on strategic questions that will guide research into the future. The themes and enduring science questions outlined in the following sections were developed from the horizon scan used in preparing this discussion paper.

The approximate 2015/16 spend from the key funding sources for which a funding breakdown by theme could be obtained is presented at the end of each theme table, and an overview of current theme-related activities supported by these funding sources is provided in the section that follows the themes ('[Current theme-related research funding and activity](#)'). These numbers provide only a partial picture, since they do not include support from core funding of Crown research agencies or funding of National Science Challenges. For some of the themes such funding may be similar to or exceed the funding from the included funding sources. They also do not include funding of research supported by the Marsden Fund, or PBRF-supported research in universities.

Also, there are often overlaps between some named areas of work (programmes) and multiple themes, for example, much 'biosecurity' work overlaps with 'populations and species' and also with 'informatics, modelling and monitoring'. Research activities on mātauranga Māori are typically included in other outcome-related themes and are not addressed separately. As a consequence there is some double counting occurring, and assigning research activities to individual themes often proved difficult because some projects overlap across several themes. Despite these caveats the data provides an indication of the relative investments occurring in each of the themes from the identified funding sources.

# Theme 1 – Climate change

Theme	Climate change
Definition/scope	Climate change mitigation, measurement, impacts and adaptation (issues relating to the New Zealand Emissions Trading Scheme are out of scope).
Enduring questions	<p><b>How can we reduce New Zealand’s net greenhouse gas emissions, and reduce and/or adapt to the impacts and risks of climate change on New Zealand’s conservation estate, environment, society, and economy?</b></p> <p><b>What opportunities and new technologies exist and can be developed, what are their priorities, costs and benefits, and how quickly will they need to be applied to meet national targets?</b></p>
Context	<p>Over the next few decades, climate change will change the landscape of New Zealand. With increased pressure to balance the needs of the economy with the needs to conserve our natural ecology, considering how we can reduce or prevent negative conservation and environmental effects through mitigation and adaptation is vital. For example, climate change will change the habitat available for New Zealand’s biodiversity by causing shifts in species range, habitat condition, or invasive species. Associated sea-level rise will affect shoreline ecology and public infrastructure and assets. Changing ocean temperature and chemistry will impact marine life and fisheries. Freshwater resources we rely on for drinking, irrigation, hydropower, ecosystem maintenance and recreation will be affected by alterations in rainfall patterns.<sup>8</sup></p> <p>We will need improved data systems, data infrastructures and models to understand the links between climate and environmental changes, and impacts on ecosystem services, biodiversity, invasive alien species, land use, fire threat, primary productivity, etc, so we can be forewarned where adaptation actions are necessary and possible. We will also need to quantify the risk associated with land-use practice and the changing frequency of stochastic events such as extreme weather events.</p> <p>New Zealand is committed (in the Paris Climate agreement) to reducing its greenhouse gas emissions by 30 per cent by 2030 (compared to 2005), and there is clear evidence that global decarbonisation will be required by the end of the century to limit temperature increases to less than 2°C. As highlighted throughout the <b>Transition to a Low Carbon Economy</b> report,<sup>9</sup> more information in a useable form (emissions, energy use, sector trends) is required for the long-term modelling and development of emissions reduction pathways.</p> <p>Achieving decarbonising targets can be helped by increasing greenhouse gas volumes sequestered from the atmosphere. As well as traditional plantation forestry, New Zealand could consider biodiversity values derived from a broader range of offsetting tools which give additional benefits, from indigenous forestry and honey production, to enhanced soil management.</p> <p>Mitigating and adapting to change will rely on evidence-based policy interventions and behaviour changes for individuals, businesses, cities, organisations and government.</p>
Vision/goals	<ul style="list-style-type: none"> <li>• <b>New Zealand understands the pathways that can lead to a low-carbon economy that will support its international commitments.</b></li> <li>• <b>The impacts of climate change on the environment, economy and society are effectively managed through planned adaptation and risk reduction.</b></li> </ul>
Emerging ideas	<ul style="list-style-type: none"> <li>• Developing ways of increasing the capacity of soil as a carbon sink.</li> <li>• Carbon capture and storage technologies for industry.</li> <li>• Developments around ‘blue carbon’ – understanding carbon and carbon storage in marine systems.</li> <li>• Increasing recognition of pressures from ocean acidification, as well as other climate-change pressures on coastal and marine ecosystems.</li> <li>• Innovative or improved policies to support low-carbon choices.</li> <li>• Risk mapping and forecasting to anticipate future needs, resources and risks to allow for better planning, policy and adaption from both climate change extreme events (eg, very high temperatures) and gradual changes (more drier areas = less fresh water).</li> </ul>

<sup>8</sup> Royal Society of New Zealand, 2016a.

<sup>9</sup> Royal Society of New Zealand, 2016b.

Theme	Climate change
	<ul style="list-style-type: none"> <li>• Developing novel land-use practices that enable New Zealand to reduce risks and capitalise on benefits from climate change (eg, to adapt to drier, more fire-prone vegetation in the east, and to increased frequency of unpredictable extreme weather events including extreme rainfall, to longer growing seasons, and to changes in regions suitable for niche horticultural crops).</li> <li>• Plant breeding and biotechnologies to address crop vulnerabilities to climate change (eg, drought resistance, heat/cold tolerance) and increase nutrient use efficiency (eg, nitrogen).</li> <li>• Innovative techniques and management practices to reduce methane emissions from ruminant animals.</li> <li>• Development of new tools for better management and control of invasive alien species that will benefit from climate change.</li> </ul>
Research questions	<p><b>1.1 How can New Zealand achieve a transition to a low-carbon economy while producing the best economic, societal and environmental outcomes?</b></p> <p><b>1.2 How will climate change affect the spread of current and new exotic pests and diseases in New Zealand on land, and in fresh waters and the ocean?</b></p> <p><b>1.3 How will ocean acidification affect our natural and managed coastal and marine organisms and ecosystems, and what adaptation options exist?</b></p> <p><b>1.4 How can we better predict range effect and tipping points to inform adaptive conservation management at ecosystem, process and population levels?</b></p>
New or expanding capability needs	<ul style="list-style-type: none"> <li>• Developing data systems and models to understand the links between climate change and environmental change.</li> <li>• A coordinated approach to regularly collate and make available the data and evidence to develop scenarios, and explore next steps for transition to a low-carbon economy.</li> <li>• Maintaining an accurate national inventory of greenhouse gas emissions.</li> <li>• Scientific and technical expertise on building climate change mitigation and adaptation considerations into urban and transport planning.</li> <li>• Learning from impacts, adaptation and mitigation measures already observed in other countries.</li> </ul>
Other related themes	All
Related roadmaps and strategies	<p><i>Primary Sector Science Direction</i> (MPI, in progress); <i>Protect New Zealand: the Biosecurity Strategy for New Zealand</i> (Biosecurity Council, 2003); <i>New Zealand Biodiversity Strategy</i> (Biodiversity New Zealand, 2000); <i>Environment Domain Plan 2013</i> (Statistics New Zealand, 2013); <i>Directions &amp; Priorities 2010–2020</i> (Antarctica New Zealand, 2011); <i>The Deep South – National Science Challenge</i> (NIWA, 2016a); <i>New Zealand’s Biological Heritage – National Science Challenges</i> (Landcare Research, 2016); <i>Our Land and Water – National Science Challenge</i> (AgResearch, 2016); <i>Sustainable Seas – National Science Challenge</i> (NIWA, 2016b); <i>Research for Resource Management</i> (Envirolink, 2016); <i>Science Strategy</i> (Ministry for Primary Industries, 2015).</p>
Approximate 2015/16 investment from government departments and MBIE Endeavour Fund (excludes CRI Core Funding, and National Science Challenges):	<b>\$7,357,000</b>

## Theme 2 – Integrated ecosystems and processes

Theme	Integrated ecosystems and processes
Definition/scope	Incorporates ecosystems and processes that cross land, freshwater and marine domains within a socio-ecological system context, with an emphasis on ‘interfaces’. Interfaces include riparian habitat, wetlands, estuaries and coastal areas as well as naturally uncommon ecosystems <sup>10</sup> such as springs, bogs and caves.
Enduring questions	<p><b>What information is needed to guide policy development and management, and integrate cross-domain interfaces involving complex interactions between land, freshwater and marine socio-ecological systems?</b></p> <p><b>How can decision-makers at all levels recognise, value, and manage ‘mountains to the sea’ as a single holistic domain?</b></p>
Context	<p>Traditionally, western resource, environmental and conservation management has been largely domain specific, ie, land-, freshwater- or marine-focused. There is increasing recognition that these domains are interconnected, and that management actions interact across domains. This more holistic and interconnected view is one that has long been held by iwi and hapū, and by many ecosystem scientists. Management and policy initiatives that address the joined-up challenges of these spaces might also act to address those in the individual domains of land, fresh water and marine, and have conservation, environmental, social, economic and cultural benefits. Enabling integrated decision-making to allow these benefits to be realised is a key element in this theme.</p> <p>Spatially, pressures on land lead to pressures on fresh water, which then flow down to the sea and lead to marine issues. Temporally, some stressors and pressures can be immediate; some have decades or more of lag effects. An important interface where we see the final impact of these cascading effects is at our coastal estuaries and lagoons (and hapū). These areas are highly productive environments, and culturally significant to iwi and hapū for kaimoana and other resources. Being at the bottom of the cascade, they are more easily negatively influenced by management in other domains, including through inflows of sediments, nutrients, and hazardous substances; and frequently by encroaching urban environments (see also <a href="#">Theme 5, coastal and marine ecosystems and processes</a>).</p> <p>Other examples of key interface environments where integration is increasingly seen as necessary are land and fresh water (see <a href="#">Theme 3, freshwater ecosystems and processes</a>) and land and coastal-marine environments. Continuing to increase our baseline knowledge of New Zealand biodiversity and ecosystems will help us identify risks, ecosystem vulnerability or resilience, and the potential impacts of threats from disturbance, climate change, human impacts, fire, agriculture, etc.</p>
Vision/goals	<ul style="list-style-type: none"> <li>• <b>There are integrated system models that explain the connections and interdependencies between key ecosystem components and environmental domains (and how these are influenced by climate change in particular).</b></li> <li>• <b>Decision-makers (including iwi/hapū) understand the consequences of upstream land and water use actions on receiving environments, including coastal and marine, but also on those rarer areas such as ephemeral springs, wetlands, bogs, and gumlands that have unique assemblages of biodiversity.</b></li> <li>• <b>Communities are appropriately engaged and informed during decision-making and policy development.</b></li> <li>• <b>Ecosystem processes are sufficiently protected to allow for and to support cultural and social well-being, and customary practices across domains.</b></li> </ul>
Emerging ideas	<ul style="list-style-type: none"> <li>• Increasing interest in how impacts of land use can be modelled and related to cascading and often non-linear effects on freshwater and coastal-marine environments, and the important role that ‘interface’ environments such as estuaries play.</li> <li>• Integrated systems models that incorporate and balance all the needs of society: social, economic, environmental, cultural.</li> <li>• Developing integrated spatial models that show the connections and allow us to predict more accurately the impact of land-use choices.</li> </ul>

<sup>10</sup> Naturally uncommon ecosystems are terrestrial ecosystems that were rare before human colonisation of New Zealand, and often comprise highly specialised, endemic and nationally rare species (see [www.landcareresearch.co.nz/publications/factsheets/rare-ecosystems](http://www.landcareresearch.co.nz/publications/factsheets/rare-ecosystems)).



Theme	<b>Integrated ecosystems and processes</b>
	<ul style="list-style-type: none"> <li>Increasing emphasis on ‘soft’ edge/interface technology, ‘green infrastructure’ and management arrangements, eg, riparian margins (see <a href="#">Theme 3, freshwater ecosystems and processes</a>); especially in modified agricultural and urban landscapes.</li> </ul>
Research questions	<p><b>2.1 What tools and baseline information do we need to enable more effective conservation and environmentally-aware management of our land, water and coastal/marine spaces so these interface environments are well protected?</b></p> <p><b>2.2 Can we develop interactive and integrated systems models that allow informed policy making across domains?</b></p> <p><b>2.3 How can concepts like ecosystem services be used to inform decision-making in ‘interface’ environments and in environmental policy making integrated across ecosystem domains?</b></p> <p><b>2.4 How do we best create data infrastructures that allow us to leverage from our wealth of data collected and maintained by, for example, government and Crown research institutes</b></p>
New or expanding capability needs	<ul style="list-style-type: none"> <li>Scenario and modelling capability.</li> <li>More specific training around interconnected landscapes.</li> </ul>
Other related themes	<p>Theme 1 – climate change; theme 3 – freshwater ecosystems and processes; theme 4 – land ecosystems and processes; theme 5 – coastal and marine ecosystems and processes; theme 7 – populations and species; theme 9 – mātauranga Māori; theme 10 – social and economic dimensions; theme 11 – informatics monitoring and modelling.</p>
Related roadmaps and strategies	<p><i>Primary Sector Science Direction</i> (MPI, in progress); <i>Protect New Zealand: the Biosecurity Strategy for New Zealand</i> (Biosecurity Council, 2003); <i>New Zealand Biodiversity Strategy</i> (Biodiversity New Zealand, 2000); <i>Environment Domain Plan 2013</i> (Statistics New Zealand, 2013); <i>Our Land and Water – National Science Challenge</i> (AgResearch, 2016); <i>New Zealand’s Biological Heritage – National Science Challenges</i> (Landcare Research, 2016); <i>Science Strategy</i> (Ministry for Primary Industries, 2015); <i>Research for Resource Management</i> (Envirolink, 2016); <i>The New Zealand Geospatial Strategy</i> (Land Information New Zealand, 2007); <i>New Zealand Geospatial Research and Development Priorities and Opportunities 2016–2020</i> (Land Information New Zealand, 2015).</p>
Approximate 2015/16 investment from government departments and MBIE Endeavour Fund (excludes CRI Core Funding, and National Science Challenges):	<b>\$13,228,800</b>

## Theme 3 – Freshwater ecosystems and processes

Theme	Freshwater ecosystems and processes
Definition/scope	Covers the biota, ecosystems and processes in ice, snow, lakes, rivers, wetlands, (estuaries and lagoons as appropriate) and groundwater.
Enduring question	<p><b>What novel tools, systems and processes can be put in place to improve water quality, access and use that will enable productive human use of water resources while ensuring:</b></p> <ul style="list-style-type: none"> <li>• <b>freshwater ecosystems are healthy and resilient</b></li> <li>• <b>health impacts on people are minimised</b></li> <li>• <b>cultural needs are recognised?</b></li> </ul>
<p><b>Context</b></p> <p>Fresh water is vital to New Zealand’s way of life and economy. Our rivers, lakes, wetlands, and groundwater support the creation of wealth through agriculture, horticulture, hydroelectricity generation, and tourism, and will continue to do so into the foreseeable future. In the face of the demands on our fresh water we need to understand how we can best improve our water quality while at the same time growing our economy. A similar challenge is faced around the quantity of water (flow in rivers, and levels in lakes, aquifers and wetlands) needed to sustain conservation and environmental interests. These need to be underpinned by sound, forward-thinking and innovative research.</p> <p>New Zealanders enjoy many forms of recreation in our lakes and rivers. For Māori, fresh water is a taonga and essential to life and identity. Access to fresh water for food, materials, and customary practices is important to Māori. New Zealand’s fresh water supports a range of aquatic plants and animals including crayfish and more than 77 fish species, 57 of which are indigenous to New Zealand (see <a href="#">Theme 7, populations and species</a>). Many of these species are threatened or at risk.</p> <p>The quality of water in New Zealand’s lakes, rivers, wetlands, and aquifers is variable, and is impacted by land use in the catchment.<sup>11</sup> Despite governments, iwi and community investments in freshwater management and restoration, there remain some negative trends in freshwater health. Water quality is very good in areas with indigenous vegetation and less intensive use of land, and poorer where there are pressures from urban and intensive agricultural land use. Waterways in these areas have reduced water clarity and aquatic insect life, and higher levels of nutrients and <i>Escherichia coli</i> (<i>E. coli</i>) bacteria. Meeting community aspirations to be able to swim in many rivers is a challenge.</p> <p>Land use and population growth have placed increasing pressure on waterways. Agricultural land has a broad, diffuse impact because it surrounds 46 per cent of New Zealand’s rivers, whereas urban growth has more concentrated impacts. Population growth has increased pressure on urban sewage plants and increased the level of polluting run-off from roads and roofs entering rivers and streams. Anticipated changes in rain levels and intensity, wind, sea-level, temperature and hydrology arising from climate change will put additional pressure on our freshwater ecosystems and will require an adaptive and flexible management response.</p>	
Vision/goals	<p><b>New Zealand will have developed and be utilising novel tools, processes and policies that achieve improved water quality and restoration of freshwater ecosystems. Appropriate environmental limits and targets will be set that enable conservation and environmental outcomes along with sustainable levels of economic growth, social and cultural well-being.</b></p>
Emerging ideas	<ul style="list-style-type: none"> <li>• Increasing emphasis on science and collaborative decision-making to underpin policy for setting environmental limits, implementing freshwater restoration and achieving sustainable catchment management – notable in river, estuarine/lagoon and lowland lake restoration activities.</li> <li>• Increasing awareness of the need for better integration of mātauranga Māori for freshwater management.</li> <li>• Growing understanding that ‘soft’ systems deliver a range of ecosystem service benefits, but remain a challenge in articulating these messages for broad understanding and policy action.<sup>12</sup></li> </ul>

<sup>11</sup> Ministry for the Environment & Statistics New Zealand (2015).

<sup>12</sup> Land and Water Forum (2015).

Theme	Freshwater ecosystems and processes
	<ul style="list-style-type: none"> <li>• Ongoing efforts to develop more effective modelling tools that give a clearer picture of surface and groundwater dynamics, ecosystem services, outcomes of policy decisions, and projected outcomes of restoration activities.</li> <li>• Increased awareness that there are environmental tipping points, beyond which the restoration of ecosystem health is impossible or cost prohibitive, and that for sustainable land development we need to be aware of these tipping points, how resilient these ecosystems are, and what baselines to aim for that will maintain ecosystems within their natural limits of variability.</li> </ul>
Research questions	<p><b>3.1 How can communities and iwi best set and implement environmental limits to meet their aspirations, and inform further water reform, land-use planning and climate change adaptation?</b></p> <p><b>3.2 How can modelling, monitoring, data infrastructures, and data systems for water be improved, including systems to support evaluation of environmental and conservation outcomes, economic cost, and policy effectiveness?</b></p> <p><b>3.3 How can restoration of freshwater ecosystems be more cost-effective and scaled-up, to reduce land-use pressures, deliver essential biodiversity outcomes (eg, habitat for tuna, whitebait and other taonga and threatened species), and enhance ecosystem services?</b></p> <p><b>3.4 What catchment management techniques can be investigated that deliver New Zealand a world-class sustainable economy and environment?</b></p> <p><b>3.5 What steps need to be put in place to safeguard freshwater ecosystems, and the economy dependent on them, from projected impacts due to climate change, use of chemical substances, and invasive species?</b></p>
New or expanding capability needs	<ul style="list-style-type: none"> <li>• Ongoing investment in basic hydrological science and monitoring programmes.</li> <li>• Capability for restoration of freshwater ecosystem and novel catchment management techniques.</li> <li>• Discovery and documentation of biota is still a pressing need.</li> </ul>
Other related themes	Theme 2 – integrated ecosystems and processes; theme 4 – land ecosystems and processes; theme 8 – biosecurity.
Related roadmaps and strategies	<p><i>Primary Sector Science Direction</i> (MPI, in progress); <i>Protect New Zealand: the Biosecurity Strategy for New Zealand</i> (Biosecurity Council, 2003); <i>New Zealand Biodiversity Strategy</i> (Biodiversity New Zealand, 2000); <i>Environment Domain Plan 2013</i> (Statistics New Zealand, 2013); <i>Our Land and Water – National Science Challenge</i> (AgResearch, 2016); <i>New Zealand’s Biological Heritage – National Science Challenges</i> (Landcare Research, 2016); <i>Stretch goals and priorities</i> (Department of Conservation, <i>Statement of Intent</i>, 2015); <i>Science Strategy</i> (Ministry for Primary Industries, 2015); <i>Research for Resource Management</i> (Envirolink, 2016); <i>Water Information Strategy</i> (Ministry for the Environment, unpublished).</p>
Approximate 2015/16 investment from government departments and MBIE Endeavour Fund (excludes CRI Core Funding, and National Science Challenges):	<b>\$5,547,300</b>

## Theme 4 – Land ecosystems and processes

Theme	Land ecosystems and processes
Definition/scope	All land environments. Includes the soil structure and soil chemical processes, the underlying rock, soil biota (edaphon), weathering and soil formation processes and what is on the land surface, such as vegetation and human-made structures.
Enduring question	<b>How can we manage our lands to sustain and increase conservation and environmental performance while continuing to foster economic prosperity?</b>
Context	
<p>New Zealand has been occupied by humans for only 700–800 years, but in that time our land has gone through transformative change, compounded by climate change. When humans arrived, forests covered all but the tops of mountains and the wettest parts of the lowlands. Wetlands covered extensive areas of both islands, particularly in lowland and coastal areas. Today, about one-third of this forest remains, concentrated mainly in upland and mountainous areas. Wetlands are reduced to about 10 per cent of their original extent. Despite the reduced extent of forests and wetlands, these ecosystems are home to most of the common and abundant plants that are key habitat for most of New Zealand’s terrestrial fauna and other biodiversity.</p> <p>Farmland has taken the place of most of our forests and wetlands. Agricultural and horticultural land occupies about 42 per cent of New Zealand, while plantation forestry covers a further 7.5 per cent. The extent of agricultural land has not changed significantly since 1996, but its use has become more intensive in some regions. About 1 per cent of New Zealand’s land area is urban.<sup>13</sup></p> <p>The way we use our land influences its productivity, and affects our indigenous biodiversity and ecosystems. New Zealand’s land area is made up of three main use types; public conservation land (PCL), production, and urban. Activities on production and urban areas strongly influence areas of PCL that are close to these areas – these interactions are particularly apparent at interface environments (soil, land and water, for example). Typically this impact is negative, eg, pollution, the spread of plant, animal, fungal and microbial pests, loss of natural habitat and connectedness, and the impact of intensive human use. The PCL on the other hand provides valuable benefits to the production and urban areas that are normally not recognised. Mountain and forested catchments act to filter and manage the supply of water, forested areas also clean air and store carbon. Sometimes, though, activities on PCL can negatively impact on production, particularly when there are pests that then spread from conservation land back into the production and urban landscapes. Possums and many pasture plant pests (eg, thistles) are an example of these. Joined-up efforts and large landscape scale management is needed to tackle these issues. Underpinning this is a continuing need to increase our baseline knowledge of New Zealand biodiversity and ecosystems, to help us identify risks, ecosystem vulnerability or resilience, and the potential impacts of threats from disturbance, climate change, land use, fire, and agriculture, etc.</p> <p>While most of the discussion so far has focused on what is on top of the land, there is growing recognition that what lies under the surface of the land, our soils, is also a precious and finite resource, which is important for conservation, the environment, and the economy, and needs to be managed sustainably.</p> <p>Both management and research are increasingly seeking to operate at larger landscape scales and treating symptoms and opportunities at these broader scale levels. Working at this level requires cooperation among land owners, different types of land use, and clearly articulated and agreed goals, all underpinned by a good understanding of the resource base and interactions between its components. This work is increasingly being supported by high end technology, scenario and modelling tools, and concepts such as ‘natural capital’ (and to an extent ecosystems services), which tend to make the overall, holistic value of the resource more apparent in a variety of contexts (economic, socio-cultural, environmental). These approaches can then be used to build a shared understanding across normally quite disparate communities who will need to work together to achieve positive outcomes for ecosystem services, carbon sequestration, sustainable use of soils and water, and biodiversity.</p>	
Vision/goals	<p><b>Land is used in a way that is compatible with and sympathetic to other uses of nearby land, as seen through measurements of ecosystem services and biodiversity indicators.</b></p> <p><b>Land users understand the consequences of their management actions and are equipped to respond to these consequences.</b></p>

<sup>13</sup> Ministry for the Environment & Statistics New Zealand (2015).

Theme	Land ecosystems and processes
Emerging ideas	<ul style="list-style-type: none"> <li>• Scenario and modelling tools and coordinating frameworks such as ecosystem services will help us to more effectively identify and understand cross-system performance (currently used in land-use policy and decision-making here (on a small scale) and abroad).</li> <li>• New tools and management systems to enable land users to understand property-level impacts (eg, OVERSEER® and audited self management) within community-based systems of management.</li> <li>• Soils are increasingly seen as a critical resource, underpinning ongoing economic growth. But they are also seen as vital for biodiversity protection, provision of important ecosystem services like water filtration, nutrient cycling, and atmospheric absorption of pollutants, and for mitigating climate change impacts (through its carbon storage capacity).</li> </ul>
Research questions	<p><b>4.1 Can enhanced remote-sensing and mapping systems be better linked to property scale management to improve real-time management of land-use activities and to allow users to take a more holistic approach to land-use management?</b></p> <p><b>4.2 What new soil management regimes can assist in mitigating and adapting to climate change, while improving economic, environmental and conservation health?</b></p> <p><b>4.3 How can critically endangered biodiversity best be protected at national scale within the matrix of competing land uses?</b></p> <p><b>4.4 Can new ‘substances’ and approaches be developed and used that negate the concern about cumulative effects (eg, in the areas of pesticides, herbicides, antimicrobials, and fertilisers)?</b></p> <p><b>4.5 How can we ensure future land resource uses and systems management, including the use of pesticides, herbicides, fertilisers and new technologies are soil-friendly and that their cumulative impacts across environmental systems are well managed in the face of increasing pressures for intensification in land use.</b></p>
New or expanding capability needs	<ul style="list-style-type: none"> <li>• Commitment to ongoing state/condition monitoring; councils and government agencies, especially DOC working together on boundary interface land-use issues, including weed and pest control.</li> <li>• Science capability to understand and critique new tools and technologies.</li> <li>• Discovery and documentation of biota is a pressing need in land environments – it is estimated that less than 50 per cent of New Zealand’s native terrestrial biota has been discovered and documented.</li> <li>• Research connections to the private sector to enable them to build value chains to take advantage of new tools and land uses and accelerate economic and environmental gains.</li> </ul>
Other related themes	Theme 2 – integrated ecosystems and processes; theme 3 – freshwater ecosystems and processes; theme 8 – biosecurity.
Related roadmaps and strategies	<p><i>Primary Sector Science Direction</i> (MPI, in progress); <i>Protect New Zealand: the Biosecurity Strategy for New Zealand</i> (Biosecurity Council, 2003); <i>New Zealand Biodiversity Strategy</i> (Biodiversity New Zealand, 2000); <i>Environment Domain Plan 2013</i> (Statistics New Zealand, 2013); <i>Our Land and Water – National Science Challenge</i> (AgResearch, 2016); <i>New Zealand’s Biological Heritage – National Science Challenges</i> (Landcare Research, 2016); <i>Science Strategy</i> (Ministry for Primary Industries, 2015); <i>Research for Resource Management</i> (Envirolink, 2016).</p>
Approximate 2015/16 investment from government departments and MBIE Endeavour Fund (excludes CRI Core Funding, and National Science Challenges):	<b>\$8,765,000</b>

## Theme 5 – Coastal and marine ecosystems and processes

Theme	Coastal and marine ecosystems and processes
Definition/scope	Covers biota and ecosystems of the coastal-marine environment (as defined by the <i>New Zealand Coastal Policy Statement</i> <sup>14</sup> ) and 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.
Enduring question	<b>How can we ensure coastal and marine ecosystems and essential processes are maintained or rejuvenated, while at the same time unlocking the economic potential of these areas in a context of land-use intensification, increasing biosecurity risk, climate change, ocean acidification, and other cumulative environmental stressors?</b>
<p>Context</p> <p>The oceans have played an important part in the lives of New Zealanders and our economy since Polynesian settlers arrived 700–800 years ago. Hunting and harvesting depleted some sea life, particularly larger animals such as seals, sea lions, and whales. Commercial harvesting is managed now to ensure it is economically sustainable, but fishing methods such as trawling, which damage the marine environment, as well as overfishing and bycatch (when fish and other animals are unintentionally caught in fishing gear) continue to have an impact on sea life. While overfishing and trawling have decreased, many of our marine species and seabirds are still at risk from fishing activities.</p> <p>Bioinvasion of unwanted organisms, aquaculture, the extraction of oil and minerals, waste contaminants, exotic species, and run-off (including chemical contaminants) from urban and agricultural land are additional human-mediated pressures on our marine environment. Unfortunately we have little information on their cumulative impact on New Zealand’s marine environment. Most New Zealanders view the sea as an endless resource and are unaware of the cumulative impact we have on it.</p> <p>The Office of the Prime Minister’s Chief Science Advisor’s 2013 report on New Zealand’s changing climate and oceans<sup>15</sup> notes that the combined effect of chemical, temperature and current changes in our oceans, along with sea level rise, are likely to have an impact on marine biodiversity and that in the intermediate term, New Zealand will face significant adaptive requirements. Global food security is already being highlighted as a key consideration in relation to marine protected area establishment and other biodiversity conservation measures internationally.<sup>16</sup> Our oceans are also under pressure from multiple and cumulative pressures.<sup>17</sup> Connectivity of New Zealand’s marine species and ecological processes with other nations, and therefore susceptibility to regional and global pressures, will increasingly inform our domestic conservation management through agreements such as the Convention on Migratory Species. Demonstrating progress towards agreed international targets relating to marine biodiversity conservation is required, but will be constrained by increasing recreational and commercial use of the marine environment and its resources.</p> <p>The most serious immediate pressures on the estuarine and coastal environment are being caused by land-use intensification, shoreline and shallow seabed modification from infrastructure development, sedimentation, and increasing marine biosecurity threats. The most serious long-term, and extremely difficult to manage, pressures on our coastal-marine environment are likely to be caused by climate change. Coastal sea levels and long-term sea-surface temperatures around New Zealand have risen over the last century, and our oceans are displaying similar rates of change in acidification experienced elsewhere in the world. These trends will not reverse quickly and we need to find mechanisms that will optimise marine ecosystem resilience.</p>	
Vision/goals	<b>New Zealand will understand the complex coastal-marine ecosystems that surround the country and the drivers of change to these ecosystems, and will have the ways and means to reduce impact and enhance resilience to these changes in the short to medium term.</b>
Emerging ideas	<ul style="list-style-type: none"> <li>• New spatial planning tools that take account of systems modelling and cumulative stressors, including climate change.</li> </ul>

<sup>14</sup> Department of Conservation (2010).

<sup>15</sup> Office of the Prime Minister’s Science Advisory Committee (2013).

<sup>16</sup> Commission for the Conservation of Antarctic Marine Living Resources (2016).

<sup>17</sup> MacDiarmid et al (2012).

Theme	Coastal and marine ecosystems and processes
	<ul style="list-style-type: none"> <li>• New solutions to the international and domestic transport of marine bioinvaders; opportunities to rejuvenate ports and estuaries and increase their resilience to bioinvaders.</li> <li>• Insights into the roles that emerging contaminants are playing in estuaries and in the marine environment, eg, persistent and bioaccumulative chemicals, micro-plastics, marine debris.</li> <li>• Existing monitoring and species identification levels may be insufficient to underpin research on marine ecosystem processes and spatial management.</li> <li>• Increasing understanding of what it takes to enable resilient systems.</li> <li>• Māori tikanga (eg, rahui and taiapure) for the sustainable use of marine resources working alongside western protection philosophies (marine reserves) and in association with collaborative processes involving ‘gifting and gaining’ ideas.</li> </ul>
Research questions	<p><b>5.1 How can New Zealand future-proof its marine biodiversity conservation and implement protected areas and other conservation measures that effectively maximise the resilience of target ecosystems and communities in the face of likely pressures from climate change and cumulative impacts, while addressing emerging issues such as food security, increasing spatial conflict, and regional and global connectivity between protected areas?</b></p> <p><b>5.2 How can hazard science (eg, coastal zone erosion) be integrated with climate change modelling to better manage, in an adaptive sense, the interfaces between land, fresh water and marine (estuaries in particular), and between land and sea (the coastal environment) to better inform proactive decision-making that will benefit biodiversity conservation (see <a href="#">theme 7, populations and species</a>) and environmental management generally?</b></p> <p><b>5.3 Do we have the appropriate western science and mātauranga Māori/cultural monitoring methods, indicators and management tools for the coastal-marine environment, and are we sure our management actions are having the effect we expect?</b></p> <p><b>5.4 How can we better understand where the key marine habitats are that drive production and recruitment of fish and other species, and therefore how to manage these areas in the face of increasing pressures on the marine and coastal environment?</b></p> <p><b>5.5 What are the emerging contaminants and their implications for the coastal-marine environment and how can we proactively manage these?</b></p>
New or expanding capability needs	<ul style="list-style-type: none"> <li>• Taxonomic services and systematic research capability and infrastructure; mapping, sampling and identification of marine biodiversity across New Zealand marine ecosystems.</li> <li>• More effective modelling tools to understand and manage physical/chemical tipping points are required.</li> <li>• Effective data management, maintenance, sharing and security.</li> <li>• Systematic evaluation of approaches to manage coastal and marine environments.</li> </ul>
Other related themes	Theme 1 – climate change; theme 2 – integrated ecosystems and processes; theme 7 – populations and species; theme 8 – biosecurity; theme 9 – mātauranga Māori.
Related roadmaps and strategies	<i>Primary Sector Science Direction</i> (MPI, in progress); <i>Protect New Zealand: the Biosecurity Strategy for New Zealand</i> (Biosecurity Council, 2003); <i>New Zealand Biodiversity Strategy</i> (Biodiversity New Zealand, 2000); <i>Environment Domain Plan 2013</i> (Statistics New Zealand, 2013); <i>Sustainable Seas – National Science Challenge</i> (NIWA, 2016b); <i>Science Strategy</i> (Ministry for Primary Industries, 2015); <i>Research for Resource Management</i> (Envirolink, 2016).
Approximate 2015/16 investment from government departments and MBIE Endeavour Fund (excludes CRI Core Funding, and National Science Challenges): <b>\$6,205,900</b>	



## Theme 6 – Urban ecosystems and processes

Theme	Urban ecosystems and processes
Definition/scope	Includes the built environment and its interactions with the biophysical environment, both direct and indirect, with a strong focus on people (and by implication the social and economics dimensions theme – theme 10).
Enduring question	<b>How can we develop our urban environments to make them more resilient and liveable, and minimise their impact on adjacent terrestrial and marine environments?</b>
<p><b>Context</b></p> <p>While small in geographic scale, urban ecosystems are large in impact, and New Zealand is one of the world’s most urbanised nations with more than 86 per cent of our population living in urban areas. Increasingly there are sectors of this population who are disconnected from the natural environment, and demographic and cultural changes mean that our overall understanding of New Zealand’s unique biological heritage has weakened. Social science and environmental education research is needed to help understand and promote positive future conservation and environmental outcomes, partly so the urban population can play its role in improving the serious issues faced by all New Zealanders.</p> <p>Changing land-use patterns and urban intensification also puts increasing demands on natural resources (eg, fresh water) needed to support economic, environmental, social and cultural outcomes. We will need to understand the consequences of these changes, including the impact of urban development on conservation lands and coastlines.</p> <p>Most of our urban areas are coastal, made up of harbours, cities, ports and marinas, which are vital gateways to trade and tourism. Our unique coastal environments and resources have immense cultural value, especially to Māori. The construction and expansion of ports, marinas and other coastal infrastructure, however, has replaced large areas of natural habitat with artificial structures, and urban processes expose marine habitats to pollution or sedimentation. This has resulted in the decline of key habitats and culturally-valued species in our delicate coastal margins, causing conflict with Māori and coastal communities.</p> <p>The concentration of populations in lowland areas near our coasts means more people, communities, and infrastructural assets are exposed to natural hazards, including sea level rise and storm surge. Understanding the perceptions of these risks, and science to inform risk reduction strategies, is needed now and in the future to guide coastal development and reduce any negative environmental and conservation impacts.</p> <p>The urban environment, land, fresh water and marine, is frequently also the site of new invasive species incursions – events that require rapid and intense response in the national interest. Questions remain about new ways of undertaking these responses in socially acceptable ways.</p> <p>Finally, and clearly an enduring but changing issue, is air pollution. In cities like Auckland it is typically a summer problem – linked mainly to transport, in photochemical smog. Along the eastern South Island, including in centres such as Christchurch, Timaru and parts of Nelson, it is largely a winter issue – particulate matter (tiny airborne particles that affect respiratory and cardiovascular health) from home heating being the primary cause. While we know the primary causes, we do not know all the environmental or health impacts.</p>	
Vision/goals	<b>An urban ecosystem model is developed that can be used to link complex people-environment interactions to complex policy responses, which lead to improved environmental and conservation outcomes across the range of air, land, freshwater, interface and coastal-marine systems.</b>
Emerging ideas	<ul style="list-style-type: none"> <li>• There is growing recognition that city dwellers need to play a greater role in addressing significant environmental issues, eg, urban streams, air quality, estuaries.</li> <li>• Many city dwellers are becoming increasingly disconnected from the natural environment and struggle to appreciate their own needs and responsibilities.</li> </ul>

Theme	Urban ecosystems and processes
Research questions	<p><b>6.1 Can we develop a model of the urban 'ecosystem' that enables us to more directly link aspects of human behaviour to environmentally-responsible behaviour in a seamless way?</b></p> <p><b>6.2 How can we develop resilient and liveable cities that have minimal impact on the wider natural environment?</b></p> <p><b>6.3 Can an urban ecosystem model be developed that is informative, interactive and realistic, and that can be used to inform community level responses to key environmental drivers?</b></p> <p><b>6.4 What tools can be used to increase the levels of engagement of city dwellers with environmental issues and their role the responses to those issues?</b></p>
New or expanding capability needs	<ul style="list-style-type: none"> <li>• Risk analysis practitioners who can take a long-term view and who use appropriate scenario and modelling tools to manage any potential adverse effects appropriately.</li> <li>• Social science and environmental education research.</li> <li>• Urban design researchers who are well connected to international developments.</li> </ul>
Other related themes	Theme 1 – climate change; themes 2–5 (ecosystems and processes); theme 8 – biosecurity; theme 9 – mātauranga Māori; theme 10 – social and economic dimensions.
Related roadmaps and strategies	<i>Smart Cities – Smart Nation project</i> (Land Information New Zealand, 2014); <i>Building Better Homes, Towns and Cities – National Science Challenges</i> (Ministry of Business, Innovation and Employment (2016).
Approximate 2015/16 investment from government departments and MBIE Endeavour Fund (excludes CRI Core Funding, and National Science Challenges):	<b>\$1,040,100</b>

## Theme 7 – Populations and species

Theme	Populations and species
Definition/scope	All populations of native species in all environmental domains: land, fresh water, and marine, including New Zealand's arc of influence from Tokelau and the Kermadecs to Antarctica.
Enduring question	<b>Are there smarter, more innovative and cost-effective ways of managing and protecting our indigenous biodiversity in the face of multiple and increasing cumulative challenges?</b>
Context	<p>Of 2378 indigenous vascular plants, 235 are threatened with extinction and 683 are at risk (ie, they are not currently threatened with extinction, but risk becoming so). Combined, this represents nearly 40 per cent of our indigenous vascular plant species.<sup>18</sup> Seventy-two per cent of our indigenous freshwater fish species are at risk or threatened.<sup>19</sup> Freshwater habitats are directly affected by the way we use land – through discharges of effluent from industrial and urban sources; run-off from farmland; dams and other barriers to aquatic migration; and clearance of vegetation along waterways. Individual impacts on species' survival of each activity may appear marginal, but the aggregated, cumulative effects erode species' resilience. Of our 203 living bird species, more than 80 per cent are now threatened or at risk. Many are marine birds, but all birds roost and breed on land where they are prey to rats and mice.<sup>20</sup> Our lizard species are also decreasing – nearly 90 per cent are threatened or at risk.<sup>21</sup> The extinction risk for a number of land species worsened between 2005 and 2011, including 30 plant, 11 bird, and one bat species. The extinction risk for eight species of birds, three species of weta, and one bat species improved.<sup>22</sup> Freshwater fish, invertebrates, fungi, native aquatic plants and soil biota are also threatened by habitat modification, loss of connectivity, and water quality, availability and use. In the marine environment most focus to date has been on threats to iconic taxa such as marine mammals and seabirds, yet threats and serious impacts on other marine species, populations and habitats are increasing.</p> <p>The range of threats faced by these species is diverse and includes ongoing habitat loss, disease, invasives, and anthropogenic substances. Increasingly, however, there are biotechnology tools that could potentially be applied to address these, eg, genomic selection for resistance to kauri dieback, gene drives for eradication of invasive pest species, better pheromone traps for pest animal species (including insects). Also there is a potential for specialist biocontrol agents, particularly for weed plants.</p> <p>Better management of ecosystems and processes is an important feature of populations and species management (see themes 2–6, all ecosystem themes). Biosecurity management is also vital (see <a href="#">theme 8 – biosecurity</a>). But equally there are some very specific sets of management actions that can be taken to help safeguard populations and species, and New Zealand has a positive international reputation in this regard. Despite our best efforts, the more traditional species and population management approaches we have used in the past can no longer keep pace with new and increasing cumulative threats. As more species are threatened, the cost of intensive management is less and less affordable. We need to ask some very hard questions about the value and importance of some of the management techniques, and we need to carefully consider the cost benefit of traditional species-focused approaches versus new and emerging trends around managing for functional traits and ecosystems components.</p>
Vision/goals	<b>Have new and innovative tools available, which can protect the highest priority populations and species, at scale, within the context of multiple stressors including biosecurity, habitat loss, and climate change.</b>
Emerging ideas	<ul style="list-style-type: none"> <li>• <b>Genomics emerging as an important tool in managing species with very small populations, with potential to enable defensible decisions about populations that should probably not be invested in, and to provide basic information for considering how to enable resistance to biotic and abiotic stressors.</b></li> <li>• <b>A growing recognition that some species are beginning to adapt rapidly in the face</b></li> </ul>

<sup>18</sup> de Lange et al (2013).

<sup>19</sup> Goodman et al (2014).

<sup>20</sup> Robertson et al (2013).

<sup>21</sup> Hitchmough et al (2013).

<sup>22</sup> Ministry for the Environment & Statistics New Zealand (2015).

Theme	Populations and species
	<p>of mounting pressures – and the need to understand more fully how such genetic fitness occurs.</p> <ul style="list-style-type: none"> <li>• Preservation of germplasm to maintain future options when new tools become available.</li> <li>• Biosecurity interception and risk management tools mean we can more rapidly detect and manage risks to our threatened populations.</li> <li>• New institutional arrangements including community initiatives and trusts, and public-private research and innovation partnerships (eg, Zero Invasive Predators and Predator Free New Zealand, Aotearoa Foundation, NEXT Foundation), are driving innovation.</li> <li>• Advances in species recovery through gene technology means that even those species near extinction or more recently extinct could be recovered in time (eg, recreation of the extinct aurochs (cattle) in Europe from its domesticated progeny).</li> <li>• The influence of climate change on where desired populations and species can live, and recognition that these changes will have profound conservation implications, (eg, some species may no longer be able to tolerate altered environmental conditions).</li> <li>• Communities and species assemblages increasingly being used to understand and assess the effectiveness of policy interventions.</li> <li>• Integrating mātauranga Māori and western science approaches to identify new ways of managing species, including farming to increase numbers, ultimately allowing for sustainable customary harvest.</li> </ul>
Research questions	<p><b>7.1 What new developments in genomics can be used to better inform species management priorities and how do we ensure we stay at the forefront of this development?</b></p> <p><b>7.2 Can overlapping climate change and species tolerance models and maps be developed to identify range effects and ongoing conservation needs so we can more proactively manage species and populations, particularly in light of the very slow ability many species have to evolve to climate change?</b></p> <p><b>7.3 How can we more readily identify species bottlenecks and tipping points and then develop the most effective means of managing these in a more holistic way?</b></p> <p><b>7.4 What existing and emerging tools can be applied to mitigate pressures from disease, invasives, anthropogenic hazardous substances, are they consistent with mātauranga Māori concepts of whakapapa, and what are the trade-offs compared to the loss of taonga species?</b></p>
New or expanding capability needs	<ul style="list-style-type: none"> <li>• Increased skills in techniques and technologies along with increased science literacy and understanding of mātauranga Māori to inform the challenging discussion that will occur around trade-offs in management objectives.</li> <li>• Better cataloguing of the New Zealand biome.</li> </ul>
Other related themes	Theme 1 – climate change; themes 2–5 (ecosystems and processes); theme 8 – biosecurity; theme 9 – mātauranga Māori.
Related roadmaps and strategies	<i>Protect New Zealand: the Biosecurity Strategy for New Zealand</i> (Biosecurity Council, 2003); <i>New Zealand Biodiversity Strategy</i> (Biodiversity New Zealand, 2000); <i>Environment Domain Plan 2013</i> (Statistics New Zealand, 2013); <i>Our Land and Water – National Science Challenge</i> (AgResearch, 2016); <i>Sustainable Seas – National Science Challenge</i> (NIWA, 2016b); <i>Science Strategy</i> (Ministry for Primary Industries, 2015); <i>Research for Resource Management</i> (Envirolink, 2016).
	Approximate 2015/16 investment from government departments and MBIE Endeavour Fund (excludes CRI Core Funding, and National Science Challenges): <b>\$18,641,900</b>

## Theme 8 – Biosecurity

Theme	Biosecurity
Definition/scope	Biosecurity is the exclusion, eradication or effective management of risks posed by pests and diseases to the economy, environment and human health. <sup>23</sup> It includes activities off-shore, at the border and post-border. In the context of this roadmap it is concentrating on the environment and in particular conservation needs.
Enduring question	<b>How can Aotearoa/New Zealand achieve cost-effective national-level prevention or management (including eradication) of unwanted pests and diseases?</b>
Context	<p>Collectively, invasive plant, fungal and animal (including insects) pests and pathogens pose one of the greatest threats to our native biodiversity<sup>24</sup> – they impact on our land, freshwater and marine systems, including on ecosystem processes and functions as well as individual species and populations. Over the course of the next 20 years, increased travel and trade, changing global distributions of pests, and climate change, will increase this threat significantly. The management of biosecurity risks will remain an enduring issue, both in preventing new invasive species becoming established and reducing the impacts of established invasive species.</p> <p>Historic introduction of ‘valued’ animals such as possums, stoats and ferrets, has contributed to major population reduction of many native species,<sup>25</sup> and their ongoing management is a significant cost to society. Likewise invasive plant species such as old man’s beard, wilding trees and lupins now have major impacts on our native landscapes, and diseases such as kauri dieback<sup>26</sup> pose a major threat to the iconic species. Other exotic species such as didymo have invaded fresh waters in the South Island, with significant recreational impact but unknown ecological impact. In the marine environment Mediterranean fanworm, as one example, has impacted on northern coastal areas and threatens to spread further. Other invasive species are increasingly spreading their ranges and beginning to cumulatively threaten key ecosystems and processes (eg, wilding trees in the South Island high country impacting on native plant and animal habitats and on water quality and quantity).</p> <p>The cumulative challenge posed by these threats is increasing, and while there are advances in technology and new approaches to management at scale that offer the possibility of huge conservation gains, these advances are unlikely to be sufficient. We need breakthrough science to help turn the tide on biodiversity loss. The need for such breakthroughs is urgent, given the rapidly escalating risk to New Zealand. A major focus needs to be on increasing the sensitivity and cost-effectiveness of surveillance and management tools, as this will provide better opportunities to prevent, eradicate or suppress species within current budgets.</p> <p>We need more robust and evidence-based data coordination between all biosecurity agencies, so the fundamental question at the border – whether the intercepted organism is new to New Zealand or not – can be answered promptly, maximising opportunities for rapid response. Synchronising agencies’ databases with national databases needs to be prioritised to overcome the frustration of disjointed and outdated information held by key agencies.</p>
Vision/goals	<b>New Zealand will be equipped with a tool box of rapid identification, risk analysis, organism and pathway control and detection techniques that are state of the art and deliver economic, environmental, health and cultural benefits at increasingly large scales while being culturally and socially acceptable.</b>
Emerging ideas	<ul style="list-style-type: none"> <li>• Surveillance tools that radically improve our ability to detect pests or diseases at very low densities.</li> <li>• Improved automated detection alongside integrated control technologies.</li> <li>• The ability to harness socially acceptable technologies to better manage unwanted organisms.</li> <li>• Remote monitoring of traps, automated traps technology, the use of drones to drop bait in targeted areas.</li> </ul>

<sup>23</sup> Biosecurity Council (2003).

<sup>24</sup> Parliamentary Commissioner for the Environment (2013); *Part 1, Biodiversity Challenges* (New Zealand Biodiversity, 2000).

<sup>25</sup> Ministry for the Environment & Statistics New Zealand (2015).

<sup>26</sup> See [www.kauridieback.co.nz/](http://www.kauridieback.co.nz/).

Theme	Biosecurity
	<ul style="list-style-type: none"> <li>Emerging integrated community-based approaches to ecosystem-scale pest management – especially around control of small mammal species.</li> <li>The important role of citizen science for rapid detection of potential incursions and for monitoring the extent and spread of managed pests.</li> </ul>
Research questions	<p><b>8.1 Can we develop species-specific tools, including biotechnology, which are acceptable community wide and will allow us to eradicate and/or better manage pests and diseases?</b></p> <p><b>8.2 Can we develop improved and integrated detection and eradication or suppression tools and management systems that significantly increase the cost effectiveness of current management regimes and work at a variety of scales?</b></p> <p><b>8.3 What sets of institutional arrangements, including integrating the aspirations of community stakeholders and iwi and hapū, deliver the most enduring biosecurity and related outcomes that work at (increasingly larger) scale?</b></p> <p><b>8.4 How can we better understand social licence and the drivers of social acceptability for use of biosecurity tools?</b></p> <p><b>8.5 What new approaches can we use to develop a step change in our prediction of biosecurity risks and our understanding of opportunities to manage them?</b></p>
New or expanding capability needs	<ul style="list-style-type: none"> <li>Some policy and regulatory constraints in parts of the biotechnology area need to be addressed. Without progress in these areas, New Zealand is locked into a system that will constrain conservation and economic performance.</li> <li>The sustainability of taxonomy and systematics capability – and related infrastructure, such as collections – is a crucial issue that needs to be addressed.</li> <li>Consider how the science system can enable regulators, designers, engineers, managers and ecologists to work together to identify, design and undertake rapid testing and continuous improvement, to deliver world-leading detection and control technologies that are cost effective and deliver at a large scale.</li> </ul>
Other related themes	Themes 2–6 (ecosystems and processes); theme 7 – populations and species; theme 10 – social and economic dimensions; theme 11 – informatics monitoring and modelling.
Related roadmaps	<i>Primary Sector Science Direction</i> (MPI, in progress); <i>Biosecurity 2025</i> (Ministry for Primary Industries, 2016); <i>Research for Resource Management</i> (Envirolink, 2016); <i>New Zealand’s Biological Heritage – National Science Challenges</i> (Landcare Research, 2016); <i>Our Land and Water – National Science Challenge</i> (AgResearch, 2016).
Approximate 2015/16 investment from government departments and MBIE Endeavour Fund (excludes CRI Core Funding, and National Science Challenges):	<b>\$12,294,300</b>

## Theme 9 – Mātauranga Māori

Theme	Mātauranga Māori
Definition/scope	Mātauranga Māori (Māori knowledge systems) encompasses traditional and contemporary knowledge, wisdom, understanding of human-environmental relationships, and understanding the world and universe from an indigenous perspective. In the context of this roadmap, it is knowledge that can inform and in some areas direct environmental and conservation management.
Enduring question(s)	<p><b>How can mātauranga Māori be recognised and utilised to improve environmental sustainability and the delivery of positive environmental outcomes?</b></p> <p><b>How can mātauranga Māori and tikanga Māori be better integrated into assessing environmental condition, and into environmental policy development and management, and what are the key mechanisms for engaging iwi, hapū and whanau?</b></p>
Context	<p>The natural environment – whenua, waters, coasts, oceans and biota – and how Māori engage with it, is crucial to their cultural identity. Māori as Treaty partners, tāngata whenua, iwi, hapū, and business owners have a series of important relationships with the natural environment. These relationships are underpinned by manawhenua (relationship to the land), knowledge, practice, protocols, rules and customs (kawa and tikanga). Many of these relationships are formalised through statutory obligations and partnerships. Recognising the holistic nature of those relationships is important for improving regulatory outputs (consents, monitoring frameworks, standards), resource management and conservation outcomes. Mātauranga Māori in this document is defined as an evolving body of knowledge that is fundamental to how Māori form perspectives and approaches to environmental management. Mātauranga Māori traditionally was key to resolving complex resource management issues with tools such as rahui and tapu, based on tikanga and kawa. Whanau, hapū and iwi have clear duties to exercise kaitiakitanga to sustainably manage resources throughout Aotearoa.</p> <p>Māori attitudes to resource and conservation are often seen by practitioners as indirect. This can be compounded by the fact that mātauranga Māori varies across and within iwi. The variation can be explained by whakapapa, tikanga and kawa, which evolve as a result of pressure and responses within te taiao. These relationships for Māori have evolved, and can be recited from creation through to contemporary times. Māori organisations individually and collectively in a region are often punching above their weight with their contribution to local and central government environmental policy and targets. They do this because their shareholders or beneficiaries have high sustainability expectations. This could be related to lakes and rivers or biodiversity.</p> <p>Mātauranga Māori is sought by regulatory and government agencies to inform their processes and outputs. That knowledge is then divided, dissected, and compartmentalised to fit specific circumstances, often without understanding or respect for the context in which that Māori knowledge was given. 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 involved in a range of key communities to identify the opportunities for innovation that arise from mātauranga Māori. This continues to cause a disconnect in policy, regulatory and practice and ultimately effective partnerships.</p>
Vision/goals	<ul style="list-style-type: none"> <li>• <b>Conservation and resource management outcomes are seamlessly informed by mātauranga Māori.</b></li> <li>• <b>Māori communities, iwi, hapū and businesses are recognised as actively participating and contributing to the achievement of New Zealand’s conservation and resource management goals.</b></li> </ul>
Emerging ideas	<ul style="list-style-type: none"> <li>• Restoration of taonga requires that science and mātauranga are catalysed to provide deeper and more meaningful sustainability solutions.</li> </ul>

Theme	Mātauranga Māori
Research questions	<p>9.1 What are the exemplars of mātauranga-informed resource management and conservation outcomes? Is it feasible or appropriate to scale these up?</p> <p>9.2 How can Māori organisations, through increased connectivity between science research and mātauranga Māori, improve resource management, sustainability and conservation outcomes?</p> <p>9.3 In valuing our natural capital what and how can we learn from Māori that would promote a more holistic approach to sustainable management?</p> <p>9.4 What functions and powers are Māori organisations currently implementing and undertaking to promote sustainable development of our natural resources that could be enhanced through research?</p>
New or expanding capability needs	<ul style="list-style-type: none"> <li>• Bicultural competency in the natural resource sector is variable. Enabling practitioners and researchers to understand the landscape so that Māori barriers to success are reduced.</li> <li>• There are few Māori scientists, researchers and hapū practitioners employed in the natural resources sector. The policy drivers or levers that could support initiatives to grow this capacity seemingly do not prioritise accordingly.</li> </ul>
Other related themes	All
Related roadmaps and strategies	<p><i>Primary Sector Science Direction</i> (MPI, in progress); <i>Protect New Zealand: the Biosecurity Strategy for New Zealand</i> (Biosecurity Council, 2003); <i>New Zealand Biodiversity Strategy</i> (Biodiversity New Zealand, 2000); <i>Environment Domain Plan 2013</i> (Statistics New Zealand, 2013); <i>New Zealand's Biological Heritage – National Science Challenges</i> (Landcare Research, 2016); <i>Our Land and Water – National Science Challenge</i> (AgResearch, 2016); <i>Sustainable Seas – National Science Challenge</i> (NIWA, 2016b); <i>Research for Resource Management</i> (Envirolink, 2016); <i>Science Strategy</i> (Ministry for Primary Industries, 2015).</p>
<p>Approximate 2015/16 investment from government departments and MBIE Endeavour Fund (excludes CRI Core Funding, and National Science Challenges): <b>\$5,724,200</b></p>	



## Theme 10 – Social and economic dimensions

Theme	Social and economic dimensions
Definition/scope	Social/human factors affecting conservation and the environment, including links between values, beliefs and environmental attitudes, environmental literacy, social licence for technology and development, cultural background, community involvement, governance and decision-making. Economic factors including the effect of changes in international (external) market forces.
Enduring question(s)	<p><b>How can people – individually and as a society – be enabled and encouraged to make and implement long-term, sustainable decisions that are mutually beneficial for society and the environment?</b></p> <p><b>What are the drivers and barriers to behaviour change, and how do we create the right incentives and opportunities that lead to better environmental and conservation outcomes?</b></p>

### Context

Many factors underpin individual and societal decision-making and action related to achieving positive future conservation and environmental outcomes. Societal preferences combined with environmental and science literacy influence how we value and then treat the natural environment and the services it provides. To value nature we must understand its importance in all its facets, from its cultural and spiritual significance through to the resources that we need to survive, before we are confronted with potentially irreparable adverse scenarios. We also need to be more aware of where resources come from for the products and commodities we consume and the flow-on effect of this consumption. As our society becomes more economically and educationally diverse, there are varying degrees of understanding of the importance and impact of the natural environment and healthy ecosystems. Integrating a common value of maintenance and enhancement of the environment, and the value of natural resources (such as water) into production cycles is key to ensuring the nation's prosperity and well-being.

Peoples' behaviours are complex, and changing patterns of behaviour requires an in-depth understanding of beliefs, attitudes and values of individuals, as well as the knowledge of changing social norms and specific socio-cultural, economic and other contextual triggers. This is particularly relevant to biodiversity and conservation issues, which often have drivers and impacts that are intergenerational. The values and priorities of iwi and mātauranga Māori must also be considered in this area, as well as the different cultural uses that may exist. There are also opportunities to use this cultural frame in a way that connects all New Zealanders to our environment.

It cannot be assumed that provision of research findings alone will shift the behaviour of individuals or groups. Research findings will need to be made available and opportunities created for informed discussion to occur with multiple and diverse stakeholders with varying views and knowledge acknowledged and valued. This reflects that the drivers of, and barriers to, individual and societal behaviour change are many and varied, and can result in tensions across different participants in the community, and their location in the socio-cultural, political and physical environment as a whole. There is a wealth of new evidence and practices around how to implement effective behaviour change that can be used to support this effort. Social science theories and methods are required to explore and understand people's knowledge, beliefs, attitudes, values and behaviours. Integrating social sciences more closely with the natural sciences is required to make sure challenges of sustainability, impacts, resilience, vulnerability, adaptation and/or mitigation are considered holistically.

Communities need to be engaged to support conservation management practices. There will be new and emerging practices and potential mitigating solutions that are likely to significantly challenge community acceptance and trust. Social science helps us understand how people make decisions and how they might respond to different options. Better use of social science disciplines will benefit government agencies, industry bodies, non-government organisations, etc, as they seek to understand, interpret, and potentially influence behaviour.

Such approaches should support the development of cooperative and collaborative partnerships, in which all involved feel empowered to participate in informed debate, and encourage individual and collective responsibility for shifts in behaviour to support the desired future conservation and environmental outcomes.

Theme	Social and economic dimensions
Vision/goals	<ul style="list-style-type: none"> <li>• People (both as individual but also as collective communities) understand trade-offs and can make decisions that are mutually beneficial for society and the environment.</li> <li>• New Zealanders effectively manage the physical and economic impacts of climate change and resource use.</li> <li>• Intergenerational equity is taken into account.</li> <li>• People have the knowledge and skills to meaningfully engage in sustainable practices.</li> </ul>
Emerging ideas	<ul style="list-style-type: none"> <li>• Participatory/citizen science is becoming mainstream.</li> <li>• Concepts in environmental education for sustainability from the primary years (to encourage sustainably-minded citizens as well as 'greener' career opportunities).</li> <li>• 'Hybrid forum'<sup>27</sup> strategies for collaborative decision-making.</li> <li>• Innovative 'social marketing'<sup>28</sup> and 'behavioural insights'<sup>29</sup> strategies for behavioural change.</li> </ul>
Research questions	<p><b>10.1 How do societal preferences influence what we value and how we manage the environmental and conservation domains?</b></p> <p><b>10.2 How do we value ecosystem services, not just from a dollar value, but from a holistic approach to include value within communities, aesthetics, recreation, physical protection and social sustainability?</b></p> <p><b>10.3 What factors make collaboration successful or unsuccessful (specific ethics or behaviours, institutional arrangements or types of problems that correlate to successful collaboration)? How can we create participatory processes that effectively engage multiple stakeholders, including iwi, in decision-making?</b></p> <p><b>10.4 How do we build society's understanding and trust in science, make science more responsive to society, and use these insights to refine environmental management and governance?</b></p> <p><b>10.5 Can we develop user-friendly tools that allow individuals and communities to access and understand the collective impacts of the resource choices?</b></p> <p><b>10.6 How can science and environmental literacy be continually improved so citizens pick up on, and are able to assess, the scientific credibility of emerging issues and policy debates to better inform decision-making?</b></p>
New or expanding capability needs	<ul style="list-style-type: none"> <li>• Institutions developed to align divergent interests in the environment.</li> <li>• Improved science and environmental literacy.</li> <li>• Increased numbers of practitioners in the area of social science, behaviour change science, scenario modelling, and non-traditional valuation practitioners.</li> <li>• Strengthened social science community with active, non-political discussions among participants in relevant research.</li> </ul>
Other related themes	All
Related roadmaps and strategies	<i>Higher Living Standards</i> (The Treasury, 2016); <i>Environment Domain Plan 2013</i> (Statistics New Zealand, 2013); <i>Draft National Strategy for Environmental Education for Sustainability</i> (Department of Conservation, in development)
Approximate 2015/16 investment from government departments and MBIE Endeavour Fund (excludes CRI Core Funding, and National Science Challenges): <b>\$24,130,000</b> <sup>30</sup>	

<sup>27</sup> Manole (2014).

<sup>28</sup> McKenzie-Mohr (2000); The National Social Marketing Centre (2016).

<sup>29</sup> Cabinet Office Behavioural Insights Team (2011); Department of Premier & Cabinet (2013).

<sup>30</sup> This area covers multiple funding streams for MBIE including, for example, community planning and transport planning as well as environmental management.

## Theme 11 – Informatics, modelling and monitoring

Theme	Informatics, modelling and monitoring
Definition/scope	Development and use of tools, databases, data infrastructures, modelling and monitoring technologies; systematic observations of environmental and ecological conditions, and biodiversity in natural and managed ecosystems.
Enduring question	<b>How can we develop, improve and integrate the systematic observations, tools, databases, modelling and monitoring technologies for understanding and managing the natural environment, ecosystems and biota, including resource management, preservation of native biodiversity, ecosystem valuation and impacts of human activity and climate change?</b>
<b>Context</b>	
<p>Extracting, reusing and sharing data – ideally using a common data infrastructure architecture – from a wide data landscape has the potential to provide a richer, more sensitive and therefore valuable picture of environmental state and trends across environmental domains. It also promotes cost savings and the growth of a common language between those using it. This will directly benefit reporting initiatives and have flow-on effects to improve and better target natural conservation or resource management and policy design in New Zealand. Policy-makers need robust and defensible evidence to allow them to confidently make effective policy, such as limit-setting. Those who use our environment (eg, farmers) need information tools to make better management decisions when these affect the environment and conservation estate.</p> <p>For example, given that land use is a significant pressure on New Zealand’s environmental health, including biodiversity, soil health and water quality, having fit-for-purpose data on spatial and temporal variation is critical to monitoring and managing natural resources. We need to understand the many underlying factors such as soil, nutrients, water, capacity and productivity, and their interdependencies, as being part of a larger system, as well as how they may be impacted by spatial use.</p> <p>Improved tools for collecting, managing, analysing and communicating data will be key to informing government and private sector decision-making with regard to making optimal land and aquatic use decisions for the benefit of the environment, society and the economy.</p>	
Vision/goals	<ul style="list-style-type: none"> <li>• <b>We will have the tools, integrated datasets (through appropriate infrastructure) and decision-support systems to support optimal freshwater, land, coastal and marine resource decision-making processes at both the macro and micro level.</b></li> <li>• <b>We will have the ability to predict and adapt to environmental changes and minimise negative impacts of human activity.</b></li> <li>• <b>Society can access user-friendly information systems to be better informed about the status of biodiversity and the environment, and enabled to actively engage as citizen scientists in the creation of new knowledge in these areas.</b></li> </ul>
Emerging ideas	<ul style="list-style-type: none"> <li>• User-friendly data access and display; infographics; open data.</li> <li>• ‘Big data’ analysis techniques, ideally in real time where needed.</li> <li>• Modelling that integrates biophysical and ecosystem processes with economic and social drivers.</li> <li>• Imagery, new low-cost sensors, humans as sensors.</li> <li>• New developments and opportunities in remote sensing and the ‘Internet of Things’.</li> <li>• Rationalising and sharing observation networks run by different organisations.</li> <li>• Citizen science, social media.</li> </ul>

Theme	Informatics, modelling and monitoring
Research questions	<p>11.1 How can we access, share and analyse large, heterogeneous and complex data from a variety of sources (imagery, sensors, humans as sensors, citizen science, social media) to understand environmental state and trend?</p> <p>11.2 What innovative sensors, tools, processes, data, technologies and data infrastructure can be made available to New Zealand communities and producers so that they can envisage and realise options for land use and water resource quality that will enhance productivity and deliver agreed cultural, social and environmental outcomes?</p> <p>11.3 How can we improve post-regulatory governance with new tools for measuring and monitoring in real time, to empower audited self-management of resource use impacts by end users?</p> <p>11.4 How do we develop natural accounting systems that put a value on natural assets that recognise their broader contribution?</p>
New or expanding capability needs	<ul style="list-style-type: none"> <li>• While there is a lot of good spatial data for New Zealand: <ul style="list-style-type: none"> <li>– they are not always accessible</li> <li>– there is a lack of communication about the data that does exist</li> <li>– there is a lack of capacity for data collection and analysis</li> <li>– vital long-term observation programmes and taxonomic collections are vulnerable to financial pressures and organisational change.</li> </ul> </li> <li>• The spatial data that does exist is fragmented. Connections between different spatial datasets are required. Quality control standards and implementation vary between data sets and organisations – harmonisation or common semantics would benefit user communities.</li> <li>• Tools and infrastructure are needed to ensure we can undertake high-quality data collection, access, processing, maintaining and enhancing databases, and information storage.</li> <li>• Development of tools to process data from novel sensors (such as hyperspectral remote imagery) to resolve complexity in land use, land-use change, and biodiversity change.</li> <li>• The stability and use of current collections and associated infrastructure/taxonomic capability will need to be future-proofed, while progressively moving towards modern information storage to increase use, accessibility and the involvement of citizen scientists.</li> </ul>
Other related themes	Theme 1 – climate change; themes 2–6 (ecosystems and processes); theme 7 – populations and species; theme 8 – biosecurity; theme 9 – mātauranga Māori; theme 10 – social and economic dimensions.
Related roadmaps and strategies	<p><i>Primary Sector Science Direction</i> (MPI, in progress); <i>Research, Science and Innovation Domain Plan</i> (MBIE, in development); <i>The New Zealand Geospatial Strategy</i> (Land Information New Zealand, 2007); <i>New Zealand Geospatial Research and Development Priorities and Opportunities 2016–2020</i> (Land Information New Zealand, 2015); <i>Government ICT Strategy and Action Plan to 2017</i> (Department of Internal Affairs, 2013); <i>New Zealand Government Open Access and Licensing framework (NZGOAL)</i> (New Zealand Government, 2014).</p>
Approximate 2015/16 investment from government departments and MBIE Endeavour Fund (excludes CRI Core Funding, and National Science Challenges):	<b>\$11,216,600</b>

## Theme 12 – New and emerging technologies

Theme	New and emerging technologies
Definition/scope	Application of biotechnological and other tools to conservation and environment science
Enduring question	<b>What developing and new technologies could lead to potential multiple benefits in conservation and environment, and how might they be applied?</b>
Context	<p>As human-created environmental pressures (climate change, disease incursions, introduction of invasive species) increase, conservation scientists will increasingly look to new and novel solutions to environmental problems, including biotechnological tools. New Zealand scientists, regulators and policy-makers will need good processes and procedures to regulate the risks associated with such methods. They will also need robust assessment and monitoring techniques to quantify the effectiveness of these tools in maintaining New Zealand’s biodiversity before they can be used in the wider environment. As with any new and novel technique or tool, researchers will also need to consider its social/cultural acceptability, both nationally and internationally. One of the biggest areas of interest will be the overall impact of these techniques and their reversibility. Gene driver and gene editing techniques are powerful new developments in the biotechnology space, however, we will need to carefully consider the impact and management of completely removing a ‘pest species’ like the mosquito, and what it might mean to the surrounding ecosystem.</p> <p>Biotechnological tools, such as gene editing and new breeding technologies, offer the potential for resistance to disease, ecosystem restoration, suppression or eradication of invasive species, and a reduced environmental footprint from agriculture. A prominent recent example of this is the engineering of disease resistance genes from bread wheat into the American chestnut, a keystone species of the forest biome of north-eastern North America, which was largely destroyed by blight. The application of these technologies in any context, however, remains to be properly debated in New Zealand, and we need to ensure we have suitable checks and balances in place to manage this.</p> <p>Technology is a theme running right across conservation and environmental science. In addition to biotechnology, numerous other high-tech tools are emerging that will be used to benefit the environment, both to help understand the impacts of change, and to mitigate or reverse negative trends. This includes innovative remote-sensing, ‘green technologies’ and production processes in industry, and other technologies to reduce carbon emissions or to sequester carbon. Some of these have been highlighted in other themes in this document.</p>
Vision/goals	<b>Innovative tools, methods, and technologies, and enabled management processes provide highly cost-effective management in the land, freshwater, marine and coastal environments, and help reduce the impacts of climate change without unacceptable adverse effects.</b>
Emerging ideas	<ul style="list-style-type: none"> <li>• Gene technologies (eg, genomic selection) for disease or pest resistance.</li> <li>• Gene drives for eradication of invasive pest species.</li> <li>• Microbes (both wild-type and gene-edited) for clean-up of polluted sites.</li> <li>• ‘Green technology’ and production processes for industry.</li> <li>• Integrated remote-sensing technologies.</li> <li>• Virtual fences, maintained by traps, etc, for predator control.</li> </ul>
Research questions	<p><b>12.1 Can the application of modern biotechnological tools have a beneficial effect on the protection/preservation/restoration of New Zealand’s indigenous biodiversity in a way that is consistent with New Zealand’s values, including the interface between whakapapa and the protection of taonga species?</b></p> <p><b>12.2 Can the application of modern biotechnological tools in the agricultural and forestry sectors help reduce environmental impacts, including the potential effects of climate change on the environment?</b></p> <p><b>12.3 What checks and balances, including modelling and scenario analysis tools, do we need to develop to ensure we do not use tools inappropriately without considering their long-term effect?</b></p> <p><b>12.4 What is the risk of new technologies compared to our current business-as-usual risks?</b></p>

Theme	New and emerging technologies
New or expanding capability needs	<ul style="list-style-type: none"> <li>• Biotechnologists, ecologists, and risk analysis practitioners who can take a long-term view and who use appropriate scenario and modelling tools to manage any potential adverse effects appropriately.</li> <li>• Social scientists who can understand what drives public opinion in these technologies and how the public can be better engaged.</li> </ul>
Other related themes	Theme 1 – climate change; themes 2–6 (ecosystems and processes); theme 7 – populations and species; theme 8 – biosecurity; theme 9 – mātauranga Māori; theme 10 – social and economic dimensions.
Related roadmaps and strategies	<i>Biosecurity 2025</i> (Ministry for Primary Industries, 2016); <i>Primary Sector Science Direction</i> (Ministry for Primary Industries, in development)
Approximate 2015/16 investment from government departments and MBIE Endeavour Fund (excludes CRI Core Funding, and National Science Challenges): <b>\$1,883,800</b>	

# Current theme-related research funding and activity

Government funding of conservation and environment science is currently allocated by individual agencies including MBIE. Decisions about research to be funded is either set by the individual agencies when they let contracts, or by research providers through processes including science and business planning by the Crown research institutes and through science planning in the National Science Challenges and other MBIE funded research streams. At a more local level MBIE supports the [Envirolink](#) funding scheme (~1.6m for 2015/16) for transferring scientific environmental knowledge to councils. In the case of DOC most of its research is undertaken by its own Science and Policy Group.

The 12 themes identified through the horizon-scanning process used to produce this discussion paper do not match perfectly with any of the main government agencies' own distinct programmes of work or investments. As a consequence, the estimated levels of current expenditure, and the highlighted programmes of research outlined here should be treated as indicative only, as there will be instances of double counting and some missing data. In addition, a theme by theme breakdown of support from Crown research institute core funding or National Science Challenge funding is not currently available, and for some themes these sources may be similar to or exceed the funding from the sources included in the table. Despite these caveats the data provides a useful indication of the relative investments occurring in each of the themes from the identified funding sources.

**Table 1. Current annual spend and funded science activity by key agencies (2015/16 financial year – approximate figures)**

Theme	Agency	Total spend per agency <sup>31</sup>	Programme <sup>32</sup>	Total spend per theme
Climate change	DOC	\$147,000	Climate change and mammalian predators in alpine ecosystems	\$7,357,000
	MBIE	\$3,896,400	Endeavour Fund	
	MfE	\$2,187,200	Modelling emissions, economic modelling, baseline data on climate and sea surface conditions, UV and ozone, carbon in standing forests	
	MPI	\$1,126,400	Research on adaptation to climate change	
Integrated ecosystems and processes	DOC	\$115,000	Estuarine conservation management and marine ecosystem services	\$13,228,800
	MBIE	\$12,821,000	Endeavour Fund	
	MfE	\$13,500	Natural capital assessment design services	

<sup>31</sup> Figures are GST exclusive and include operational funding, salaries and overheads; note also that for MfE data are for the 2014/15 year.

<sup>32</sup> Note that for DOC these are just major examples of named programmes; MBIE and MPI are both providing funding for external initiatives and projects, which is attributed to the research relevant to the roadmap's themes here.

Theme	Agency	Total spend per agency <sup>31</sup>	Programme <sup>32</sup>	Total spend per theme
	MPI	\$279,300	Farmer/grower-led research – funds 'communities of interest' to do applied research and extension projects that tackle a shared problem or develop a new opportunity	
<b>Freshwater ecosystems and processes</b>	DOC	\$488,100	Arawai Kākāriki – improved wetland management in NZ; vulnerable freshwater species management	\$5,547,300
	MBIE	\$2,502,300	Endeavour Fund	
	MfE	\$1,979,800	Groundwater, flows, water quality, sedimentation, agricultural pressure, land use and soil research related to freshwater, behaviour and freshwater management	
	MPI	\$577,100	Farmer/grower-led research – funds 'communities of interest' to do applied research and extension projects that tackle a shared problem or develop a new opportunity	
<b>Land ecosystems and processes</b>	DOC	\$323,200	Role of honey bees and indigenous ecosystems; high altitude predator control	\$8,765,000
	MBIE	\$8,044,000	Endeavour Fund	
	MfE	\$336,000	Asbestos and dioxin, erosion, contaminated soils and land	
	MPI	\$61,800	Farmer/grower-led research - funds 'communities of interest' to do applied research and extension projects that tackle a shared problem or develop a new opportunity	
<b>Coastal and marine ecosystems and processes</b>	DOC	\$77,900	Ecosystems of significance	\$6,205,900
	MBIE	\$5,025,200	Endeavour Fund	
	MfE	\$152,800	Marine trophic index, phytoplankton, sea surface temperatures, marine protected areas	
	MPI	\$950,000	Covers all aspects of the marine ecosystems, including population studies of seabirds, fish, marine mammals and algae, habitats, biodiversity, ocean acidification and vulnerable ecosystems	
<b>Urban ecosystems &amp; processes</b>	DOC	\$0	N/A	\$1,040,100
	MBIE	\$974,600	Endeavour Fund	
	MfE	\$65,500	Urban zones research	
	MPI	\$0	N/A	
<b>Populations and species</b>	DOC	\$11,793,900	Tools and models to enhance the prospects for safeguarding NZ's endangered biodiversity, eg, kiwi and many other nationally critical species	\$18,641,900



Theme	Agency	Total spend per agency <sup>31</sup>	Programme <sup>32</sup>	Total spend per theme
	MBIE	\$6,657,200	Endeavour Fund	
	MfE	\$30,000	Using citizen science data on birds	
	MPI	\$160,800	Farmer/grower-led research – funds 'communities of interest' to do applied research and extension projects that tackle a shared problem or develop a new opportunity	
<b>Biosecurity</b>	DOC	\$2,505,900	New toxins and delivery systems for future pest management linked to ecological outcomes from landscape-scale predator control	\$12,294,300
	MBIE	\$8,267,600	Endeavour Fund	
	MfE	\$0	N/A	
	MPI	\$1,520,800	Biosecurity operational research to inform policy and decision making	
<b>Mātauranga Māori</b>	DOC	\$30,500	Marine cultural health indicators	\$5,724,200
	MBIE	\$5,633,700	Endeavour Fund	
	MfE	\$60,000	Case study of iwi rights and interests	
	MPI	\$0	(Component of many projects – not specifically allocated)	
<b>Social and economic dimensions</b>	DOC	\$184,500	Kauri dieback - increasing compliance behaviour to reduce the spread	\$24,130,000
	MBIE	\$23,163,800	Endeavour Fund – this area covers multiple funding streams including, for example, community planning and transport planning, as well as environmental management	
	MfE	\$188,100	Wastewater handling, product stewardship, human health	
	MPI	\$593,600	Environmental economic analysis to support freshwater decision making; farmer/grower-led research – funds 'communities of interest' to do applied research and extension projects that tackle a shared problem or opportunity	
<b>Informatics, modelling and monitoring</b>	DOC	\$3,626,900	National Planning, Monitoring and Reporting Programme; Seasketch planning tool for marine spatial management	\$11,216,600
	MBIE	\$6,017,000	Endeavour Fund	
	MfE	\$330,000	Contributions to Environmental Monitoring and Reporting and National Environmental Monitoring Standards projects	
	MPI	\$1,242,700	Research supporting the provision of information to compile New Zealand's national agriculture and some planted forestry greenhouse gas inventory, to	

Theme	Agency	Total spend per agency <sup>31</sup>	Programme <sup>32</sup>	Total spend per theme
			meet the annual reporting requirements of the United Nations Framework Convention on Climate Change (UNFCCC); farmer/grower-led research – funds 'communities of interest' to do applied research and extension projects that tackle a shared problem or opportunity	
<b>New and emerging technologies</b>	DOC	\$1,042,400	Aerial application of para-aminopropiophenone	\$1,883,800
	MBIE	\$839,400	Endeavour Fund	
	MfE	\$2,000	Technical description of gene technologies	
	MPI	\$0	N/A	

# Roadmap phase 2: Where to from here?

As discussed at the beginning of this document, the Conservation and Environment Science Roadmap is intended to provide a 20-year vision for those big enduring questions that we believe need scientific investigation now and into the near future.

The 12 themes outlined, along with the research questions under them, if responded to, should provide government with the information it needs to make informed, evidence-based decisions to more effectively manage our conservation and environment.

We now need your views on whether we have identified the key issues, themes and research questions to ensure we develop a roadmap that can help ensure a better future for all of us.

## Consultation process

### How to make a submission

We welcome your feedback on this discussion paper. To ensure your point of view is clearly understood, you should explain your rationale and provide supporting evidence where appropriate.

You can make a submission in three ways:

- Use our online submission tool, available at: [www.mfe.govt.nz/consultation/conservation-and-environment-science-roadmap](http://www.mfe.govt.nz/consultation/conservation-and-environment-science-roadmap)
- Download a copy of the submission form to complete and return to us. This is available at [www.mfe.govt.nz/consultation/conservation-and-environment-science-roadmap](http://www.mfe.govt.nz/consultation/conservation-and-environment-science-roadmap). If you do not have access to a computer, a copy of the submission form can be posted to you.
- Type up or write out your own submission, preferably following the questions listed on page 18.

If you are posting your submission, send it to Conservation and Environment Science Roadmap, c/- Ministry for the Environment, PO Box 10362, Wellington 6143, and include:

- the title of the consultation (Conservation and Environment Science Roadmap Consultation)
- your name or organisation name
- your postal address
- your telephone number
- your email address.

If you are emailing your submission, send it to [cesroadmap@mfe.govt.nz](mailto:cesroadmap@mfe.govt.nz) as a PDF or Microsoft Word document (2003 or later version).

**Submissions close at 5.00pm on Wednesday 7 September 2016.**

## Public events and hui

Public engagement events and hui to provide further information on the detail of the proposals, and to discuss feedback on this discussion paper, will be held throughout the country. More information on these events is available at:

[www.mfe.govt.nz/more/about-us/conservation-and-environment-science-roadmap](http://www.mfe.govt.nz/more/about-us/conservation-and-environment-science-roadmap).

## Contact for queries

Please direct any queries to:

- Phone: +64 4 439 7400
- Email: [cesroadmap@mfe.govt.nz](mailto:cesroadmap@mfe.govt.nz)
- Postal: Conservation and Environment Science Roadmap, PO Box 10362, Wellington 6143.

## Publishing and releasing submissions

All or part of any written submission (including names of submitters), may be published on the Ministry for the Environment or the Department of Conservation's websites, [www.mfe.govt.nz](http://www.mfe.govt.nz) and [www.doc.govt.nz](http://www.doc.govt.nz). Unless you clearly specify otherwise in your submission, we will consider that you have consented to website posting of both your submission and your name.

Contents of submissions may be released to the public under the Official Information Act 1982 following requests to do so (including via email). Please advise if you have any objection to the release of any information contained in a submission and, in particular, which part(s) you consider should be withheld, together with the reason(s) for withholding the information. We will take into account all such objections when responding to requests for copies of, and information on, submissions to this document under the Official Information Act.

The Privacy Act 1993 applies certain principles about the collection, use and disclosure of information about individuals by various agencies. It governs access by individuals to information about themselves held by agencies. Any personal information you supply in the course of making a submission will be used by the Officials' Working Group only in relation to the matters covered by this document. Please clearly indicate in your submission if you do not wish your name to be included in any summary of submissions that we may publish.

# Appendix: Stakeholders and questionnaire for discussion paper development

Table A1 lists the stakeholders who were consulted during the development of the discussion paper.

**Table A1: Initial stakeholder engagement discussion paper development phase**

Stakeholder group	Stakeholders
<b>Policy and science thought leaders within government agencies</b>	<ul style="list-style-type: none"> <li>Department of Conservation</li> <li>Ministry for the Environment</li> <li>Ministry for Primary Industries</li> <li>Ministry of Business, Innovation and Employment</li> <li>Environmental Protection Authority</li> <li>Statistics New Zealand</li> <li>Ministry of Foreign Affairs and Trade</li> <li>Land Information New Zealand</li> <li>Te Puni Kōkiri</li> <li>Treasury</li> <li>Regional councils</li> </ul>
<b>Iwi</b>	<ul style="list-style-type: none"> <li>Iwi Leaders Groups for conservation and fresh water</li> <li>Māori academics at universities and wananga</li> <li>Iwi authorities (environmental managers)</li> <li>University Pro-Vice Chancellor or Deputy Vice Chancellor Māori</li> <li>New Zealand Māori Council</li> <li>New Zealand's Māori Centre of Research Excellence</li> </ul>
<b>Independent Officer of Parliament</b>	<ul style="list-style-type: none"> <li>Parliamentary Commissioner for the Environment</li> </ul>
<b>Non-governmental stakeholder groups</b>	<ul style="list-style-type: none"> <li>Antarctica New Zealand</li> <li>Aquaculture New Zealand</li> <li>Auckland Museum</li> <li>Beef &amp; Lamb New Zealand</li> <li>Canterbury Museum</li> <li>Cawthron Institute</li> <li>Crown research institutes</li> <li>Dairy New Zealand</li> <li>Environmental Defence Society</li> <li>Federated Farmers</li> <li>Fish and Game New Zealand</li> <li>Forest and Bird</li> <li>Foundation for Arable Research</li> <li>Land and Water Forum</li> <li>MetService</li> <li>Museums Aotearoa</li> <li>National Science Challenges – Directors</li> <li>New Zealand Agricultural Greenhouse Gas Research</li> <li>New Zealand Antarctic Research Institute</li> <li>New Zealand Conservation Authority</li> <li>Otago Museum</li> <li>Pastoral Greenhouse Gas Research</li> </ul>

Stakeholder group	Stakeholders
	Royal Society of New Zealand Science New Zealand Seafood New Zealand Sustainable Business Council (Business New Zealand) Tourism Export Council of New Zealand Te Papa Universities World Wildlife Fund New Zealand

Table A2 shows the structured, foresight-oriented questionnaire used for targeted input into the development of the discussion paper. The questionnaire was sent to the stakeholders listed in table A1.

**Table A2: Conservation and environment science roadmap phase 1 submission form**

<b>Organisation:</b>	
<b>Prepared by:</b>	
<b>Generic topic/issue title key words:</b>	<b>(Max 20 words)</b>
<b>Key driver(s)/trend(s) leading to this question:</b>	What is the trend/driver, and what is the evidence supporting its inclusion? Think about confidence around its emergence and level of impact <b>(Max 200 words)</b>
<b>Key 'enduring' research question:</b>	Express the question at a high but meaningful level – think about how, if the question is addressed, it will respond to the trend/driver and link to the management connections below <b>(Max 100 words)</b>
<b>47 Explain the key management link to this question:</b>	What is the management space, in a very broad policy sense, that this question fits within? <b>(Max 200 words)</b>

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