MINISTRY OF RESEARCH SCIENCE + TECHNOLOGY

MoRST

TE MANATŪ PŪTAIAO

environment research

ROADMAPS *for* SCIENCE

What is a Roadmap?

This is one of a series of 'Roadmaps for Science', designed to guide New Zealand's science and research activity. Roadmaps are a type of strategy, providing broad context and high level directions on a particular area of science from a New Zealand perspective.

Roadmaps represent the Government's position on science, noting how our science capabilities should develop to best meet New Zealand's future needs. These are not technological roadmaps, with milestones, targets or detailed research plans. Those details need to be decided by those with the responsibility for funding particular pieces of research, in conjunction with the end-users of research.

These Roadmaps set the context for the detailed work of the Foundation for Research, Science and Technology and the Health Research Council. The Foundation, for example, will work with relevant stakeholders to identify the key research questions at a level of detail below each Roadmap.

By producing these Roadmaps the Ministry of Research, Science and Technology is ensuring that the strategic research investment that makes up a significant part of Vote RS&T goes to those areas that will make the most difference for New Zealand over the long-term.

The Roadmaps also set the scene for better co-ordination across government. The directions in each Roadmap not only highlight the areas of science we need to build but also the future skills and connections we need to make.

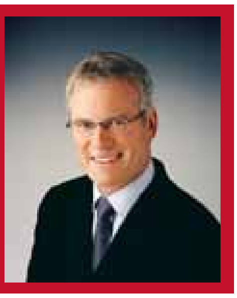
Ministry of Research, Science and Technology
ISBN : 0-478-06150-1
Publication date : May 2007

ROADMAPS *for* SCIENCE

A GUIDE FOR **NEW ZEALAND SCIENCE ACTIVITY**

Contents

Preface



The Government is committed to transforming New Zealand to a sustainable, high value, knowledge-based economy and society. We recognise the critical role science and innovation have in driving that transformation. That is why our focus has been on ensuring research, science and technology deliver on their potential to improve New Zealand.

One of the key parts of that focus has been establishing long-term directions for the science sector. By laying out these directions we will be better positioned to identify future research programmes and direct our efforts towards meeting New Zealand's long-term needs and making the most of emerging opportunities.

The Roadmaps for Science are an important step in providing that guidance. The Roadmaps cover areas of scientific and technological research and development that provide important opportunities for New Zealand.

This Roadmap deals with environment research. New Zealand's distinctive environment is the foundation for much of our economic prosperity, underpins our lifestyle, and is a key part of how we view ourselves as a nation and as New Zealanders.

Environmental science has two key roles: providing solutions to issues surrounding the increasing demands on the environment; and helping identify and develop opportunities for future sustainable, environmental, economic and social outcomes.

We recognise that excellent science has to underpin sound environmental management decisions. As the Roadmap makes clear, these decisions increasingly require an understanding of the wide variety of factors and processes which affect environmental systems. This 'whole-system' approach requires information from a range of disciplines to be brought together. The challenge for New Zealand science is to create a science environment that allows a system-based approach to flourish, but not at the expense of critical disciplines and capabilities.

The Roadmap identifies how we can tackle this challenge by meeting two further broad needs – improving the transfer and uptake of environmental science so that those who need it can understand and use it, and improving how environmental data is managed.

Over the coming months and years we will be introducing other Roadmaps where we see a need for them. I know these Roadmaps will serve us well in ensuring research, science and technology provide a strong platform for an innovative and prosperous New Zealand.

Hon Steve Maharey, Minister of Research, Science and Technology

Executive summary

New Zealand's natural environment underpins our lifestyles and is a key part of how we view ourselves as a nation. The environment is also a vital component of our prosperity as the base of many of our primary industries, and a crucial component of our tourism industry.

Environmental science has two main roles: helping provide solutions to issues surrounding the increasing economic and social demands we are placing on the environment, and for the future, helping to develop and put in place opportunities for sustainable environmental, economic and social outcomes. Although New Zealand research needs to be linked to and informed by international research, New Zealand's distinct environment means that we require New Zealand-based research to develop local solutions and opportunities.

The government's desire is for a safe, healthy environment that supports a strong economy and culture. Sound environmental management will not happen unless it is supported by excellent science. Environmental research organisations and end-users have worked with the Ministry of Research, Science and Technology (MoRST) to develop a set of environmental research directions to achieve this.

Through Vote: RS&T the government invests around $150 million[1] annually in environmental research and wants to ensure its investment is creating value. This Roadmap looks forward to 2017 and provides long-term directions for the development of key environmental science capabilities. It also aims to better align New Zealand's RS&T with government strategies to manage the environment.

Environmental management decisions increasingly require an understanding of whole system processes and a multidimensional approach, including linking biophysical, socio-economic and health research. More integrated and systems-based approaches can offer environmental managers and decision-makers answers to many of the questions they are facing.

A crucial task then becomes one of creating a New Zealand science environment within which systems-based approaches can develop and flourish, acknowledging that small-scale studies remain important to underpin these approaches. With this in mind, MoRST worked alongside key stakeholders during the development of this Roadmap and identified three overarching themes that require additional focus:

- **Systems understanding and integration.** Understanding of environmental systems requires more effective integration across multiple disciplines. Examples of areas where improved systems knowledge is needed include: interaction of groundwater and surface waters; impacts of freshwater on coastal environments; understanding ecosystem aspects of fisheries management; and understanding the biophysical, socio-economic and health dimensions of urban design.

[1] For details refer Figure 3.2.

- **Transfer and uptake.** Addressing this need requires greater focus on predictive science and solutions-oriented research, improved use of management initiatives to help advance scientific understanding, and improved communication techniques such as visualisation.
- **Information systems.** This includes databases, collections, data management, accessibility to data and using new data collection technologies. Improved integration across disciplines and improved transfer and uptake of research cannot occur unless data management is improved.

This Roadmap identifies six broad environmental research areas, each with significant challenges. The way these six areas relate to the three overarching themes are as follows:

- **Global environmental change.** This area requires better modelling to predict future climate change scenarios and enhanced international collaboration. A key challenge is taking an integrated science and socio-economic approach to work out how the country should best adapt to future climate change.
- **Land, water and coasts[2].** Getting the most out of current research investments necessitates better integration of existing research programmes. Enhanced communication of relevant and user-friendly information to environmental managers is needed. Improvements are needed to data collection and management.
- **Urban design and hazards.** An urban research agenda that best suits New Zealand needs to be developed. The Ministry of Civil Defence and Emergency Management's "all hazards" framework and emphasis on risk reduction are increasingly reflected in research contracts. Work is needed to in some areas to improve connections with end-users.
- **Biosecurity[3].** Understanding risk pathways and responding to incursions is critical. In the case of an incursion, a range of disciplines needs to be brought together, often at short notice. The issues in this area relate to maintaining and integrating core capabilities. Connections with users are generally good, but improvements are needed in the area of data management.
- **Biodiversity[4].** Maintaining biodiversity is one of New Zealand's main environmental challenges. By and large, the science system in this area works well. More ecosystems-level modelling work is needed; along with further analysis on the amount of work required in descriptive (such as taxonomy) versus predictive research.
- **Oceanic systems.** Fundamental knowledge is lacking in many areas of oceanic science, making it difficult to identify knowledge needs for the offshore marine environment, or to identify key ecosystem-level questions that need answering. Connections with end-users are patchy. Ocean Survey 20/20 offers an avenue for improved datasets.

[2] Refers to terrestrial, freshwater and coastal marine environments including aquaculture and coastal fisheries.

[3] Covers terrestrial, freshwater and marine environments.

[4] Covers terrestrial, freshwater, estuarine and coastal marine environments.

Over time, a greater effort on integration in these six areas is needed. But this greater focus on integration must not be at the expense of critical disciplines. The ideal is to have both greater integration and to effectively maintain important science capabilities.

Five directions provide government's view of how the priority issues need to be taken forward. These highlight the range of disciplinary capabilities that need to be maintained as well as areas where greater integrated activity is required.

Direction 1

The government wishes to see additional emphasis on integrated multidisciplinary research to support improved understanding of environmental systems whilst maintaining effective long-term capabilities and international collaborations in key areas.

Actions:

- MoRST to lead policy work on identifying the barriers to integrated environmental research and ways to overcome these.

Direction 2

The government will work to ensure that the environmental management sector will benefit from and be transformed in the future by research, which requires greater emphasis on the transfer and uptake of research to better connect science and management.

Actions:

- MoRST to evaluate Envirolink (scheduled for 2007) and councils to continue to work with scientists to update and implement priority applications/tools.
- MoRST will work with regional councils, departments, science providers and FRST to explore, at a national level, opportunities for predictive approaches, developing applications, adaptive management, and communication through visualisation that links science and management.

Direction 3

The government wants to see additional effort on environmental sensing networks and data management to improve frameworks for measuring, monitoring and managing the environment.

Actions:

- MoRST will work with regional councils, departments, science providers and FRST to explore, at a national level, opportunities for environmental sensing networks and data management improvements.
- Research organisations and other owners of research infrastructure to continue to explore ways of working more collaboratively; partly to share the costs and partly to provide good access to critical research infrastructure.

Direction 4

Over the next few years, the government will give priority to developing more integrated multidisciplinary approaches, and to improving transfer, uptake and information systems in the following areas:

- global environmental change – with a focus on providing the knowledge for integrated ecological, physical and socio-economic modelling of climate change impacts on water and soil resources, land use, biosecurity, biodiversity and potential global impacts;
- land, water and coasts – with a focus on sustainable land and coastal aquatic use, including the impacts of land use on freshwater and the impacts of freshwater, land management and aquatic production on coastal marine environments;
- urban design and hazards – focusing on defining a world-class urban research programme which reflects national priorities/aspirations for sustainable urban development and improving connections between scientists and management agencies in certain hazards research areas; and
- biosecurity – reflecting the directions set in the Biosecurity Science Research and Technology Strategy.

Actions:

Climate

- FRST and research organisations to take account of finalised climate change investment priorities.
- FRST and research organisations to seek to maintain core capabilities relevant to other science areas, given this area underpins many other areas of science.

Land, water and coasts

- FRST and research organisations to take account of relevant government science strategies in this area, such as the freshwater science strategy and regional councils' science priorities when they are developed.

Urban and hazards

- MoRST will work with the Ministry for the Environment (MfE), FRST and councils to scope world-class urban research which reflects national priorities/aspirations for sustainable development.
- MoRST and Ministry for Civil Defence and Emergency Management (MCDEM), in conjunction with MfE, regional councils and science agencies, to lead a process for improving communication and connections between scientists and natural hazard managers with a focus on flooding, tsunami and land slipping.

Biosecurity

- FRST and research organisations to take account of the Biosecurity Science, Research and Technology Strategy.
- FRST and research organisations ensure that capabilities that are critical to biosecurity are effectively maintained.
- Biosecurity New Zealand plays a key co-ordinating role in biosecurity research.

Direction 5

Over the longer-term, the government will focus on more integrated multidisciplinary approaches, and improved transfer and uptake, and information systems in the biodiversity and oceanic systems areas.

Actions:

Biodiversity

- MoRST, FRST, researchers and relevant management agencies (for example the Department of Conservation (DoC) and Biosecurity New Zealand) work to identify taxonomy needs for New Zealand.
- Identify coastal marine biodiversity science needs, as part of the proposed marine science strategy, to be explored by MFish and MoRST (refer to action Oceanic Systems).

Oceanic systems

- FRST to ensure that core oceanic systems capabilities in the global environmental change area are effectively maintained, given this area underpins core aspects of oceanic systems science.
- Ministry of Fisheries (MFish) and MoRST to explore whether a marine science strategy should be prepared and the timing for developing this.

When implemented this Roadmap will make a difference by:

- Equipping environmental managers with integrated research results and tools which will help them avoid, remedy or mitigate future environmental problems.
- Enhancing New Zealand's potential as a test bed and world leader for new innovations and business developments in environmental technologies.
- Improved predictions of and responses to natural hazards events.
- Improved responses to climate change.

1 Introduction

1.1 Why an Environment Roadmap?

The natural environment is a critically important factor underpinning New Zealanders' lifestyles, prosperity and sense of identity. New Zealand's sparse population, relative isolation and land-based conservation ethic[5] has helped build the country's 'clean green' image and its international branding. The success of this branding, along with our highly productive land and seas, has allowed our industries such as forestry, meat, dairy, wool, fish, wine and fruit to flourish. It is also a critical component of our tourism industry.

The role of environmental science in all of this is twofold. Firstly, through a greater understanding of the environment, to help provide solutions to issues surrounding the increasing economic and social demands we place on our environment. Secondly, to help develop and put in place opportunities for sustainable environmental, economic and social outcomes in the future.

In deciding to develop this Roadmap the Minister of Research, Science and Technology recognised a number of distinctive aspects about the role environmental research plays in New Zealand:

- New Zealand is a natural-resource based economy with a wealth of natural capital, including a large ocean territory, abundant fresh water, productive soils, and unique biodiversity. Future economic prospects are dependant on generating opportunities and more value from these natural resources[6], as biophysical resource limits are reached[7] and natural capital is depleted[8]. Environmental research plays a key role in driving economic transformation through incremental productivity gains in the primary sector, while improving environmental quality and helping provide knowledge for diversifying the economy through the emergence of new products, approaches and economic niches.
- New Zealand's distinct environment means that we need New Zealand-based research to help us develop local solutions and to create local opportunities. Yet, if we are to develop a solutions-oriented research platform, we also need to ensure our research is fully informed by findings and developments from offshore.
- Environmental research plays a key role in managing and conserving the environment for recreation, for future uses and to bolster our national identity. The environment is part of New Zealand's identity in social and economic terms. It is highly valued by New Zealanders and an important aspect of New Zealand's competitive advantage. Environmental research produces the knowledge and expertise to effectively manage the social and economic demands on the environment.
- New Zealand is prone to natural hazards such as floods and earthquakes. Environmental research and innovation play an important role in monitoring, predicting and better managing hazard risk.
- New Zealand is not a large player on the world science stage. We cannot invest in the full range of RS&T associated with the environment or compete effectively with global efforts in some areas. Consequently, New Zealand needs to be selective in the research areas it chooses, and this Roadmap has a role in helping guide those investment choices.

[5] The conservation estate covers one-third of the country.

[6] For example, Fonterra is seeking 3% pa growth in milk supply, and fishing and aquaculture industries are both seeking to increase 'added value'.

[7] For example, water is fully allocated in parts of the Waikato and in Canterbury; the area of land suitable for dairying is constrained by competing enterprises and lack of suitable terrain/soils.

[8] Such as soil erosion on North Island hill country and declining water quality throughout the central North Island Lakes District.

In preparing this Roadmap we have:

- worked closely with an Advisory Group[9] that has advised on the context, issues and directions;
- drawn on an analysis of New Zealand's current environmental R&D, *Evaluation of the Environmental Output Class*[10];
- held a series of regional workshops during 2006 with, and received formal submissions from, the research sector, industry and government agency representatives (October 2006); and
- drawn information from a range of research and policy reports (listed in Annex One).

1.2 Context and scope of this Roadmap

MoRST has explored the linkage that exists (or does not) between research results and social, environmental, and economic management – the findings of which are published as *Evaluation of the Environmental Output Class*. This evaluation, outlining a series of actions and recommendations to move the sector forward, provides important context for this Roadmap. In brief, actions and recommendations were to:

- provide improved direction for the science system by developing an environmental research priorities statement in conjunction with key stakeholders;
- develop specific policy for maintaining long-term environmental data;
- identify options for building environmental policy research capability in New Zealand;
- develop a set of actions for regional councils and natural resource departments to engage more effectively with the science system;
- in conjunction with key stakeholders, clarify roles and responsibilities of main actors involved in environmental RS&T;
- investigate advantages and options for increasing differentiation of environmental research funding processes as part of work to clarify roles and responsibilities; and
- work with FRST to review its environmental communications strategy to develop clear communications with the environmental science system.

Several of these actions are now underway. Efforts have concentrated on assessing current environmental data systems and exploring options for long-term environmental data management. Further work has centred on end-user connections. Actions to date to strengthen the position of environmental research have included strengthening support for end-user linkages by establishing the $1.6m Envirolink funding scheme to improve access to the science system for regional councils.

Until now, one action recommended in the *Evaluation of the Environmental Output Class* has not been addressed directly: that is, a more strategic approach to environmental research investment and the formulation of an environmental research priorities statement. This Roadmap is the government's response to this recommendation. It gives direction for the next ten years and is intended to be reviewed in five years.

The base premise of this Roadmap is that New Zealand is unlikely to achieve sound environmental management without excellent science to support it. Its vision is that environmental science provides the knowledge to enable the New Zealand environment to be managed sustainably. It is not the Roadmap's role to set outcomes for the environment, however, science will contribute to these outcomes.

To ensure that tomorrow's problems are identified and explored, this Roadmap aims to build a level of flexibility and creativity into the research agenda. This is to ensure that issues that are not yet on the agendas of management agencies can be uncovered and addressed.

[9] Representatives on the Advisory Group were from the Foundation for Research, Science and Technology (FRST), Treasury, Tourism New Zealand, Ministry for the Environment (MfE), Department of Conservation (DoC), Ministry of Agriculture and Forestry (MAF), Ministry of Fisheries (MFish), Biosecurity New Zealand, Auckland Regional Council (ARC), Environment Canterbury (ECan), West Coast Regional Council, Horizons Regional Council, Dairy Insight, Landcare Research, AgResearch, GNS, NIWA, Lincoln University, University of Auckland, and Wananga.

[10] MoRST (2004), *Evaluation of the Environmental Output Class*.

1.3 Audience

The primary audiences for this Roadmap are:

- agencies with responsibility for investing in publicly funded research through Vote RS&T, primarily FRST in the environment area;
- the New Zealand environment sector and other industry sectors (primary industries and others such as tourism, manufacturing, processing etc) that will benefit from, or otherwise be affected by, the uptake of environmental research;
- research communities involved in environmental research; and
- central and local government agencies with environmental research needs and an interest in the application and implications of environmental research.

1.4 Report structure

This Roadmap identifies three common themes as requiring attention across environmental research areas. The three themes are: (1) systems understanding and integration; (2) transfer and uptake of research; and (3) information systems.

It identifies six environmental research areas and considers how these three themes apply across each research area. The six environmental research areas are: (1) global environmental change; (2) land, water and coasts; (3) urban design and hazards; (4) biosecurity; (5) biodiversity; and (6) oceanic systems.

The Roadmap deals with the three themes first, then goes on to discuss the direction for the six environmental research areas.

Chapters 2 and 3 set the scene for environmental research in New Zealand, covering progress on environmental issues in New Zealand and funding of environmental research across the economy. Chapter 4 focuses on overarching themes for environmental research. Chapter 5 focuses on the six environmental research areas, explores key issues, and identifies priorities. Chapter 6 indicates the next steps in implementing the Roadmap and outlines the expected benefits of the directions signalled in this Roadmap.

2 The environmental context

Summary of this section:

- New Zealand's natural environment supports the country's primary production sector[11] and other industries such as tourism. Further, the environment is an integral part of New Zealanders' desire for a high quality of life and economic growth.
- A number of government strategies and policies provide frameworks and directions for environmental management. Parallel science strategies are few.
- This Roadmap addresses this gap and provides direction to the future development of New Zealand RS&T, aligning it closely and more effectively with government strategies.
- Global research points to the complex and unpredictable nature of ecosystem behaviours. New theories and powerful tools are being developed to tackle these challenges. In New Zealand, we have started to move in this direction, but more work needs to be done.

2.1 Meeting the New Zealand challenge

In the last decades, New Zealand has made considerable progress addressing a range of environmental issues, such as cleaning up discharges to rivers, lakes and the coast. Nevertheless, a diverse set of environmental challenges remain. Table 2.1 summarises the issues for the six environmental research areas.

Table 2.1 Environmental issues and challenges

Global environmental change	To date, climate and hydrological records have provided a good understanding of floods and droughts in New Zealand. New Zealand knowledge of overall earth systems is reasonable and has helped with the overall development of the country, including understanding the scale and magnitude of geological hazards. There is a need to better understand the effects of changing climate systems. Predicted climate change impacts include increased frequency of extreme weather events, rising sea levels, and changes in marine and terrestrial ecosystems. These challenges will impact on the economy (especially the primary production sector), biodiversity, biosecurity, and natural hazards.

[11] Includes coastal ecosystem function and aquatic production systems.

Land, water and coasts[12]	During the 1960s through to 1990, industry, farmers and the government made significant investments in erosion control and cleaning up discharges, resulting in improved water quality in many areas of New Zealand. In the last decade, however, the intensification of land use and habitat modification has impacted on water, soil and landscape integrity and increased hazard vulnerability. This has resulted in the degradation of some important ecosystems in parts of New Zealand – particularly affected are wetlands, lowland streams, estuaries and groundwater ecosystems. Competing demands for use of land, water and coasts will increasingly put more pressure on these environments and their sustainability, and increase hazard vulnerability. For example, intensification of agriculture and growth in urban areas will increase water needs. At the same time greater demands for energy, particularly renewable energy, place increasing pressure on rivers and landscapes. Coastal biodiversity and ecosystem function, including marine production systems, are under strain from increasingly intense and diverse marine use, runoff from intensification of land use, and coastal pollution.
Urban design and hazards	This is a relatively "new" research area in New Zealand. Today 87% of New Zealanders live in urban areas. Increasing urbanisation will place greater emphasis on strategic investment in urban research. Within government, there is an increasing focus on the impact that urban areas have on the environment. Future challenges in the urban area include urban development that integrates social, economic and environmental dimensions, taking account of waste streams, stormwater contamination, biodiversity, air and water quality, energy use and hazard risk.
Biosecurity[13]	New pests and pathogens could potentially cause huge economic and environmental damage. Biosecurity pressures are growing due to trade and travel across the border, and the potential impact of climate change in terrestrial and aquatic ecosystems. Future challenges include understanding and prioritising risk pathways which could threaten human health, maintaining disease and pest-free status in valuable markets, and increased threats to indigenous biodiversity.

[12] Freshwater and cities are priorities under the Sustainable Development Programme of Action.

[13] The Biosecurity Strategy was released in 2003.

Biodiversity[14]	Research in the 1990s has significantly altered managers' understanding of biodiversity issues in New Zealand. For example, in the early 1990s, scientists indicated populations of native birds were likely to be stable. Research has since shown that many remaining populations on the mainland are at risk of extinction due to predation. This has resulted in the development of management techniques for biodiversity recovery. The immensity of the terrestrial, freshwater and coastal marine biodiversity challenges New Zealand faces are now well understood by conservation managers. Indigenous biodiversity continues to decline as a consequence of land use, habitat reduction, competitive harvest, ecosystem change, threats from pests and pathogens, and possibly climate change. The challenge now is to build on advances in understanding, particularly in the area of pest/pathogen control, and focus on development of more effective management techniques for biodiversity recovery.
Oceanic systems	Scientists and fisheries managers are only beginning to understand the impacts of fishing on oceanic marine biodiversity and ecosystems, such as the impact of bottom-trawling on benthic communities. Debate about oceanic marine issues is hampered by a lack of information, including a limited understanding of basic ecosystem processes. Challenges include: increasing pressure to expand into new fisheries while understanding of oceanic marine ecosystems remains limited; the need to understand resilience and recovery times for systems; and the development of standards for sustainable use. Climate change also has the potential to impact oceanic marine ecosystems.

New Zealand's natural environment provides the backbone for the country's primary production, supporting exports and foreign exchange earnings from agriculture, forestry, aquaculture, fisheries and tourism. Further, social science research shows that the environment is an integral part of New Zealanders' desire for quality of life and economic development. A 2003 survey by the Growth and Innovation Advisory Board[15] demonstrates that New Zealanders place high importance on quality of life and the environment and believe the purpose of economic growth is to enhance both.

A 2001 survey by MfE[16] on the value of the 'clean green' image to industry showed that, in terms of export markets, industries considered the environment will become more important in the future. MfE estimated that in 2001 New Zealand's 'clean green' image was worth hundreds of millions of dollars to the New Zealand economy each year.

The demand for New Zealand environmental knowledge and problem solving continues to rise as a consequence of both national and international environmental drivers. Within this setting, research, science and technology plays a pivotal role in contributing knowledge to enable a balance of economic growth and a high quality environment.

[14] The Biodiversity Strategy was released in 2000.

[15] Growth and Innovation Advisory Board (2004), *Research on Growth & Innovation.*

[16] MfE (2001), *Valuing New Zealand's Clean Green Image.*

2.2 Relevant New Zealand government policy and strategy

A number of government strategies and policies have been developed or are being developed, providing frameworks and directions for environmental management. Strategies and policies guide central and regional government natural resource agencies.

There are a range of issues – and sector-specific strategies, policies and work programmes relating to the environment sector, including:

- Biodiversity Strategy (2000) – which seeks that biodiversity decline be halted and then reversed;
- Biosecurity Strategy (2003) – aims to protect New Zealand's unique natural resources, plants and animals against damaging pests and diseases;
- Biosecurity Science, Research and Technology Strategy (2006) – which seeks to advance our biosecurity system through excellence in science, to better protect New Zealand;
- National Civil Defence and Emergency Management Strategy (2004) – with a vision of 'resilient New Zealand communities understanding and managing their hazards';
- Marine Protected Areas Policy and Implementation Plan (2005) – which seeks to protect New Zealand's marine biodiversity by establishing a comprehensive and representative network of Marine Protected Areas;
- New Zealand Waste Strategy (2002) – which sets in place a framework for minimising waste and improving waste management;
- New Zealand Tourism Strategy 2010 (2001) – which sets out a framework for the tourism industry's future, based on securing and conserving a long-term future, marketing and managing a world-class visitor experience, working smarter, and being financially and economically prosperous;
- Oceans Survey 20/20 (2005) – which could contribute substantially to a comprehensive picture of New Zealand's oceanic interests, and the resources and ecosystems they contain over the next 15 years;
- Regional Policy Statements and Plans – which provide policies and methods to achieve integrated management of natural and physical resources and guide the development of subordinate plans (regional as well as district) and the consideration of resource consents;
- Sustainable Development Programme of Action (2003) – which although officially completed in 2006, sets an important context for the freshwater and city areas;
- Strategy for Managing the Environmental Effects of Fishing (2005) – which seeks to identify the limits to acceptable modification of the marine environment by fishing and reduce any adverse impacts;
- Sustainable Water Programme of Action – which seeks to improve the management of freshwater, protect freshwater resources into the future, and acknowledge the fundamental importance of water to all New Zealanders;
- Energy Roadmap (2006) – which identifies the broad range of energy research capabilities New Zealand needs to develop and gives direction on how to maintain and improve those capabilities; and
- Biotechnology Roadmap (2007) – which identifies the broad range of biotechnology research capabilities New Zealand needs to develop, and gives direction on how to maintain and improve those capabilities.

Some key areas of national policy are currently under review or in development, including:

- Coastal Policy Statement (under review) – which seeks to guide local authorities (regional, city and district councils) in their day-to-day management of the coastal environment;
- Climate Change Policy (in preparation) – which seeks to develop a long-term strategic framework for climate change which meets Kyoto liabilities;

- New Zealand Energy Strategy (in preparation) – which seeks to provide a reliable, resilient system delivering New Zealand sustainable low emissions energy;
- National Energy Efficiency and Conservation Strategy (under review) – which seeks to improve energy efficiency and provide a transition to renewable sources of energy; and
- Government response to the Food and Beverage Sector Taskforce Report and New Zealand Aquaculture Strategy (in preparation) – both seek to identify improvements to innovation, and market and skills development in the relevant sector.

Government strategies tend to have a broad environmental focus. They formulate strategic policy outcomes carried by one or more agencies. Generally, strategies tend to not identify RS&T needs, with the exception being government's climate change and biosecurity research strategies.

Central government sets the national direction on environmental issues by issuing national policy statements or setting national environmental standards. Regional councils identify issues for their region in regional policy statements. To date, these have not been compiled into a national set of priorities that compares issues between the regions. Combined national science priorities have not been identified, but regional councils are now developing these.

This Environment Research Roadmap is developed within the context of government strategies. It is intended to provide direction to the future development of New Zealand research, science and technology by aligning it closely and more effectively with government strategies and aiming to maximise the value of environmental research investment.

2.3 Global research trends

Worldwide, increasing volumes of large-scale and long-term environmental, socio-economic and health data are becoming available. These data are showing system behaviours that are complex and difficult to predict. Scientists have shown that properties of whole complex systems cannot be discovered through the study of only the systems' parts. System behaviours cannot be precisely predicted and, therefore, also cannot be controlled or inflexibly managed.

New methods for integrating multidisciplinary research have developed. The internet, growing computing power, and advances in mathematics and numerical modelling techniques are helping to integrate information from multiple disciplines. Visualisation software is increasingly used to demonstrate system behaviours to researchers and environmental managers.

Climate science is a good example where the platform of knowledge is expanding rapidly. New discoveries of system behaviour (specifically the non-linear behaviour of climate systems) have come from the power of satellite remote sensing, increased worldwide environmental monitoring, and research on paleoclimate archives. At the same time, climate science well demonstrates that models need good data to parameterise and validate them, with small-scale experiments and surveys essential to interpreting remotely sensed data.

New knowledge of environmental systems is advancing systems theory and is proving useful for the improvement of economic, social and industrial systems. The literature is increasingly referring to theories on the evolution of complex adaptive systems when discussing pathways for goals such as economic transformation, social and economic resilience and sustainable development.

In other countries the impetus for integrated environmental science has been a pressing need for scientific solutions to environmental problems. Integration has not happened without active intervention and once started, integration has proven its worth.

Countries that have realised the opportunities arising from advances in environmental monitoring and systems theory (for example, the UK, USA, Canada and Australia) are investing in integrated biophysical, socio-economic and health modelling capabilities, improving linkages between computer science and environmental sciences, e-science capabilities and high-performance data networks. Other trends include:

- development and deployment of distributed, intelligent sensor networks;
- growth of numerical models as tools for investigating processes;
- availability of more sophisticated mathematical and statistical tools;
- adoption of new methods for studying complex adaptive systems; and
- a growing ability to blend different models and datasets.

In comparison, in New Zealand there is an evolving recognition of the need for a more systems-based approach to be taken with environmental issues and research. There is also recognition that this approach requires integration of research and multidisciplinary ways of working.

There are good New Zealand examples of successfully using systems-based approaches (see case studies Chapter 4), using some of the tools mentioned above. However, these somewhat isolated examples need to become more of the norm.

There are barriers to undertaking integrated research in New Zealand. Developing the necessary linkages will involve a close look at the way science is carried out in this country at a range of levels, including governance and data collection/management and considerations for intellectual property. (Note: These ideas are developed and expanded in Chapter 4, 'Directions across all environmental research').

3 The New Zealand research investment landscape

Summary of this section:

- Central government funds account for around 85% of all environmental research investment in New Zealand. The total Vote RS&T contribution to environmental research is about 60%. The Environmental Research Output Expense contributes approximately 45% of New Zealand's environmental RS&T.
- Funding in many areas of environmental research through Vote RS&T has declined in real terms since 1998 and investment has been spread over more providers and disciplines. On the other hand, the CRI Capability Fund has increased in recent years.
- Environment research receives about $150m[17] in annual funding through Vote RS&T.

3.1 Who is allocating environmental research funding?

Overview

Environmental research is funded under the Environmental Research Output Expense and other portfolios within FRST, as well as by other central and local government agencies and industry (see Figure 3.1)[18].

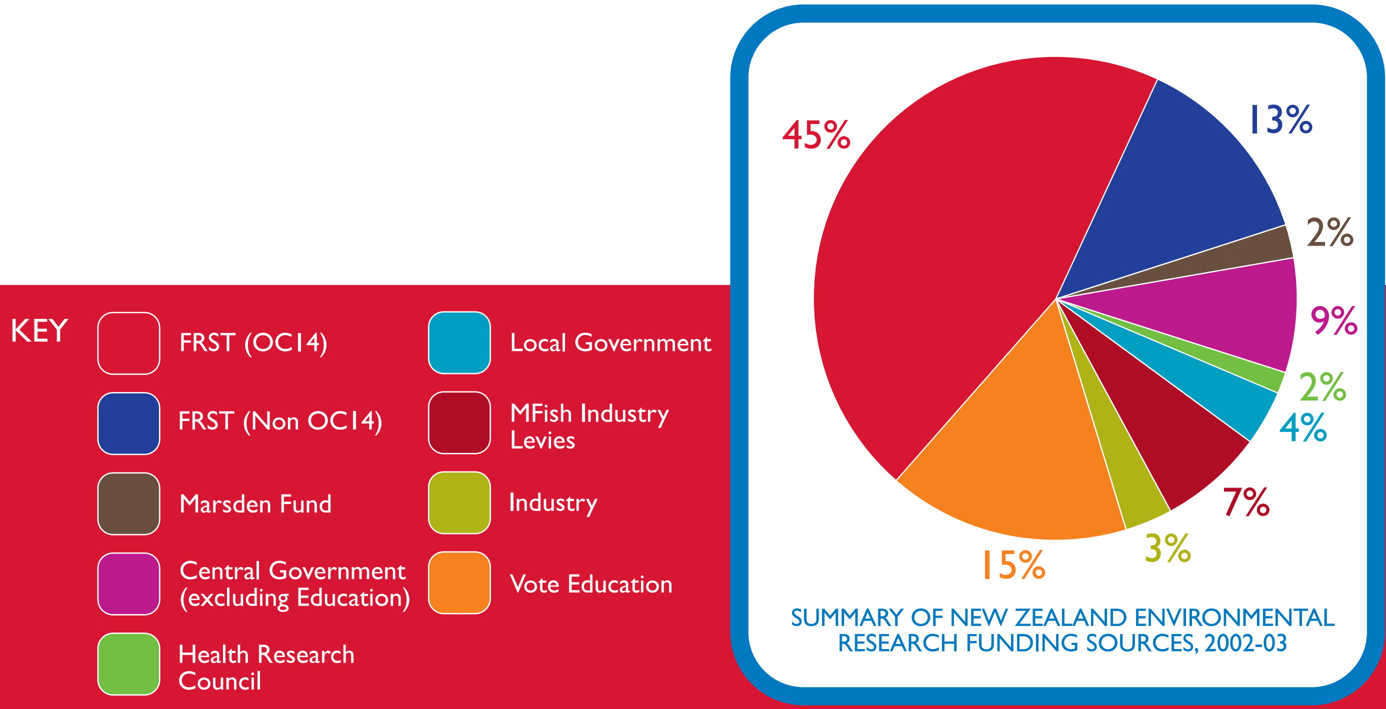


Figure 3.1 Summary of New Zealand environmental research funding sources, 2002-03. Note: Vote RS&T environmental research funding under the Environment Output Expense is noted as OC14. Vote RS&T environmental research funding outside of the Environment Output Expense is noted as Non-OC14. Research funded by MFish industry levies is largely on fish stock abundance and not the environment per se (Source: MoRST (2004). 'Evaluation of the Environmental Output Class').

[17] 2005/06 government funding level through Vote RS&T, for details refer Figure 3.2. Figure includes environmental research outside of the Environmental Research Output Expense.

[18] Pie chart based on 2002/03 environmental research funding as reported in MoRST's 2004 Evaluation of the Environmental Output Expense.

Vote RS&T environmental funding (including FRST, Marsden and HRC) represents approximately 60% of the economy-wide investment. The Environmental Research Output Expense (managed under FRST) accounts for approximately 45% of the economy-wide expenditure on environmental RS&T. The next largest percentage is Vote Education at 15% of the total environmental RS&T expenditure, reflecting tertiary sector research contributions.

Funding sources

FRST funding covers approximately 60% of total investment in environmental RS&T. It funds environmental research through three principal avenues (see Appendix 2):

- Environmental Research Output Expense – supports public good RS&T that enhances understanding and management of the environment;
- Research for Industry and New Economy Research Fund – targets existing industries and new economic opportunities; and
- Māori Knowledge and Development Output Expense – addresses areas such as Māori natural resource management.

The Marsden Fund represents approximately 2% of the total investment in environmental RS&T and covers geography and geology research, ecosystems, and pest reduction and management.

The Health Research Council (HRC) operates under the Health Research Output Expense and supports public good research, science and technology that improves the health status of New Zealanders. It represents 2% of the total investment in environmental RS&T.

Several agencies[19] contribute funding to environmental RS&T independent of FRST. These include government departments outside Vote RS&T (9%), local government (4%), and private businesses and others (3%).

3.2 Current investment levels

Portfolios

Environment research receives about $150 million[20] in annual funding through Vote RS&T. This is made up of the environmental research output expense ($90m), research for industry (RFI), research on the environmental effects of new technologies (together approximately $45-50 million), and a portion of the CRI Capability Fund.

Public good science funding is allocated against marine production, biosecurity, global geology, global climate, urban and hazard preparedness, natural ecosystems and land, water and coasts - the last receiving the largest proportion of funding at about 35% (see Figure 3.2).

Across environmental categories, approximately 40% of funding is invested in fundamental research of natural systems. The remainder is invested in research on human-environment interactions and impacts. The relevant portfolios and their target outcomes are given in Annex 2.

There have been some changes in the investment in Environmental Output Expense Portfolios between 2001 and 2006. Figures 3.3 and 3.4 show that the funding for the environmental output expense has increased. The increases have all been in specifically targeted areas (Fig 3.3), including:

- ecosystems – new funding covering databases, collections and large-scale pest control;
- global – increased funding the research vessel RV Tangaroa;
- sustainable cities and settlements – new funding in 2004/05 for maintaining air quality capability; and
- sustainable resource use – new funding in 2003/04 for possum control.

[19] Note: Data on funding levels are obtained from multiple sources and are not of the same degree of precision as data for Vote: RS&T.

[20] 2005/06 government funding level through Vote RS&T, for details refer Figure 3.2.

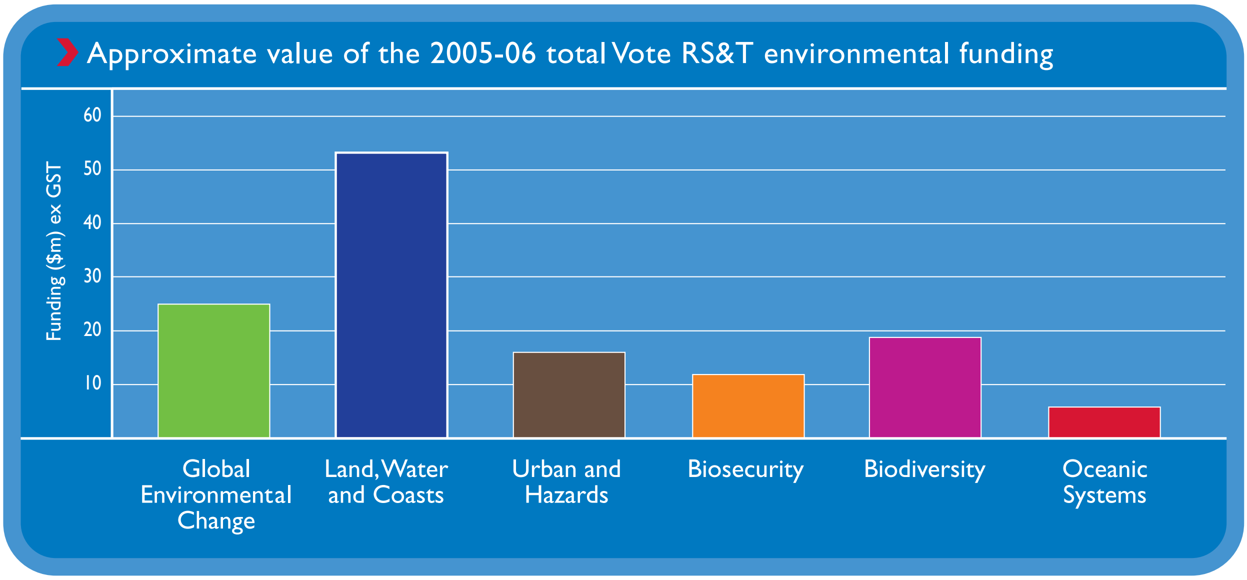


Figure 3.2. Approximate value of the 2005-06 total Vote RS&T environmental funding by the six environmental research areas identified in this Roadmap. This graph covers the range of Vote RS&T Output Expenses which fund aspects of environmental research. It includes but is not limited to the Environmental Research Output Expense, but excludes the CRI Capability Fund.

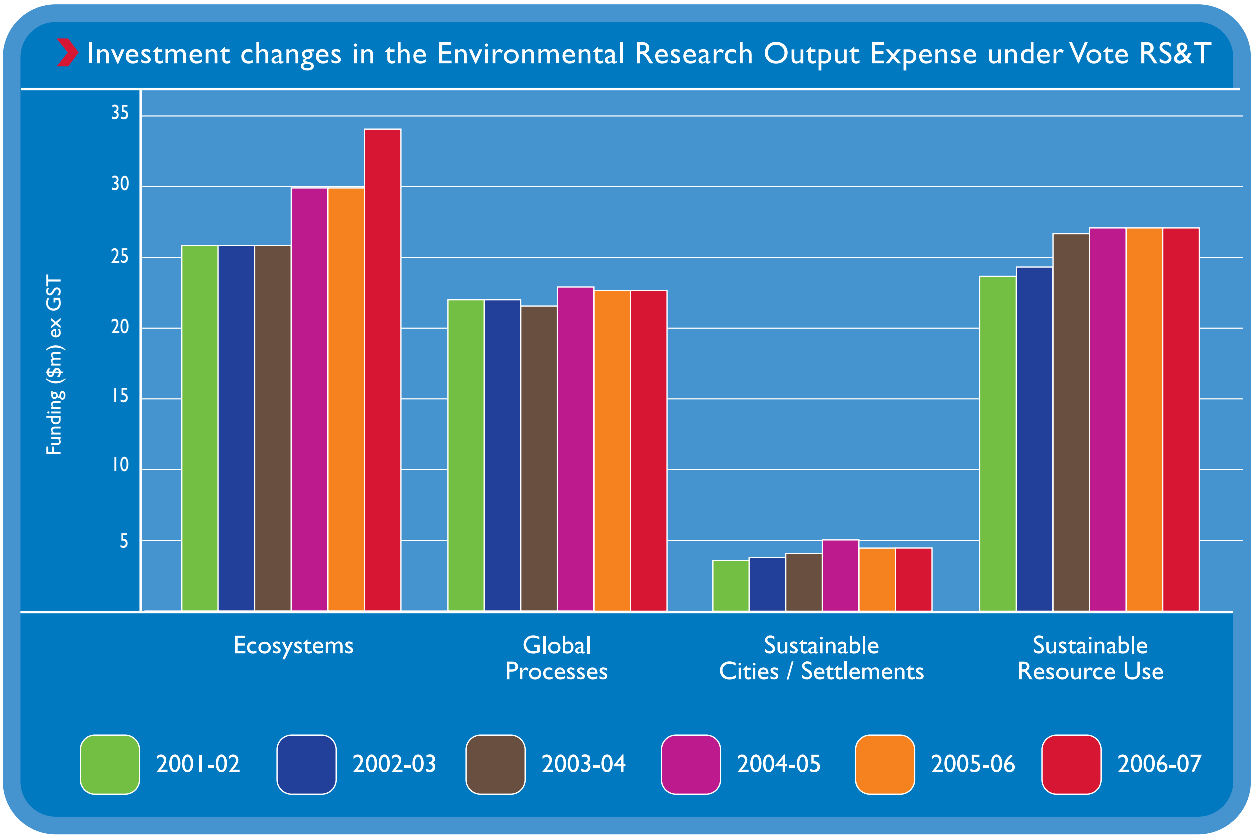


Figure 3.3 Investment changes in the Environmental Research Output Expense[21] under Vote RS&T. Figures exclusive of Vote RS&T environmental research funding outside of the Environmental Research Output Expense.

[21] Annex 2 contains details of the Environmental Research Output Expense portfolios and target outcomes.

Trends

Between 1999/00 and 2005/06 funding for the Environmental Research Output Expense has increased from $ 74 million to $ 90 million (see Figure 3.4). As a percentage of GDP, funding has declined from 0.077% in 1999/2000 to 0.062% in 2005/06. Over this period, based on an average science CPI of 5% annually, the Environmental Research Output Expense funding has effectively declined by approximately 8%.

During this period, investment in environmental research was spread over more providers and disciplines, and a greater focus given to application pathways, end-user linkages, and translating research into outcomes. This resulted in reprioritisation and reductions in the support for some science disciplines. MoRST's 2004 evaluation of the Environmental Research Output Expense indicated that capability in many environmental research areas is declining. On the other hand CRI capability funding has increased in recent years.

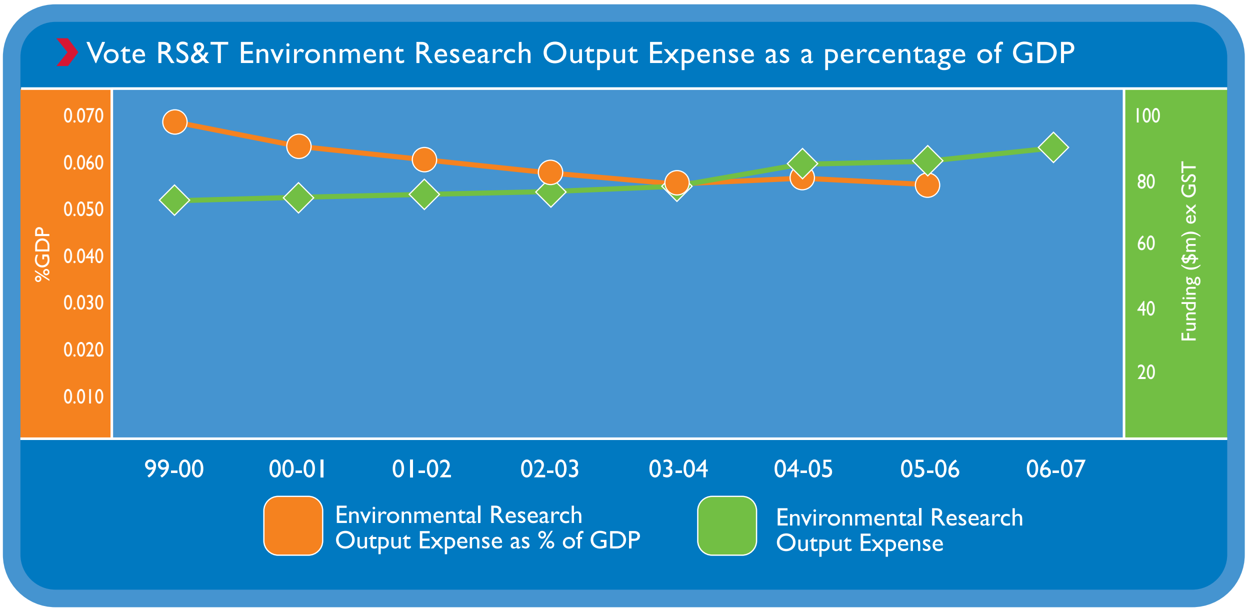


Figure 3.4. Vote RS&T Environmental Research Output Expense as a percentage of GDP. Note: Pre 1999/2000 data could not be included due to changes to output expense structure. GDP figures for 2006/07 are not yet available. Figures do not include Vote RS&T environmental research funding outside of the Environmental Research Output Expense.

4 Overarching themes for environmental research

Summary of this section:

- Integrated systems approaches (across multiple disciplines) are key to delivering environmental science programmes that provide effective answers to the questions environmental managers want answered. So, the challenge for the New Zealand science system is to create an environment that, building on baseline data collection and small-scale studies and surveys, enables a more systems-based approach to develop and flourish.
- This section identifies three main themes requiring additional focus if New Zealand is to create such a research environment:
  - systems understanding and integration;
  - transfer and uptake; and
  - information systems.
- Science in New Zealand is making some progress in these directions. This Roadmap endorses the present direction environmental science in New Zealand is moving in and recommends greater progress.

4.1 Introduction

As more large-scale and long-term data become available, scientists are increasingly understanding that system behaviour is more complex and unpredictable than they realised. The logical consequence of this is that system behaviours cannot be controlled or inflexibly managed. To understand systems, knowledge of the parts (which will most probably come from a range of disciplines) must be integrated in a way that their interactions can be observed, which requires a focus on process. In other words, you need a systems-based approach to understand and deal with the challenges raised by biological systems. An environmental systems-based approach can help pinpoint what can and cannot be modified, controlled or reversed in a system – critical information for environmental managers.

The technology enabling a systems-based approach is available here and now. New techniques and approaches, largely enabled through developments in information and communication technology (ICT), are now allowing more complex interactions to be observed and modelled, enabling progress towards systems approaches. Uptake of this technology in New Zealand has been patchy up to now.

A great deal is at stake here. Being able to precisely measure the dynamics of New Zealand ecosystems is crucial in enabling environmental managers to address the intertwined challenges of environmental and economic sustainability. Knowledge of these dynamics, when integrally linked to land use decisions and markets, will enable New Zealand to not only sustainably manage resources but also maintain a competitive advantage in increasingly discerning global markets. This chapter identifies the key areas that require additional focus if New Zealand is to develop the kind of science environment we need.

During the development of this Roadmap three themes, which apply to all of the six environmental research areas, emerged as requiring additional focus and attention. These three themes are explored in this chapter and are:

- **Systems understanding and integration.** Understanding of environmental systems requires more effective integration across disciplines. Examples of areas where improved systems knowledge is needed include: interaction of groundwater and surface waters; impacts of freshwater on coastal environments; understanding ecosystem aspects of fisheries management; and understanding the biophysical, socio-economic and health dimensions of urban design.

- **Transfer and uptake.** Addressing this need requires greater focus on predictive science and solutions-oriented research, improved use of management initiatives to help advance scientific understanding, and improved communication techniques such as visualisation.
- **Information systems.** This includes databases, collections, data management, accessibility to data and using new data collection technologies. Improved integration across disciplines and improved transfer and uptake of research cannot occur unless data management is improved.

4.2 Systems understanding and integration

Based on analysis of environmental science in other developed countries and discussions with New Zealand scientists and managers during development of this Roadmap, it was identified that building integrated systems understanding is needed. Recent moves towards greater integration in science, such as the development of Outcome Based Investments (OBI), are steps in the right direction.

To encourage integration of systems approaches, further improvements can be made to the way science is carried out. These include:

- shared high level goals/questions that provide an overarching framework or "big picture", within which a number of research programmes are set and connected with each other;
- modelling that links different programmes and disciplines, ranging from conceptual models to detailed computer models;
- scaling up science;
- multidisciplinary capabilities; and
- identifying knowledge gaps and prioritising future science activity.

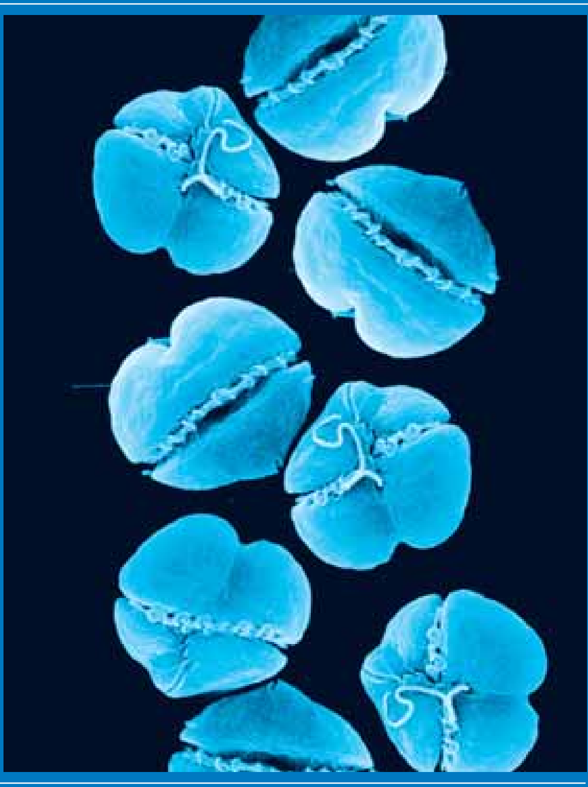
Case studies in this section describe integrated research programmes and how they are providing the kinds of answers environmental managers are seeking. They highlight that integrated programmes do not occur without active planning, engagement of different disciplines and managers, and enabling governance.

Shared high-level goals/questions

One of the main prerequisites for integrating research and knowledge is shared goals, usually expressed as questions or objectives that can help focus researchers. A common set of questions, pitched at the right level, helps align and focus research activities. This approach provides a big picture which gives context for the research. Development of these questions or objectives can require extensive dialogue with stakeholders – both scientists and environmental managers.

Discussions with scientists and managers in preparing this Roadmap show that New Zealand needs to improve the way it identifies the big picture goals/questions for science. FRST's target outcomes framework is one step in this direction. MoRST's environmental evaluation survey further identified that work is needed to more effectively involve stakeholders, particularly regional councils, in identifying the key questions or objectives for science.

Joining forces in combat against biotoxins



Toxic micro-alga Karenia brevis, *which New Zealand scientists use to study toxins. (Source: Cawthron Institute)*

In 1993, New Zealand experienced its first large-scale toxic algae bloom, resulting in more than 180 cases of shellfish poisoning. At the time there was a realisation that similar outbreaks in the future would pose a significant threat to the long-term economic viability of New Zealand's aquaculture industry.

Regional Shellfish Specialist at the New Zealand Food and Safety Authority, Brian Roughan, says while this was not the first episode of a harmful algal bloom observed in New Zealand, it was a crisis of significant enough proportion to spark a novel approach to organising New Zealand's knowledge on marine biotoxins.

Industry, scientists, health authorities and seafood regulators, supported by the Royal Society of New Zealand, ventured on a new path of joint strategising with a focus on identifying synergies and maximising science investment in the sector. Symposia, a national research strategy and effective linkages between science provider and end-users were all part of this novel approach embraced by the sector.

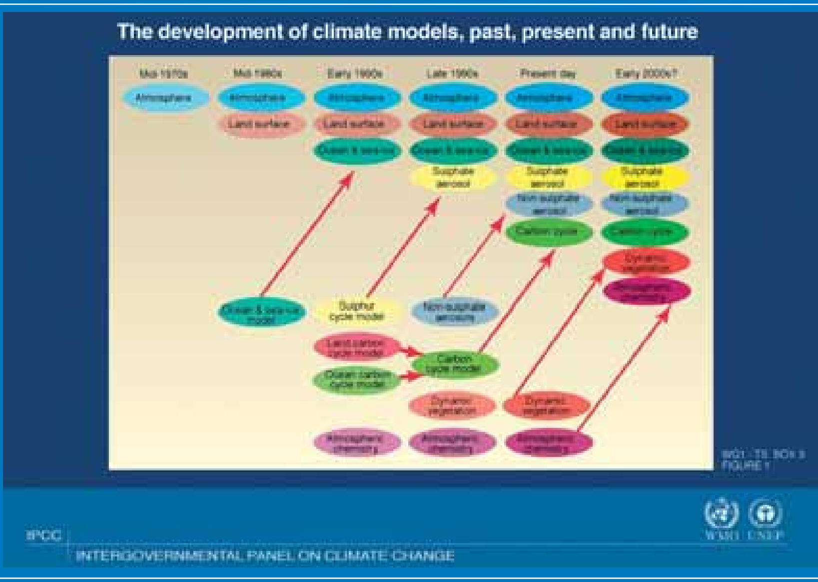
'Bringing people together in one space to discuss current issues and the future direction was immensely rewarding. This sparked off the development of the national research strategy, which made it easier to prioritise and get runs on the board subsequently.'

The group identified key questions and goals as a first guiding framework. It then developed a national research strategy which gave direction to science investment and further assisted in prioritising future science activity.

'Thirteen years later, New Zealand has established itself as an international leader in the application of new biotoxin identification technologies. Gene probing and biochemical analytical techniques are revolutionising this area.'

The speed of New Zealand's progress in biotoxin technology is largely attributable to successful across-sector collaboration. Joint strategising and high-level direction setting early on has given an impetus to reach these new frontiers.

Getting to grips with global climate change



Historic view of the modular development of earth system models. (Source: IPCC, 2001)

Since the 1970s scientists have been on a mission to understand and model the global climate system. Over time, increased knowledge of the functioning of key components of the environment has resulted in increased model complexity. For example, the study of atmospheric, land and ocean/sea ice systems in the 1990s saw the development of coupled atmosphere-ocean-ice climate models. In recent years, added knowledge on aerosols and carbon cycle resulted in further modular enhancement of atmospheric chemistry in climate models.

Now, using high resolution earth system models of incrementally growing complexity, international teams of scientists are attempting to simulate the full climate system and to understand how the different components interact. Principal scientist, Dr Jim Renwick, of NIWA's National Climate Centre in Wellington, says this modelling approach is leading edge in environmental science.

'Simulating large complex systems requires approaches of a highly collaborative and integrated nature to effectively distil the available information and identify and fill gaps in understanding.'

Earth system models simulate the interactions among several components of the climate system. The models allow for long-term climate simulations over hundreds or even thousands of years, or a broad range of sensitivity experiments over several decades.

'Improved understanding and tighter bounds on the uncertainties in climate change projections will help us get a better handle on what is likely to happen on a global scale over coming decades. The earth systems approach should improve scientific understanding of one of the biggest global problems of the twenty-first century.'

While earth system modelling is still maturing, the models are subject to careful comparison with observed data, thereby identifying processes we do not understand and assisting with research prioritisation. New research feeds back into model components, and further comparison between model output and observed data creates a system of continuous improvement.

Modelling

Modelling is an important means for achieving integrated research programmes. Models can range from conceptual models (such as food webs) to simple regression equations to complex numerical simulations. They can link social, economic and environmental data and knowledge over various spatial and temporal scales. Environmental modelling gives scientists the ability to understand ecological interactions occurring at different time scales (into the past and future) and spatial scales (beyond the range of sight) that cannot normally be observed. The roles of models can range from problem formulation to sophisticated predictions on which management decisions are based. Modelling, to be effective, must be supported by quality datasets, processes to test and expand ideas and concepts, and end-users utilising and experimenting on the basis of the models.

Internationally, and to some extent in New Zealand, environmental research teams are increasingly developing modelling frameworks that link and nest model components. For example, NIWA is currently developing river catchment models, including data layers on water temperature, nutrient level, variations in dissolved oxygen, and shading. The model components can be linked in different ways to answer a range of questions, such as the impact of increased nutrient levels and/or shading and/or abstracting water on the ecosystem. Models can further be developed and added to over time as knowledge improves. Included in these modelling frameworks are shared user interfaces, data curation systems and output presentation and visualisation tools.

The modelling tool kit is growing and becoming more sophisticated, both in design and in application. Greater focus is needed on modelling and providing frameworks that integrate diverse programmes and disciplines.

Scaling up science

Most environmental research focuses on small parts of the environment or the individual effects of one part on others. The spatial and temporal scale of projects does not tend to approach the scale at which system patterns and processes begin to emerge, which is the level environmental managers are interested in. For example, scientists may study a particular part of a stream, whereas environmental managers are interested in understanding how whole catchments function. Scaling research results up to a level that is relevant for environmental management requires better understanding of the emerging properties of systems.

Several technical factors have enabled advances in systems/integrated approaches and helped overcome the problem of scale. These include increased computing power, progress in numerical modelling algorithms, and improved methods for blending models and datasets. Greater focus is needed to support progress in systems science, including integrative approaches, large-scale and long-term data collections, modelling, classification systems and inter-operability of different datasets.

Multidisciplinary capabilities

Integration increasingly requires disciplines to work together. One approach has been to train 'generalist' scientists who would then integrate across disciplines. The trend is now steering away from this approach towards ensuring scientists have a solid disciplinary base and are trained to participate more effectively in multidisciplinary environments.

During the preparation of the Roadmap, scientists have identified several "social" barriers to establishing integrated programmes in New Zealand which require further analysis. Barriers include:

- peer recognition and peer review that principally recognises success within a discipline but is less able to deal with integrated approaches;
- aspects of the funding system which make it difficult to effectively link projects between different funding rounds and even within funding rounds; and
- the additional effort and costs in preparing bids for integrated programmes (as compared to more discipline-based bids) due to the need to incorporate a greater number of agencies and disciplines.

Prioritising

An effective process for deciding which disciplines need additional effort and which processes need additional understanding is a key element of implementing an integrated approach. Focusing on uncertainties in the models can help to direct science resources to where new data or knowledge will be of most benefit.

Uncertainties in integrated climate modelling have been used, for example, to direct research into new questions such as what role clouds and marine algae play in driving climate. In the land area, the Ministry of Agriculture and Forestry (MAF) has led an integrated modelling exercise which has been instrumental in identifying uncertainties, priority questions and model enhancement in the nutrient management area. The Integrated Regional Aquifer Protection Programme (IRAP) project (refer case study 'clean water - productive land') plans to use this approach to identify priorities for further research. Overall, improvements are needed for prioritisation processes, following the establishment of clearer goals/questions and better integration of research programmes.

Roadmap directions and actions

Direction 1

The Government wishes to see additional emphasis on integrated multidisciplinary research to support improved understanding of environmental systems whilst maintaining effective long-term capabilities and international collaborations in key areas.

Actions:

- MoRST to lead policy work on identifying the barriers to integrated environmental research and ways to overcome these.

4.3 Transfer and uptake

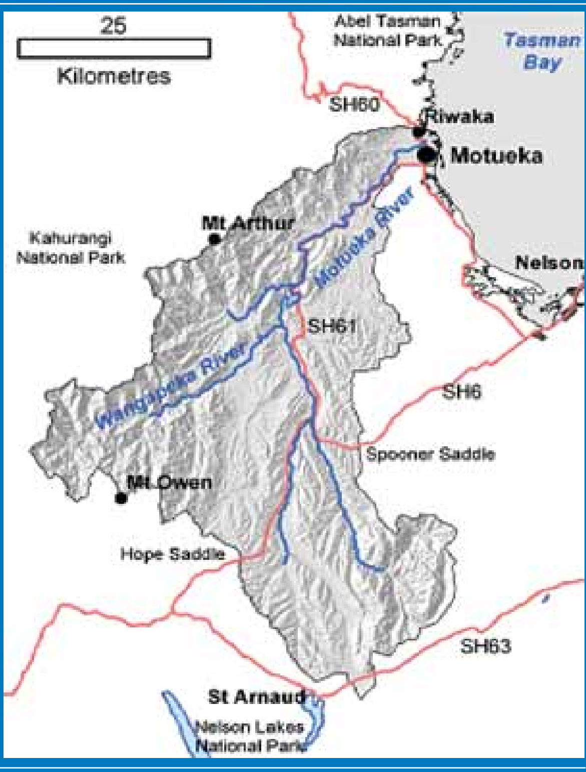
Improved transfer and uptake of science is key to effectively delivering on environmental outcomes, by orienting and shaping science in such a way that its form is guaranteed to be understandable and useful to resource managers, businesses and the wider community. MoRST's environmental evaluation[22] identified the need to improve transfer and uptake of research. Further improvements can be made to the way science is carried out, including:

- **prediction to solution** – a focus on predictive science so environmental managers can evaluate the possible impacts of different management scenarios and devise solutions;
- **applications** – such as decision support and modelling systems that environmental managers can use. Envirolink is helping to support the development of these;
- **adaptive management** – where management decisions are used as live 'experiments' to see how the environment responds to management and how accurate scientific predictions are, thereby better connecting science and management; and
- **communication through visualisation** – improved communication tools, such as visualisation of computer modelling outputs.

Science in New Zealand is making some progress in these directions. This Roadmap confirms the present direction environmental science in New Zealand is moving in and recommends greater progress.

[22] MoRST (2004), *Evaluation of the Environmental Output Class.*

Motueka River benefits from Integrated Catchment Management



Integrated Catchment Management is a holistic approach for managing land, water and coastal environments. The 2,170 km2 Motueka catchment is subject to a long-term ICM project by the Tasman District Council. (Source: Landcare Research)

The Motueka River in the South Island is benefiting from the attention of a multidisciplinary team working through an Integrated Catchment Management (ICM) process.

ICM is a holistic approach for managing land, water and coastal environments, and includes consideration of social, economic and political factors in achieving best-practice sustainable natural resource management. Programme Leader, Andrew Fenemor, from Landcare Research in Nelson, says the landscape and communities of the 2170 km2 Motueka catchment and Tasman Bay into which it drains were a good choice for a long-term ICM project.

'The Motueka catchment is in reasonable shape and we want it to stay that way. It has diversity of climate, geology, soils, land and water uses, but also a range of contentious environmental issues. For example, water allocation between 'out-of-stream' water uses, especially forestry and horticulture, and flow needs for 'in stream values' such as the internationally recognized trout fishery.'

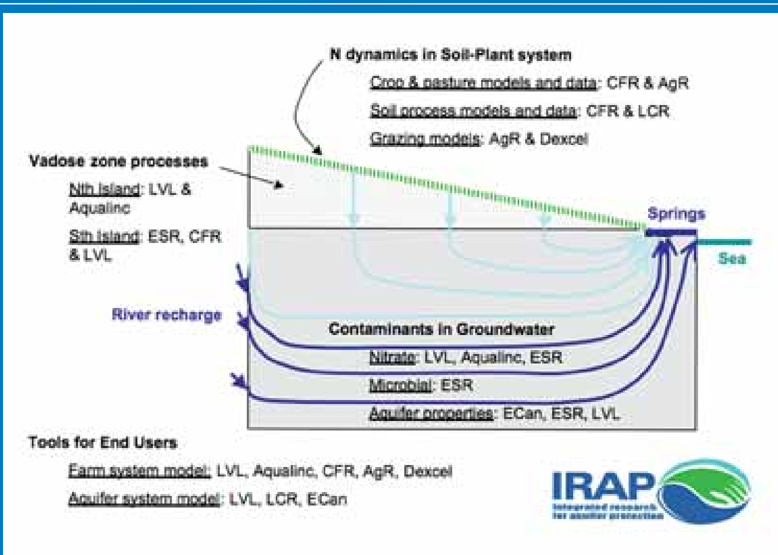
Research so far include the Sherry River water quality experiment which resulted in farmers building bridges for herd crossings, a Geographic Information System based iwi knowledge system, a review of water allocation systems, an interactive Motueka catchment CD-ROM Toolkit, trout radiotagging to track responses to river flows, and insights into the impacts of river sediment discharges on seabed shellfish productivity.

The research team comprises scientists from a range of disciplines including hydrologists, freshwater biologists, forestry ecologists, geomorphologists, economists, social scientists, planners and policy analysts. Collaboration between researchers and the community, stakeholders, and iwi is key to an integrated approach to catchment research.

The Motueka catchment is a world demonstration catchment in the UNESCO-WMO global programme 'Hydrology for the Environment, Life and Policy'.

For more information see http://www.unesco,org/water/ihp/help, or http://icm.landcareresearch.co.nz

Clean water - productive land



New Zealand is set to continue to develop its agricultural potential and rural economy, while at the same time ensuring high quality contaminant-free water for drinking and irrigation. Managing clean water and productive land is a tight balancing act.

The Integrated Research for Aquifer Protection, or IRAP, is a collaborative research project to understand the big picture of water quality - from the plant to the aquifer. Dr John Bright, programme leader for Lincoln Ventures Ltd, says that IRAP has been a timely project for New Zealand.

Crop & Food Research, AgResearch, Dexcel, Landcare Research, ESR, Lincoln Ventures Ltd, Aqualinc and Environment Canterbury are the partners in the IRAP project.

An end-user advisory group involving Environment Waikato, Environment Southland, Selwyn District Council, MAF, MfE, Foundation for Arable Research, HortNZ, Te Runanga o Ngai Tahu, and Federated Farmers ensures that the research remains relevant, delivers appropriate tools, and facilitates rapid uptake of research results and tools.

'We're interested to find out what impact land use changes will have on the quality of groundwater in the future. How do nutrients move through the soil to the aquifer and then through the aquifer system? Will using best practice farm management techniques be enough to maintain acceptable groundwater quality? These are our guiding questions.'

IRAP is a result of growing concern expressed amongst the public and policy makers that the intensification of land use may result in deterioration of groundwater quality.

'The IRAP group will look at how nitrates from different land uses move through to groundwater, and develop computer tools to guide management at paddock, farm, and aquifer levels throughout New Zealand.'

In the future resource managers will be able to use these computer-based tools to develop policies for land use decisions, water quality protection and to promote best practice management techniques. Further, comparison of predicted and actual measurements will help identify knowledge gaps and guide future research priorities.

For further information on IRAP's research programme visit: http://www.irap.org.nz

Prediction to solution

Increasingly, environmental managers are seeking predictions from scientists about how environments will respond to change and how change can be managed to meet multiple objectives. Coupled with the predictive approach is a focus on solutions and testing of management scenarios. Solutions oriented research is identified as a key requirement by councils. An example is the Central North Island lakes, where environmental managers are seeking predictions from scientists on the impacts of different land uses on water quality of the various lakes, to help inform future management scenarios.

Predictive science requires a greater emphasis on mathematics and modelling than more descriptive approaches. These predictive capabilities are important to build, as discussed in section 4.2. Further, improved understanding needs to trigger solutions oriented research and application.

Environmental managers seek certainty from scientists' predictions and the testing of management scenarios, whereas models include uncertainties that managers need to be aware of and understand. Environmental science is developing new ways of dealing with uncertainty, such as focusing on the key variables that control the resilience of systems, identifying different potential ecosystem states, and identifying the thresholds of change from one state to another. Leading science in this area is moving towards identifying a range of possible outcomes and the probabilities of different outcomes occurring. New Zealand scientists need to build capacity in communicating uncertainties in predictions to environmental managers, in a way that managers find useful.

Applications

Developing applications ('tools') for environmental managers is an important way of assisting the uptake of science. The environmental evaluation identified that more could be done to develop tools for environmental managers. As a result, the government established the Envirolink[23] fund in 2005, which provides funding for the development of tools, as well as enabling nine regional councils to access advice from science agencies.

Envirolink will be evaluated in 2007. Initial reactions from both councils and researchers are very positive. For example, regional councils have worked closely with research agencies to develop a priority list of tools; this has resulted in new and improved relationships between councils and scientists.

Adaptive management

In an adaptive management approach, managers and scientists work together iteratively to continuously improve management policies and practices, by learning from the outcomes of operational programmes. Monitoring the results of actions provides a flow of information that may indicate a need to change a course of action. Scientific findings and societal needs may also indicate the need to adapt resource management to new information. Improved environmental sensing networks will make adaptive management more feasible than it has been in the past.

In some areas, managers and scientists have successfully used adaptive management approaches to improve environmental outcomes, while also improving scientific knowledge. DoC's 'mainland island' and pest management programmes are good examples.

Environmental managers and scientists both need to be actively engaged in the adaptive management process, which is a significant challenge. For example, flexibility in institutional design to allow trials and mistakes to occur, inform, and be corrected, is limited by the requirements for certainty in policy and resource allocations.

Although New Zealand has several examples of adaptive management programmes, these tend to be the exception. Greater focus on and a more supportive environment for adaptive management programmes is needed to improve environmental management, environmental science and connections between the two.

[23] http://www.frst.govt.nz/research/Envirolink.cfm

Communication through visualisation

New simulation and visualisation technology lets scientists, managers and the wider community see the environment at a range of different time and spatial scales. Visualisation techniques enable environmental processes to be effectively demonstrated and explained. International initiatives such as Digital Earth, introduced by Al Gore in 1998, are pushing the boundaries of software engineering, computing systems and data management systems that are needed to support effective visualisation.

Advances in environmental modelling and visual software, that provide images of our environment on multiple scales, can help bridge communication gaps between scientists, managers and the wider community (see Figure 4.1). This in turn will enable greater dialogue and interactions between managers, scientists and the community, particularly in terms of understanding key environmental processes and possible scenarios. New Zealand needs to ensure that it builds and supports developing the capability in visualisation to help communicate science findings to environmental managers.

Figure 4.1. The Macaulay Institute's Virtual Landscape Theatre is a mobile curved screen projection facility in which people can be 'immersed' in computer models of their environment to explore landscapes of the past, present and future. Here the Theatre is being used to research reactions to future urban change. (Source: David Riley, Macaulay Institute, Aberdeen, UK). http://www.macaulay.ac.uk/landscapes/index.html

Roadmap directions and actions

Direction 2

The government will work to ensure that the environmental management sector will benefit from, and be transformed in the future by, research which requires greater emphasis on the transfer and uptake of research to better connect science and management.

Actions:

- MoRST to evaluate Envirolink (scheduled for 2007) and councils to continue to work with scientists to update and implement priority applications/tools.
- MoRST will work with regional councils, departments, science providers and FRST to explore, at a national level, opportunities for predictive approaches, developing applications, adaptive management, and communication through visualisation that links science and management.

4.4 Information systems

Quality data, data management and information systems are a prerequisite for sound environmental science and management. MoRST's environmental evaluation[24] identified the need to improve data collection and management. To encourage enhanced information systems, several improvements can be made to the way science is carried out. These include:

- data management, including inter-operability of datasets and data standards to support more effective curation of data across the environmental sector;
- scaling down datasets (through, for example, classification systems) to a level that is useful to environmental managers and scientists; and
- collecting information that uses state of the art environmental sensing technologies to provide real-time environmental data.

Science in New Zealand is making some progress in these directions. This Roadmap confirms the present direction environmental science in New Zealand is moving in and recommends greater progress. Greater emphasis needs to be given to developing real-time monitoring and data analysis tools, data standards including metadata, and to more effectively curate existing data from a wide range of public sources. MoRST is developing policy in the data management area and is refining policy on long-term funding arrangements for data networks and other science "backbone" assets. Policy work in the environmental data area needs to be done in partnership with scientists, industry and environmental managers including government agencies (central and local).

Data management

Data needs are now largely driven by the requirements for modelling and, as a consequence, researchers are more focused than they were about what data is needed and the necessary scale of resolution. Further, new instrumentation coupled with ICT infrastructure, such as the Advanced Network, has the capacity to generate and transmit large amounts of data cheaply. In the longer-term, it is expected that environmental sensor networks will become cheaper and more common.

Research organisations are making progress in improving the curation of and access to environmental data, through, for example, web portals. However, overall progress in the environmental data management area is slow and lagging behind what is possible with available technology. Improvements in data management would enable more sophisticated science programmes to be developed, particularly larger-scale integrated research programmes that draw on data from a range of disciplines, locations and time scales.

The national level science databases often provide the "template" and key operational features for data management, such as metadata standards. Improved data management in the science sector will therefore benefit data management in the broader environmental management community.

Scaling down

Opportunities exist to make better use of large-scale datasets, for example, from satellite monitoring and climate models. Approaches and techniques for scaling down these datasets are needed (such as using classification systems) to bring the data to a scale that is useful to environmental managers and scientists. In New Zealand, good progress has been made in this area, such as:

- The development of the Land Environments New Zealand (LENZ) classification system, which is used to predict the ecology of an area and its potential production uses, such as whether an area is suitable for a certain grape variety.
- The River Environment Classification (REC) system (see Figure 4.2), which is used to identify similarities and differences in rivers, factors different rivers are sensitive to, and values expected in different types of rivers.
- The Marine environment classification system, which has been developed at a broad scale for the Exclusive Economic Zone (EEZ).

[24] MoRST (2004), *Evaluation of the Environmental output Class.*

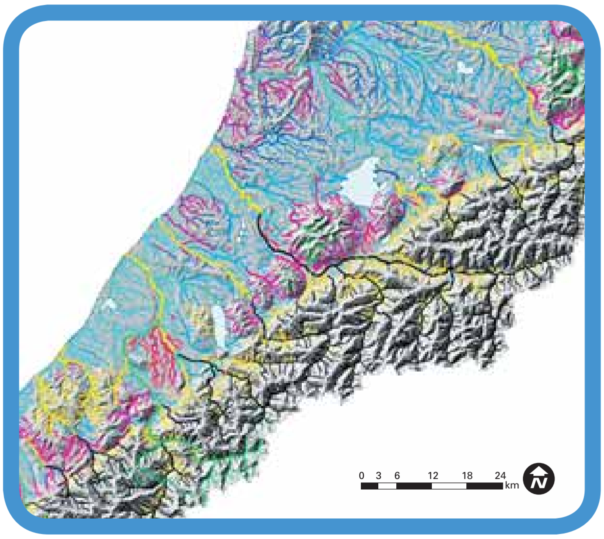


Figure 4.2. An example output from the River Environment Classification System developed by NIWA and MfE. Similar types of rivers on the West Coast are shown in the same colour. For rivers of the same type, similar environmental attributes can be expected (for example, water quality parameters, ecology and sediment regimes). Broad data sets, such as a national level digital terrain model, geological data and data of permanent ice/glacier, are scaled down to catchment and reach scale. (Source: NIWA)

Environmental sensing

Vivid and precise data is needed to inform on-land decisions on issues such as irrigation, fertiliser application, carbon trading, biodiversity, and waste management. Being able to precisely measure the dynamics of systems is crucial in enabling environmental managers to address the intertwined challenges of environmental and economic sustainability. This knowledge, when integrally linked to land use decisions and markets, will enable New Zealand to not only sustainably manage resources but also maintain a competitive advantage in increasingly discerning global markets.

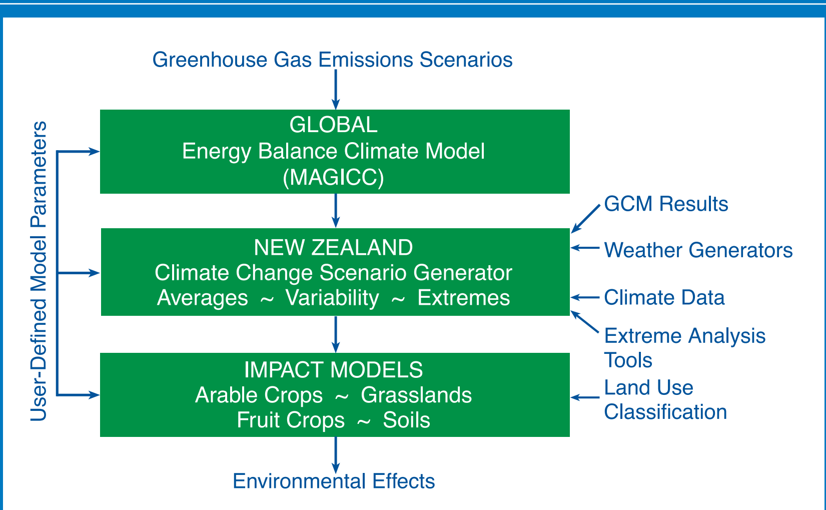
Effective visualisation coupled with information systems operating in 'real-time' allow communities and businesses to understand the short-term effects they are having, see the short-term responses to their behaviours or interventions, and monitor the long-term responses. These information systems depend on improved sensing and measurement technologies coupled with effective presentation systems.

Valuation and trading of ecosystem services are likely to be an important feature of the production sector in the future. Markets operate on a basis of reliable, cost-effective and auditable trading data. Environmental science can enable the collection and transmission of environmental data in a form that makes detailed real-time monitoring cost-effective – a prerequisite for creating markets in ecosystem services.

New capabilities in environmental sensing could involve, for example:

- Satellite remote sensing brought beneath the forest or pasture canopy; measuring critical variables such as nutrient flux and water flows and delivering data through electronic networks direct to farm management systems; and

CLIMPACTS examines sensitivity of NZ environment to climate change



Since 1993, the 'CLIMPACTS: Developing Capacity for Climate Change Adaptation' programme has been working to increase our understanding of the sensitivity of New Zealand's environment and resources to climate variability and change. Led by the University of Waikato's International Global Change Institute (IGCI), the programme has been implemented by an interdisciplinary, multi-skilled research team involving Crown Research Institutes (CRIs), universities and the private sector.

IGCI Deputy Director and programme leader, Richard Warrick, says natural variations in New Zealand's climate can already affect primary production systems, amongst other sectors, with the potential for large disruptions. 'On longer time-scales, changes in New Zealand's climate may exacerbate many of these problems. Within this context there is a need, both nationally and regionally, to understand better the effects of such variations and changes as a basis for sustainable resource management.'

One major focus of the programme has been the development of a computer-based integrated assessment model (IAM) known as the CLIMPACTS system. The CLIMPACTS systems provides the capacity for conducting analyses of the sensitivity of New Zealand's natural and managed environments, especially the agricultural and horticultural sectors, to climate variability and change over time and space, including an extreme event analysis tool.

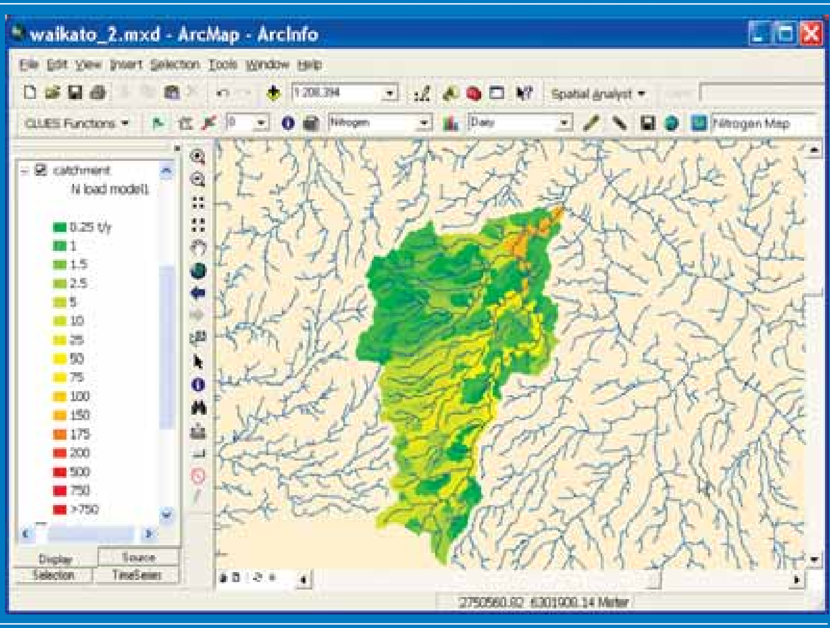
'The system has the flexibility to allow the user to generate a vast number of climate change scenarios and ask a range of "what if" questions about the climate sensitivity of selected sectors.'

The system is easily updated as new information becomes available. The multi-scale nature of the system means that analyses can be conducted on a national, regional, or site specific basis. A recent development has been the development of a very user-friendly, 'open-framework' version of CLIMPACTS for distribution to end-users. With this version, the user can customise the system for their own purposes by adding data and attaching models for impact analyses.

The CLIMPACTS Programme was started by the IGCI and developed in collaboration with NIWA, and has included contributions from AgResearch, Crop and Food Research, HortResearch, Landcare Research and the University of Auckland, with funding from the Foundation for Research, Science and Technology.

For more information about the CLIMPACTS programme see http://www.waikato.ac.nz/igci/climpacts/. For availability of the CLIMPACTS "Open-Framework" Model, see www.climsystems.com

CLUES answers water quality questions



Output from CLUES model showing N loads in different parts of a catchment. (Source: CLUES Study Team)

Catchment Land Use for Environmental Sustainability (CLUES) is the first modelling system of its kind to answer water quality impact questions faced by regional resource planners. Designed specifically for New Zealand, the system under development is computer-based and allows a GIS (geographical information system) user to model nitrogen and phosphorus loads in streams as land use changes, on both regional and catchment scales. The system combines the strengths of several specialised land-use change models and also provides data on socioeconomic implications.

The current Project Leader, Graham McBride from the National Institute of Water and Atmospheric Research (NIWA), explains: 'If we allow large-scale conversion of forestry to dairying, what would be the effect on downstream water quality and on local living standards? That's the sort of big question faced by regional resource planners. To answer such questions we're developing tools for predicting the cumulative effects of nutrients (nitrogen and phosphorus), faecal contamination, and sediment inputs, which also incorporate an economic and social dimension. Such predictions have to take into account a wide range of variables including; soil type, terrain, drainage and aquifer permeability, rainfall, fertiliser use, and groundwater processes.'

The project has included creating national maps of land-use, soils and pollution risk; as well as developing extensive databases including predictions of nitrogen leaching for many combinations of crop, fertiliser, climate and soils. The types of land-use which can presently be fed into the model include arable farming, horticulture, forestry, and several sheep, beef, dairy and deer farming variations.

The project has been commissioned by the Ministry of Agriculture and Forestry, funded via FRST's Cross Departmental Research Pool, in association with the Ministry for the Environment, Environment Waikato and Envirolink. The project involves a team of scientists led by NIWA, with input from AgResearch, HortResearch, Landcare Research, Lincoln Ventures, and Harris Consulting.

- Environmental performance and traceability information being applied to enhance brand value and provide point-of-purchase information to customers in offshore markets.

Strengthened capacity will be needed to integrate and build capacity in environmental sensing and informatics platforms, to drive development and application from user needs, and to pilot new systems.

Roadmap directions and actions

Direction 3

The government wants to see additional effort on environmental sensing networks and data management to improve frameworks for measuring, monitoring and managing the environment.

Actions:

- MoRST will work with regional councils, departments, science providers and FRST to explore, at a national level, opportunities for environmental sensing networks and data management improvements.
- Research organisations and other owners of research infrastructure to continue to explore ways of working more collaboratively; partly to share the costs and partly to provide good access to critical research infrastructure.

5 The six environmental research areas

Summary of this section:

- This chapter discusses how the three themes – systems understanding and integration, transfer and uptake, and information systems – relate to the six environmental research areas. In summary:
  - **Global environmental change.** This area requires better modelling to predict future climate change scenarios and enhanced international collaboration. A key challenge is taking an integrated science and socio-economic approach to work out how the country should best adapt to future climate change.
  - **Land, water and coasts**[25]. Getting the most out of current research investments necessitates better integration of existing research programmes. Enhanced communication of relevant and user-friendly information to environmental managers is needed. Improvements are needed to data collection and management.
  - **Urban design and hazards**. An urban research agenda that best suits New Zealand needs to be developed. The Ministry of Civil Defence and Emergency Management's 'all hazards' framework and emphasis on risk reduction are increasingly reflected in research contracts. Work is needed in some areas to improve connections with end-users.
  - **Biosecurity**[26]. Understanding risk pathways and responding to incursions is critical. In the case of an incursion, a range of disciplines need to be brought together, often at short notice. The issues in this area relate to maintaining and integrating core capabilities. Connections with users are generally good, but improvements are needed in the area of data management.
  - **Biodiversity**[27]. Maintaining biodiversity is one of New Zealand's main environmental challenges. By and large, the science system in this area works well. More ecosystems-level modelling work is needed; along with further analysis on the amount of work required in descriptive (such as taxonomy) versus predictive research.
  - **Oceanic systems**. Fundamental knowledge is lacking in many areas of oceanic science, making it difficult to describe knowledge needs for offshore marine biodiversity and the marine environment, or to identify key ecosystem-level questions that need answering. Connections with end-users are patchy. Ocean Survey 20/20 offers an avenue for improved datasets.
- Over time, a greater effort on integration in these six areas is needed. But this greater focus on integration must not be at the expense of critical disciplines. The ideal is to have both greater integration and to effectively maintain important science capabilities.

[25] Refers to terrestrial, freshwater and coastal marine environments including aquaculture and coastal fisheries.

[26] Covers terrestrial, freshwater and marine environments.

[27] Covers terrestrial, freshwater, estuarine and coastal marine environments.

5.1 Global environmental change

Scope of research area

Global environmental change science covers four main areas:

- Atmospheric and climate processes. This research is important for understanding and predicting climate variability and change. This work supports natural hazard management, land and water resource management, and renewable energy.
- Terrestrial systems and atmosphere exchange. This research area is important for understanding the exchange of greenhouse gases (carbon dioxide, methane, and nitrous oxide) between terrestrial systems (native ecosystems, forests and agricultural systems), opportunities for mitigation, the consequences for international reporting, and social and economic adaptation to global change.
- Ocean processes. This research is important because New Zealand's climate and weather are strongly influenced by oceanic processes. This research also supports marine environment management (including fisheries and aquaculture).
- Plate tectonic processes. This research supports mineral exploration, understanding of landscape-scale processes (such as the formation of mountains and river plains) and understanding natural hazards, such as flooding, landslips earthquakes and tsunamis.

Global environmental change research provides the basic knowledge about earth processes and future climatic states. Other areas of science depend on a range of capabilities that this research provides. For example, geothermal energy research relies heavily on research on earth processes[28]. Renewable energy, floods and coastal hazards, and water resources all draw heavily on research to understand climate and weather processes.

Research in this area tends to be well connected to international research. For example, New Zealand hosts international measurement campaigns and shares global data. Our climate change research draws heavily on international climate models and contributes regional data to them. Our geological process work is well connected with international research to better understand global-scale tectonic processes.

Global environmental change research has expanded beyond traditional disciplinary studies of atmospheric processes and chemistry, oceanography, and paleoclimates. It now includes increased activity in Antarctic research, biogeochemistry for carbon accounting, methods for measuring and mitigating greenhouse gas emissions, and the impacts of current and future climate on social and economic sectors.

Climate change is an increasingly important area for the government. MfE is leading the development of climate change research priorities. These priorities will help inform FRST's investment decisions and set directions for future science capability in this area.

Capabilities

Many agencies and areas of science rely, often at short notice in times of crisis, on the global environmental sciences to provide a range of core capabilities to support their work in a range of work areas related to natural hazards and climate change. Agencies include the Earthquake Commission (EQC), MCDEM, MfE, MAF, MFish, and regional councils.

New Zealand has significant links with international science agencies. New Zealand leverages its considerable strengths to attract international collaborations and research resources. These strengths include proximity to tectonic faults and geothermal activity, deep-sea geological resources, location in the South Pacific Ocean, Antarctic research base, wealth of paleoclimate archives, internationally significant atmospheric monitoring sites, and leading scientific expertise. The importance of these collaborative relationships means it is important that New Zealand maintains core capabilities in this area.

[28] This is an area of cross-over with the Energy Research Roadmap.

Good databases, computing power, infrastructure, and capability in global environmental change disciplines will benefit a number of areas of science and the activities of a range of agencies. Maintaining good capabilities is also an important conduit for participation and credibility in international fora and climate change policy negotiations, and meeting international reporting and research obligations.

Funding

At present, the pool of research funding for understanding geological processes and predicting geological hazards and their impacts is about $10 million. The pool for climate variability and change is about $15 million. Much of the research funding in the climate sciences goes towards climate databases of national and international importance.

Issues

New Zealand's economy relies on knowledge about global earth systems. Climate knowledge, for example, helps optimise agriculture production and energy security. Good understanding of climate and particularly microclimates will help New Zealand develop more niche land uses and develop higher quality products.

This area of research also contributes to understanding global threats. New Zealand's physical environment faces two types of global threat. The first is climate change, which is expected to result in increasingly severe floods, storms and droughts and coastal inundation. Better understanding of climate change will enable New Zealand to adapt more effectively.

The second risk is from geological events. Earthquakes, tsunamis and volcanic eruptions threaten New Zealand society with devastating financial, economic and human consequences. The risks may be greater than the relatively benign experience of the last 60 years would indicate.[29] Scientific advances in predictability of geological hazards are still being made.

MoRST and MCDEM are working together to improve co-ordination, promotion, delivery and uptake of hazard risk research, for the civil defence emergency management sector.

Links to key themes in Chapter 4

An area requiring additional focus is climate change. There needs to be a stronger focus on predicting future climate in New Zealand, as environmental managers need these predictions to help society adapt to future climate regimes. This will in turn require New Zealand to enhance its modelling capability. Stronger links are needed with international climate change modelling initiatives, as these are expanding and in the next few years are likely to generate significant advances in understanding future climate.

As improved predictions become available, the focus will increasingly move to what New Zealand has to do in order for it to adapt to future climate.
This necessity will require improved integration of climate science with other areas, particularly socio-economic disciplines.

Knowledge needs

Developed in discussion with stakeholders, a range of knowledge needs and capabilities that need to be maintained and enhanced, within the area of global environmental change, were identified. These include:

- Better understanding of climate processes in the South West Pacific, that is, New Zealand's part of the world - because the Southern Ocean is a key influence on our climate, it is a data-sparse region, and global models are too coarse to account for our landscape.
- Predicting changes in extreme and adverse weather events to provide improved risk estimates for planners, engineers, land managers, biosecurity management etc.
- Knowledge about New Zealand greenhouse gas sources and sinks to support New Zealand's climate change policies.
- Knowledge on climate change resilience and adaptation options and costs.
- Understanding of the geomorphologic processes and associated hazard risks in New Zealand.
- Understand our volcanoes and the threats and resources they may represent.
- Better understanding of earthquakes and deformation, both rapid and slow, to improve risk analysis.

[29] EQC submission.

Some key questions that managers are seeking advice on are:

- What will New Zealand's climate be like in years to come?
- How much will the sea level rise and when?
- Can we better predict geological and climatic hazards?
- How do we control and reduce greenhouse gas emissions?
- What are the impacts and adaptation strategies for these?

Actions

- FRST and research organisations to take account of finalised climate change investment priorities.
- FRST and research organisations to seek to maintain core capabilities relevant to other science areas, given this area underpins many other areas of science.

5.2 Land, water and coasts

Scope of research area

Land and water and coasts research can be broken into the following main areas:

- Freshwater science, including hydrology, freshwater ecology, water quality, fluvial geomorphology;
- Land science, covering soil science, production, nutrients, erosion, land cover, greenhouse gas emissions etc;
- Estuarine and coastal marine science, including aquatic production, estuarine and coastal ecology, nutrient dynamics and cycles etc; and
- Connections between the water, land and estuarine/coastal marine science, including understanding anthropogenic changes.

In recent years, research into land and water resources in New Zealand has moved towards a more holistic and systems-based approach. There is greater attention to a range of spatial scales and scaling up and down between these. Research on social and cultural behaviours has progressed from studies of attitudes and perceptions, to methods for transfer of information, changing attitudes and behaviours, and participatory planning.

Capabilities

Science capabilities in the land, water and the coasts are critical to helping New Zealand achieve long-term goals relating to sustainability of land use, water use and marine production systems. Departments, councils and industry draw heavily on science in this area to underpin their own operational research and/or help improve the sustainability and economic viability of production systems.

Much of the science in this area relies on capability in the global environmental change area (section 5.1). For example, hydrology connects with climate science, and research in the aquaculture area draws on research on ocean systems.

Understanding coastal and estuarine systems are areas where integration of terrestrial, freshwater and marine sciences is essential to inform resource management decisions.

Databases such as the water resources archive, groundwater archive and the soils database are an important capability. Environmental managers rely on the science system to provide these long-term and wide-scale environmental data sets.

Likewise, integration and modelling are important. To help support environmental management, capability is needed to build and maintain large-scale models of the environment, covering surface freshwater, groundwater, land use, estuaries and coasts.

Funding

The total value of research funding for sustainability of land, water and coasts in New Zealand is about $50-55 million annually. This is nearly 40% of the total funding for environmental research. Many of our environmental issues in the coastal marine area as well as on land stem from unsustainable land-use patterns and this level of investment is in proportion to the scale of the challenges. About 8% of research funding in this area is spent on coastal marine production and ecosystems.

Issues

Land-based primary industries and aquatic-based production provide the basis for much of the New Zealand economy. Exports from the primary sector (including seafood, some of which is covered under the oceanic environmental research area) make up about 60% of total goods exports[30] and primary industries contribute more than 10% of GDP[31]. Furthermore, around 65% of electricity production in New Zealand comes from hydropower stations[32].

The pastoral industry[33] has identified water availability and quality, systems for environmental measurement and monitoring, reducing greenhouse gases, nutrient management and residue reduction as the main priorities for research into environmental sustainability. Erosion is also a significant issue in some parts of the country. The pastoral strategy has a stated target of 100% of New Zealand farms having environmental management plans by 2010.

The dairy sector has taken the pastoral strategy further and has produced a specific sustainable environmental strategy[34]. It is seeking increased research into tools for measuring environmental state, change and performance on farms, mitigation tools, improved planning tools and development of a scientific basis for water allocation.

A key issue in the pastoral sector is greenhouse gas emissions, particularly from livestock, which is actively researched at present. Biotechnology research may provide solutions. This is a cross-over area with the Biotechnology Research Roadmap.

The arable food industry strategy[35] targets the issue of sustainability and maintaining productive capacity and economic viability whilst minimising impacts on ecosystems. Specific targets are minimal leaching or run-off through effective nutrient and water budgets, and minimal greenhouse gas emissions and raised soil carbon levels by 2012. Similarly, the horticulture sector strategy[36] targets sustainable production, specifically needing research on soil, fate of agrichemicals, natural alternatives to chemicals, waste management, and R&D necessary to underpin carbon, water, and energy efficiency.

The forestry sector strategy equally targets sustainability issues, with focus on maintaining productive capacity and economic viability whilst minimising impacts on ecosystems. The strategy specifically identifies a need for sustainable forestry practice research, including research into harvesting practices, waste management, multi-purpose forestry, tourism, social values and climate change.

MfE and MAF are leading work on identifying freshwater science needs through the Sustainable Water Programme of Action[37]. These are expected to be completed in 2007. Regional councils are also developing a set of research priorities which should be completed in 2007. Most of these will be relevant to land and water science.

Our estuaries and coastal embayments support important aquaculture facilities and inshore fisheries, and provide many other ecosystem services such as nutrient recycling and contaminant sequestration. Research in these areas underpins operational research by departments and decision making by councils. Inappropriate land use can have significant consequences for coastal marine and estuarine systems, yet our understanding of the ability of these systems to absorb or bounce back from the pressures on them is limited.

[30] http://www.stats.govt.nz/products-and-services/ext-trade-stats/default.htm

[31] Statistics New Zealand National Accounts Year ended March 2005.
http://www2.stats.govt.nz/domino/external/pasfull/pasfull.nsf/7cf46ae26dcb6800cc256a62000a2248/4c2567ef00247c6acc2570c8006bff0c?OpenDocument

[32] New Zealand Energy Data File MED (2006).

[33] Pastoral Research Strategy (May 2004).

[34] Dairy Industry Strategy for Sustainable Environmental Management (March 2006).

[35] A Strategic Framework for the Arable Food Industry (July 2004).

[36] Creating Value in the Horticulture Industries (May 2004).

[37] http://www.mfe.govt.nz/issues/water/prog-action

Based on the various strategies in this sector and government reports, key issues requiring scientific knowledge and advice include:

- ways to reverse declining water quality in lowland rivers, lakes and coastal waters;
- ways to reduce greenhouse gas emissions from the agricultural sector;
- reducing human-induced erosion of top soil and sedimentation of waterways;
- protecting productive land and infrastructure from flooding and other extreme climatic events;
- managing competing demands for available water in rivers and aquifers;
- ways to reverse declines in coastal marine productivity and marine biodiversity;
- Improving pest control; and
- Social research on processes for effective Māori engagement in freshwater management.

Links to key themes in Chapter 4

Significant issues in this area include the need for a clear strategy that can help drive integration of research programmes. For example, there are presently 21 FRST-funded research programmes addressing aspects of water quality, 17 research programmes on some aspect of improving the sustainability of agriculture, 10 programmes addressing aspects of water quantity, and 23 on aquatic ecosystems. It is unclear how the programmes knit together. Improved integration of these programmes would increase the benefits to be gained from existing investments.

Progress is being made in the transfer of information particularly through the Envirolink initiative. Continued and enhanced focus is needed on developing the tools that environmental managers need.

Opportunities exist to substantially enhance environmental data in this area, through for example, real time monitoring of production systems. Better data and information will both improve the science and will enable environmental mangers to more effectively manage production systems.

Knowledge needs

It is now widely recognised that integrating research on land-based production systems with research on maintaining or restoring the health of soil and water ecosystems, and availability of soil and water resources, is key to sustainable management of whole catchment ecosystems. However, this thinking needs to be extended to estuarine and coastal marine systems which can be badly affected by poor land management decisions.

Some key questions that managers are seeking advice on are:

- How can production be increased whilst reducing environmental impacts, including greenhouse gases?
- What role do ecosystems play in maintaining key environmental services, such as groundwater purification, and where is understanding of these services the weakest?
- How will land, water and coastal systems be impacted by climate change and how can production systems adapt to climate change?
- How can the decline in water quality, particularly in lowland streams and lakes, be addressed?
- How can water allocation be made more sustainable, especially in the dry east coast areas of both islands?
- How can nutrient leakage be reduced?
- How do we predict more accurately the consequences of land management decisions for freshwater, estuarine and coastal marine systems?
- To what extend can freshwater, estuarine and coastal marine systems absorb adverse effects and multiple uses without approaching critical tipping points?
- How can estuaries and coastal marine environments be protected from further degradation from land-based sources?

Actions

- FRST and research organisations to take account of relevant government science strategies in this area, such as the freshwater science strategy and regional councils' science priorities when they are developed.

5.3 Urban design and hazards

Scope of research area

Urban research includes:

- air quality;
- water quality in urban areas, including stormwater run-off; and
- transport and urban design.

Hazards research is also included here, because a key part of sustainable communities is their resilience to hazards. The hazards research area has a strong dependency on research in the global environmental change area.

Capabilities

Urban research capability is not well-developed in New Zealand, with the exception of certain areas such as air quality, hazards planning and engineering. A priority is to identify what a suite of world-class urban research programmes that reflect national priorities/ aspirations for sustainable urban development would comprise. Once this is defined, other capabilities (such as datasets) can be more effectively prioritised.

Hazards research has a long history in New Zealand, dating back to understanding earthquakes and flooding in New Zealand in the first half of the 20th century. Research on hazards draws on the capabilities developed as part of the global environmental change area. For example, understanding of tectonic processes underpins research on seismic and volcanic risks.

In recent years, hazards research has become increasingly integrated, moving towards an 'all hazards' approach, where a range of hazards are researched simultaneously and research outcomes are focused on risk reduction. This approach reflects the realisation that many parts of New Zealand are prone to multiple hazards, for example, the Hutt Valley is prone to flooding and is the site of a major active fault; both need to be considered if community resilience is to be enhanced.

Management agencies have developed good science capabilities for some hazards and are directly supporting science capabilities (for example, the Earthquake Commission support of earthquake data collection). In some areas, further work is needed to connect science capability with end-users. Excellent capability for connecting science and management is needed when dealing with hazards because good information flows can help save lives.

Funding

Through Vote RS&T, research investment in urban environments and community resilience is about $16 million annually. About $5 million of this is on sustainability, including air quality, sustainability planning, low impact design and waste minimisation. Around $11 million is spent on natural hazard resilience and infrastructure. The Earthquake Commission also encourages and funds research about matters relevant to natural disaster damage and mitigation.

Issues

When our cities are well designed, safe and secure, clean and green, with world-class infrastructure and a skilled, innovative workforce, New Zealand could be a major draw-card for high-performing businesses and individuals. The government recognises this in its Sustainable Development Plan of Action 2003 which includes the vision 'our cities are healthy, safe and attractive places where business, social and cultural life can flourish'. This is also reflected in MfE's Urban Design Protocol[38].

Eighty-seven percent of New Zealanders live in urban areas. Urban areas are the source of a range of environmental problems including air pollution and coastal pollution. Many ecosystem services are likely to be lost in cities, but there may also be gains in ecosystem services. Understanding what is lost, what is gained and what services can be restored is a key research area.

[38] http://www.mfe.govt.nz/issues/urban/design-protocol/index.html

[39] http://www.sustainableauckland.govt.nz/index.html

Our biggest cities and many peri-urban areas face rapid growth, resulting in considerable pressures on the environment and infrastructure. This often means that demands for information and knowledge to support planning and provision of services and infrastructure exceed the current knowledge base. On current trends, they will continue to do so. Issues that require attention in urban research include urban design, quality of life/well-being and low environmental impact. There are gaps currently in infrastructure, energy and designing future cities more sustainably.[39]

Understanding the integrated nature and functioning of urban form, systems and design is critical to identifying environmental impacts of urban environments. Future urban research needs to take a multidisciplinary approach, drawing on social, economic and environmental science.

Natural hazards are an integral part of the New Zealand landscape. Over the years New Zealand society has built a remarkable resilience to a range of hazards, such as floods, volcanic eruptions and earthquakes. Design of flood and drainage infrastructure is based on past rainfall patterns. But increasingly, flood frequency and severity (due to climate change) may challenge this infrastructure. Flood risk management may become more dependent on climate modelling, which places increased pressure on climate change science to provide reliable predictions of the future.

Compared with other hazards, tsunami may warrant a greater focus. Recent analysis indicates that the risk associated with tsunami may be greater than previously thought.

An issue that has emerged during the major flooding events of 2004 and 2006 is communication between science agencies and flood hazard managers in regional councils. This needs to be improved.

Links to key themes in Chapter 4

In the urban area more work is needed to define a world-class urban research agenda for New Zealand. This is a critical first step towards developing an effective knowledge base in the urban area, including identifying what datasets might be needed. Some good connections exist between researchers and managers, which provide a good platform for developing this more comprehensive research agenda.

In the resilience/infrastructure area the science is well integrated through the "all hazards" framework promoted by MCDEM and increasingly reflected in research contracts. The Department of Building and Housing also carries responsibility in this area. A critical need in some areas is improving the connection with end-users. MoRST is working with MCDEM (under the National Civil Defence Emergency Management Plan) and other agencies to establish "science clusters" in key natural hazard areas, such as tsunami, floods, earthquakes and volcanic eruptions. MCDEM is responsible for the national civil defence emergency management warning system, which takes input from research organisations to provide alerts of hazards events.

Knowledge needs

Urban research is not well developed in New Zealand. A key gap is a good understanding of what a world-class urban portfolio of research would look like in the New Zealand context. Some key urban research questions include:

- How can research on transport, energy, employment, health, housing, biodiversity and resource use be integrated into an effective knowledge platform that delivers useful and timely knowledge to planners and managers?
- How can water and biodiversity be sustainably managed in urban areas?
- What factors contribute to making urban areas vibrant, desirable and economically successful places to work and live?
- How can urban infrastructure be planned/adapted to meet the challenges of climate change?

Hazard research is well-developed in New Zealand and managers are increasingly benefiting from integration of that research. The main knowledge need is to better understand the impacts of climate change. In the area of weather-related hazards a fundamental shift in paradigm may be needed, from using the past to predict the future, to using modelling to predict the future. This shift will place significant demands on climate science. Tsunami is also an area where additional focus is needed.

Some key questions include:

- What will the extreme weather regime in New Zealand be over the next 50-100 years?
- How can New Zealand be better prepared for tsunami hazard?
- How can new buildings and infrastructure be made more resilient to a range of hazards?

Actions

- MoRST will work with the MfE, FRST and councils to scope world-class urban research which reflects national priorities/aspirations for sustainable development.
- MoRST and MCDEM, in conjunction with MfE, regional councils and science agencies, to lead a process for improving communication and connections between scientists and natural hazard managers with a focus on flooding, tsunami and land slipping.

5.4 Biosecurity

Scope of research area

Biosecurity is the exclusion, eradication or effective management of risks posed by pests and diseases to the economy, environment and human health[40]. The overall scope of this research area is very broad and covers terrestrial, freshwater and marine ecosystems. Biosecurity science draws on a wide range of disciplines. Relevant disciplines noted in the Biosecurity Science, Research and Technology Strategy include[41]:

- biochemistry[42], botany, ecology, entomology, nematology, zoology, mycology, molecular biology, taxonomy and diagnostics, biometry, bacteriology, virology, immunology, agronomy and animal husbandry;
- medicine and veterinary science;
- oceanography, meteorology and geology, economics;
- engineering, mathematics and physics;
- remote sensing, computer science and information technology;
- behavioural psychology and market research; and
- Mātauranga Māori.

Biosecurity is an area where disciplines from different areas need to be pulled together at very short notice, sometimes in completely new ways. For example, in a foot and mouth disease scenario, air quality modelling is crucial for predicting where the virus could spread to and could have come from.

Capabilities

Increasingly, research is being focused on shifting risks offshore and preventing entry of pests and diseases. Scientific research in biosecurity is used to:

- recognise and understand risk vectors and pathways;
- develop the tools and methods to detect, identify and eliminate unwanted organisms before they reach New Zealand, or at the border;
- develop improved surveillance technologies which involve industry and the general public, and which are directed towards pests and diseases where there is potential for early detection and eradication;

[40] Biosecurity Strategy for New Zealand (2003).

[41] Page 5, Draft Biosecurity Science, Research and Technology Strategy for New Zealand (2006).

[42] Biosecurity science covers parts of Biotechnology research and this is an area of cross-over between the Biotechnology and Environment Research Roadmaps.

[43] http://www.biosecurity.govt.nz/science-strategy in draft at the time of writing this Roadmap.

- develop sustainable tools for pest management using cost-effective and socially, culturally and environmentally acceptable technologies; and
- support our export sector by providing authoritative information on New Zealand's status with regard to pests and diseases.

Biosecurity New Zealand is responsible for co-ordinating biosecurity science to effectively harness capability that lies across the science disciplines and focus it on biosecurity. The Biosecurity Science, Research and Technology Strategy[43] provides a framework for co-ordinating science capability in the biosecurity area. The draft Strategy highlights current biosecurity research needs, areas where biosecurity science delivery and uptake need to be improved, and the need to plan and maintain core science capabilities to ensure a timely and effective response to incursions. It also calls for an effective risk-based priority setting process, which includes end-users, funders and research organisations.

Funding

Defining funding for biosecurity science is complex because of the range of disciplines that can contribute to biosecurity research. Annual funding is around $12 million, using a tight definition of environmental biosecurity and acknowledging that a substantial amount of pest control research is funded through the biodiversity area.

Issues

Biosecurity is a key issue in the protection of New Zealand's social, cultural, economic and environmental values. Biosecurity pressures are growing substantially with the increased volume and globalisation of trade and travel. Climate change is also expected to add to this pressure – potentially creating more suitable habitats in New Zealand for a greater range of pest and pathogen species or vectors.

In addition to this, biosecurity is a substantial area for negotiation in international trade, and New Zealand still has valuable pest-free status regarding many species of concern to our trading partners. It is important that New Zealand retains these significant trade advantages for exporters of primary produce.

Controlling existing pests and diseases/pathogens throughout terrestrial, freshwater and marine ecosystems is a costly burden on the New Zealand economy. It has impacts on agriculture, horticulture, forestry, aquaculture, fisheries, the conservation estate and amenity areas.

As outlined above, a range of capabilities from across the science sector are required to address biosecurity issues. The multidisciplinary and unpredictable nature of biosecurity poses some challenges for the science system, for which there are no easy solutions.
These include:

- The degree to which a science "standing army" is needed that can be called upon at short notice to focus on an incursion.
- When to start research programmes into new pests or scale down biosecurity research programmes on existing pests and diseases when knowledge is sufficient or the problem is deemed intractable.
- The species identification area, which is critical to biosecurity. Establishing the quantum and nature of taxonomic capability needed is particularly challenging and advancement of new molecular tools can make this area ever more complex.
- How to get support for capabilities in funding rounds that, on the face of it, have very little connection with biosecurity. For example, air quality science is a key capability for biosecurity (it would be used in any foot and mouth disease outbreak and is used to model the dispersion of moths), but is currently funded as part of the urban research area, with a human health focus.

Links to key themes in Chapter 4

Biosecurity science covers a range of disciplines that can be brought together in different ways and at different times, often in response to an incursion. Greater focus is needed on how capabilities are integrated, defining "core" capabilities and a strategy to help guide how capability is organised. The Biosecurity Science Strategy aims to improve integration and focus on strategic priorities. Connections with users are generally good. Improvements are needed in the data management area, particularly in the development of sensing tools to assist with surveillance.

Knowledge needs

Priority setting for new technologies, and operations to exclude exotic pests from New Zealand, requires knowledge of risk species, their potential entry pathways and impacts on New Zealand's natural and productive ecosystems. Post-border, priority setting depends on the relative impact levels of pests, and opportunities for and costs of their eradication or management.

Some key questions include:

- How can potential pests be identified, prioritised and systems put in place to keep them out?
- What impact will climate change have on biosecurity and how can this impact be effectively managed?
- How can pests and pathogens be effectively detected pre-border and in the EEZ?
- How can pests and pathogens that make it across the border or into the EEZ be detected and eradicated before they become well established?

Actions

- FRST and research organisations take account of the Biosecurity Science, Research and Technology Strategy.
- FRST and research organisations ensure that capabilities that are critical to biosecurity are effectively maintained.
- Biosecurity New Zealand plays a key co-ordinating role in biosecurity research.

5.5 Biodiversity

Scope of research area

Biodiversity covered in this section includes terrestrial, freshwater, estuarine and coastal marine (oceanic marine biodiversity is included in the oceanic systems research area under 5.6). The areas of research include:

- Identifying what we have in terms of species and understanding the flora and fauna and ecosystems;
- The types of ecosystems and processes that drive them and influence their integrity;
- How ecosystems have evolved and factors affecting ecosystems, such as glaciation, eruptions and changes in sea levels; and
- Understanding the threats to biodiversity and how to manage these. The impacts of pests/pathogens and ways to manage these is a significant part of biodiversity research in New Zealand.

Science in the terrestrial area has evolved over time from describing biodiversity, to understanding how indigenous biodiversity is declining, to focusing on how to halt the decline. There is also a move from a single species focus to large-scale modelling of terrestrial-freshwater ecosystems and understanding interactions between pests, pathogens and biodiversity. Terrestrial research has also expanded in the biotechnology area with the search for more effective toxins and ways to disrupt pests breeding.

Capabilities

In 2001, the government published the Biodiversity Strategy which sets out a twenty year vision for biodiversity management. The strategy aims to firstly halt biodiversity loss and in time reverse the decline. It recognises New Zealand's international obligations, the value New Zealanders place on natural heritage, and the economic importance of nature tourism[44].

[44] The *New Zealand Tourism Strategy 2001* has, as its first goal, 'Environmental Protection: to recognise the value of the natural environment and actively protect, support and promote its sustainability'.

The 2006 five-year review of the Biodiversity Strategy[45] identified significant progress in the restoration of offshore and mainland island sites, pest eradication, intensive species management, marine reserves, weed control, biosecurity, the establishment of funding and assistance for private and community groups involved in biodiversity restoration, and work with and by Māori. The review also identified significant challenges, notably the difficulty of tracking how New Zealand's native species are doing, and the complexities of how and where to expand the number of natural areas and species under intensive management on public and private land.

Science has played a key role in helping to document changes in terrestrial biodiversity and understand the causes of it. For example, as a result of terrestrial research the role of pests in biodiversity decline is now well understood. Much harder questions are now being asked of science about effective ways to control pests. In the future, science may deliver new and more effective pest control techniques. Without more effective techniques, terrestrial biodiversity loss is likely to continue.

Science capabilities in coastal marine biodiversity are critical to helping New Zealand achieve long-term goals relating to sustainability of coastal marine production systems. Coastal marine and estuarine biodiversity is an area where integration of terrestrial, freshwater and marine sciences is essential to inform marine biodiversity management decision such as the development of coastal marine protected areas.

Some good progress is being made in the biodiversity area as a consequence of science investments and use of science capability. For example:

- Possum control operations can now virtually eliminate possums over areas as large as 100,000 ha due to a combination of improved control techniques and improved understanding of the behaviour of possums.
- Some critically endangered bird species, such as kakapo, are increasing in numbers.
- Different interventions have been designed for different species and locations, such as kiwi, where eggs are removed, hatched, the chicks raised and then released into the environment when they are big enough to defend themselves against predators.
- "Mainland Islands" have been successful experiments and have provided laboratories for understanding the impacts of pests on ecosystems and how to manage these.
- New Zealand leads the world in eradicating pests from islands. The eradication of rats from the 11,000 ha Campbell Island, for example, was a significant achievement by international standards.
- There are now 28 marine reserves established in New Zealand coastal waters. Collectively, the reserves protect 7.6% of New Zealand's territorial sea.
- By integrating the roles of primary and secondary production, biodiversity and connectivity across coastal habitats, there is now improved knowledge of New Zealand rocky reef ecosystems and functions.

DoC, Biosecurity NZ, MFish, regional councils and the Animal Health Board (AHB) all draw on biodiversity science capabilities. For example, scientists are closely involved with some DoC and AHB pest control and DoC ecological restoration programmes.

Funding

At present, about $19 million is invested annually on biodiversity research, through Vote RS&T. Much of this is for long-term Outcome Based Investments (OBIs). Funding in this area also includes around $0.4 million for coastal marine biodiversity[46] and $4 million for biodiversity-related databases and collections.

Issues

Challenges in the area of biodiversity are regarded as New Zealand's largest environmental challenge in the State of the Environment Report (1996). The main challenges are due to introduced pathogens and pests, such as possums, goats, stoats, rats, aquatic weeds and pest fish species. Without effective management, much of New Zealand's terrestrial, freshwater, estuarine and

[45] http://www.doc.govt.nz/templates/MultiPageDocumentTOC.aspx?id=42598

[46] Some coastal biosecurity research also covers aspects of coastal marine biodiversity.

coastal marine ecosystems will be severely degraded[47] resulting in biodiversity loss. Another ongoing challenge is loss and modification of habitat, such as drainage of wetlands, urbanisation and extractive use.

Climate variability and trends influence biodiversity processes and the impacts of pests and weeds on biodiversity. There is a need for biodiversity research to take account of temporal climate variability.

An ongoing issue for biodiversity science is the balance of resources on description and understanding versus ways to improve biodiversity. The resources put into biosystematics, for example, are limited and the question is how to make those resources most effective in assisting with meeting the biodiversity challenge. This is also a significant issue for the biosecurity area.

Links to key themes in Chapter 4

Terrestrial biodiversity science is making good progress towards more integrated research programmes. For example, the impacts of multiple pests on terrestrial biodiversity are now being addressed. Good connections also exist between conservation managers and scientists. For example, operational programmes are being used to test new techniques, increase understanding of ecological processes and to pilot better ways to manage threats. This thinking now needs to be extended to estuarine and coastal marine biodiversity which can be badly affected by pests/pathogens, land-use patterns, habitat modification and extractive use.

Monitoring and data collection are difficult and costly areas for biodiversity science and improvements in technologies and techniques would enhance progress in this area.

Knowledge needs

Important knowledge needs and capabilities that need to be maintained in this area are:

- Understanding core natural processes in terrestrial, freshwater, estuarine and coastal marine ecosystems.
- Understanding impacts of habitat fragmentation, extractive use of resources and urbanisation etc.
- Understanding pest/pathogen dynamics, for example, capabilities to understand and model key drivers such as masting events[48].
- Modelling capabilities that enable pests/pathogens and ecosystems to be modelled over both large areas (for example, 100,000 ha) and long time scales (for example, decades/centuries).
- Understanding pests/pathogens in aquatic ecosystems, both in running freshwaters, lakes and coastal marine. This capability proved very useful, for example, when Didymo was discovered in New Zealand.

Some key questions that managers are seeking advice on are:

- How can a suite of pests/pathogens be controlled over large areas simultaneously and cost-effectively to maintain important populations?
- What are the optimal times and ways to control pests/pathogens in forest ecosystems to maintain basic forest structure?
- How can pest aquatic weeds and fish best be controlled and prevented from spreading?
- How do we predict more accurately the consequences of resource management decisions for freshwater, estuarine and coastal marine biodiversity?
- How can estuary and coastal marine biodiversity be protected from further degradation?

Actions

- MoRST, FRST, researchers and relevant management agencies (for example, DoC and Biosecurity NZ) work to identify taxonomy needs for New Zealand in the terrestrial and freshwater biodiversity areas.
- Identify coastal marine biodiversity science needs, as part of the proposed marine science strategy, to be explored by MFish and MoRST (refer to action Oceanic Systems section 5.6 below.)

[47] Tall forests will over time be replaced by unpalatable mostly shrubby species. Evidence of this change has been studied in some parts of the North Island, such as in the Kaweka and Ruahine Ranges.

[48] Masting events are when trees like beech and rimu have heavy seeding. Following these events scientists have learned that pest species increase significantly in response to increase food supplies. When the food supply runs out pests tend to focus on native birds, with severe impacts on some remaining populations.

5.6 Oceanic systems

Scope of research area

Oceanic or offshore marine systems science covers the following areas:

- biological and chemical oceanography – the study of marine life, biodiversity, nutrient dynamics, production and ecosystem functioning;
- physical oceanography – better understanding currents, water mass properties etc and how these might be impacted by climate change;
- geology – the effects of earthquakes and tsunamis;
- mineralogy – the processes leading to formation of mineral and hydrocarbon resources; and
- extraction – extractive resource uses such as fisheries, minerals, hydrocarbons etc.

Capabilities

Oceanic systems science draws heavily on capabilities in the global environmental change area – building on the understanding gained on atmospheric, oceanic and earth processes. For example, fisheries research connects with climate science.

New Zealand's emerging knowledge and expertise in temperate oceanic ecosystems has been built largely in collaboration with international science agencies. The significance of these collaborative relationships means it is important that New Zealand maintains capability in this area.

Oceanic marine production and ecosystems research provides important underpinning for New Zealand's fisheries management. A substantial proportion of New Zealand's oceanic marine funding goes into these areas, with some marine research investment in earth/oceans processes.

Databases are an important capability in this area. Data collection in the oceanic marine environment is difficult and costly, requiring good targeting. Sometimes this can be done by developing ideas and research approaches in more tractable coastal habitats before committing expensive ship time to the problem, bearing in mind that oceanic systems may be affected by different drivers than coastal systems.

Environmental managers rely on the science system to provide long-term and wide-scale environmental datasets. Likewise, integration and modelling are important. To assist environmental managers, capability is needed to build and maintain large-scale models of oceanic marine ecosystems, encompassing the subsurface, seafloor, water column and atmosphere.

Oceanic marine systems science is very much at the stage of exploration, mapping and forming basic understanding. The formulation of high-level questions/goals and capabilities in design and transfer are crucial components at the current stage of marine science development.

A key factor to take into account in the future in the oceans area will be progress on, and results from, Oceans Survey 20/20. This is a government initiative to survey waters within New Zealand jurisdiction to improve New Zealand's base information of the marine area. It has been established because existing information mostly falls short of what is required to meet New Zealand's oceans interests and responsibilities. Ocean Survey 20/20 could be relevant for minerals exploration, biodiversity, fisheries, maritime safety, oceanographic science (including geological hazards), environmental protection, conservation, resource management, recreation and tourism. The data gathered could underpin future ecosystem modelling with a view to enable predictions for management purposes, while at the same time helping identify knowledge gaps and direct research priorities.

With greater volumes of satellite data becoming available, advances in technology now give us the means to bring together a wealth and diversity of data, so we can build the more complete picture of New Zealand's marine environment.

Funding

In 2005/06, approximately $6 million public good science funding was expended on oceanic systems research. Some of the research funding in this area is used to support databases and collections. Oceanic systems research tends to be more expensive than research in the terrestrial or freshwater area because ships are often needed and these are expensive to operate.

Issues

New Zealand has the world's fourth largest EEZ and extracts significant economic returns from the sea. The commercial fishing industry earns about $1.1 billion per annum in exports and is the fifth largest export[49] industry in New Zealand. Aquaculture provides exports of over $200 million per annum and is further expanding. Hydrocarbon and mineral exploration is underway in parts of the EEZ. The economic return is potentially high if new resources are confirmed. New fields of commercial interest include bio-prospecting and mineral extraction.

There is a growing need to understand the impacts on oceanic ecosystem functioning and integrity of commercial fishing, aquaculture, mineral and oil exploitation. In the fisheries area, for example, the focus to date has been on single species approaches in data gathering and modelling. Consequently, the ecosystem-level effects of fishing are not well understood. Equally, we have limited understanding of critical habitats, biodiversity hot-spots, the impact of introduced pests and pathogens, and the distribution of marine habitats. This has the effect of slowing attempts to classify the oceanic marine environment and develop and implement government's target of a 10% marine protected areas network throughout the EEZ by 2010[50].

Oceanic marine systems research is starting to tend towards a stronger focus on ecosystem processes, habitat distribution and structuring, and the connectivity between species and systems. However, there is a paucity of systems understanding compared to other environment areas such as terrestrial biodiversity and sustainable use. Better oceanic marine ecosystem knowledge is crucial for creating the right knowledge platform to enable and support the use of adaptive marine management approaches.

A key requirement for enhancing systems understanding is targeted data gathering. Existing information has been acquired at different times for a range of diverse scientific, resource management or business purposes. It is highly variable in its specification and quality, is fragmented and incomplete in its coverage, and is often inaccessible to those who need it.

The oceanic environment is a source of natural hazards with landslides and earthquakes potentially causing tsunamis. Emerging sonar technology is beginning to enable some of these hazards to be more clearly identified and understood.

An additional threat is climate change and its impact on the oceanic marine environment. The consequences of changes to ocean acidity, currents and primary production are not well understood but could significantly affect fisheries, aquaculture and marine biodiversity.

Links to key themes in Chapter 4

A combination of significant knowledge gaps and an evolving policy environment means that it is difficult to set a clear strategy for marine science. Greater effort is needed on ecosystems, that is, more integrated science. Greater effort is needed to identify the key questions in the marine environment within an ecosystems framework.

Connections with users are patchy, in part due to the knowledge in this area being still in the early stages of development, compared with other areas of science.

Oceans Survey 20/20 should result in improved datasets for the marine area and improved data management and is a key vehicle for driving marine data management forward.

[49] Ministry of Fisheries (2006), *Statement of Intent for the period July 2006 to June 2011*.

[50] Marine Protected Areas Policy and Implementation Plan (2005).

Knowledge needs

New Zealand has a range of knowledge requirements and capabilities that need to be maintained in the oceanic marine systems area. These include:

- ecosystem-level impacts of fishing, that is, the impacts of fishing one stock on other stocks and on marine biodiversity generally;
- mineral and hydrocarbon resources and processes leading to their formation and location;
- understanding of our current oceanic marine biodiversity and what the critical threats are;
- functioning of oceanic marine ecosystem processes to underpin management of human uses of the ocean; and
- natural hazard sources in the oceanic marine environment.

Some key question that managers are seeking advice on are:

- How can fisheries be managed on an ecosystems basis?
- What are the broader ecosystem-level effects of different resource uses?
- Where are New Zealand's mineral and hydrocarbon deposits likely to be found?
- What are the oceanic marine-based natural hazard processes and what threats do they pose?

Actions

- FRST to ensure that core oceanic systems capabilities in the global environmental change area are effectively maintained, given this area underpins core aspects of oceanic systems science.
- MFish and MoRST to explore whether a marine science strategy should be prepared and the timing for developing this.

5.7 Priorities

Working with key government departments and research organisations throughout 2006, priorities for the next three to five years and the subsequent three to five year period by environment research area were identified.

Looking across the six environmental areas and considering current funding, recent trends in funding and capabilities, risks and needs, the following are priority areas for additional focus over the next three to five years:

- **Global environmental change** – reflecting the growing importance of this issue, increasing demand for science in this area and that funding has been static since 1998;
- **Land, water and coasts** – with a focus on better integrating research and more effective delivery of tools for managers, better ways to manage nutrients and a focus on water resource management;
- **Urban design and hazards** – reflecting the pressures in urban environments and the limited knowledge-base New Zealand presently has in this area; and
- **Biosecurity** – to reflect the directions set in the Biosecurity Research Strategy.

Priorities for the following three to five years are:

- **Biodiversity** – reflecting that the OBIs will take time to clearly identify priorities and there has been growth in this area in recent years.
- **Oceanic systems** – which should enable science to leverage off the datasets collected through OS20/20, and allow for more substantive analysis and understanding of oceanic systems. In turn, this should lead to the development of tools and resources for resource managers.

Roadmap directions

Direction 4

Over the next few years, the government will give priority to developing more integrated multidisciplinary approaches, and to improving transfer, uptake and information systems in the following areas:

- global environmental change – with a focus on providing the knowledge for integrated ecological, physical and socio-economic modelling of climate change impacts on water and soil resources, land use, biosecurity, biodiversity and potential global impacts;
- land, water and coasts – with a focus on sustainable land and coastal aquatic use, including the impacts of land use on freshwater and the impacts of freshwater, land management and aquatic production on coastal marine environments;
- urban design and hazards – focusing on defining a world-class urban research programme which reflects national priorities/aspirations for sustainable urban development and improving connections between scientists and management agencies in certain hazards research areas; and
- biosecurity – reflecting the directions set in the Biosecurity Science Research and Technology Strategy.

Direction 5

Over the longer-term, the government will focus on more integrated multidisciplinary approaches, and improved transfer and uptake, and information systems in the biodiversity and oceanic systems areas.

6 Roadmap implementation

6.1 Putting the Roadmap in place

This Roadmap has been approved by the Minister of Research, Science and Technology who will retain stewardship of the Roadmap and, supported by MoRST, will ensure that the directions are communicated and actions taken where appropriate. MoRST will maintain oversight of the Roadmap, advising the Minister of Research, Science and Technology on the progress of implementation as well as the ongoing relevance of its directions.

The Minister of Research, Science and Technology will instruct FRST, Marsden and the HRC to take account of the relevant directions in the Roadmap in their future investment decisions. MoRST will work with FRST and other agencies to develop an implementation plan. Key components of the implementation plan will include MoRST:

- analysing barriers and opportunities for implementing roadmap directions as signalled in roadmap actions;
- identifying any adjustments needed within the science system or other areas to ensure environmental research priorities are addressed in an integrated fashion;
- working with relevant agencies to identify priority frameworks for the environmental research areas, including continuing work with MfE on climate change science priorities, freshwater science priorities and implementing the biosecurity research strategy with Biosecurity New Zealand; and
- using this roadmap to inform is RS&T investment strategy.

The Minister of Research, Science and Technology will encourage organisations in the wider science system to take account of the directions in the Roadmap. MoRST will maintain leadership for co-ordinating policy development and strategic activity to ensure responsible management and development of environmental research in New Zealand.

This Roadmap is expected to remain current for five to ten years. It is, however, inevitable that unforeseen developments and events will occur and that some of these may in time alter the outlook of the Roadmap. The Minister of Research, Science and Technology will consider the need for an update to the Environmental Research Roadmap by 2011.

6.2 Expected benefits

The overall benefits resulting from the Environment roadmap directions will be increased systems science and integrated multidisciplinary programmes, and improved end-user connections and information systems. The aspirations for environmental research signalled in this Roadmap include:

Enhanced innovation for new business opportunities – Strengthened expertise in environmental sensing technologies and environmental ICT could establish New Zealand as a test bed and world leader for new innovations and business developments in environmental technologies.

Tailor-made information systems for enhanced productivity and value – Improved measuring and monitoring of environmental trends will enable greater precision in resource use, new markets to be developed for trading in ecosystem services, and greater delivery of information to customers and trade partners to enhance brands and protect exporters from non-tariff trade barriers.

Improved predictive capacity – Large-scale integrated modelling and monitoring will lead to continually improving predictive capacity for climate change and natural hazard events and their impacts leading to a more informed and prepared society.

Improved adaptive capacity – Improved supply of predictive information and particularly improved integration of biophysical and socio-economic modelling will keep communities, cities, and businesses well informed and able to adapt to future environmental change.

Improved understanding of, and compatibility with, natural system designs – Improved knowledge of factors contributing to resilience, productivity and efficiency of the environment can help primary producers avoid costs, increase productivity and protect natural capital.

Addressing larger more complex issues – Moving to multidisciplinary, large-scale, holistic environmental research will provide understanding and decision support tools for more complex environmental management questions. This increased knowledge will enable managers to avoid, remedy or mitigate future environmental problems more effectively than they are dealt with currently.

Improved responsiveness and affordability of science – An increased focus on solutions – orientated science will mean councils and managers will have better access to management tools.

Effectively sharing knowledge – Visual display of modelling simulations and interactive scenarios will develop into more powerful tools for building shared understanding of the environment and appreciation of trade-offs within multiple values, objectives and consequences of actions. Better informed policy makers, environmental managers and communities will be able to work closely with scientists in a positive feedback loop. These improved connections will help enhance the quality of decision-support tools, technology and policy design.

Synergy, cohesion and motivation – Larger linked research teams that regularly review their progress together are expected to deliver synergy from collaboration, cohesion from a shared sense of purpose and motivation from peer recognition and encouragement. All these factors will improve the outputs from RS&T funds and enable greater returns from limited resources.

Annex I

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Annex 2

Foundation portfolios and target outcomes incorporating environmental research

New Economy Research Fund	Target Outcomes
NZS: Technologies to Leverage New Zealand Strengths	1. Economy diversified through opportunities that leverage New Zealand's strengths
Research For Industry	
PQA: Production, Quality and Assurance	1. Market access and consumer acceptability 2. Cost effectiveness
SPS: Sustainable Production Systems	1. Environmentally, economically and socially sustainable primary production 2. Existing and new pest threats managed
NPB: Niche Biological Products and Services	1. Higher value non-food biological products and services
MAN: High Value Manufacturing Processes, Products and Materials	1. Improved productivity and international competitiveness of New Zealand's manufacturing sector
OPI: Optimising Physical Resource Use and Infrastructure Services	1. Improved energy management and supply 2. Wealth for New Zealand's natural resources 3. Improved infrastructure; transport, water, waste and design
RIC: Resilient Infrastructure and Communities	1. Informed management of economic, infrastructural, social, political and other public risks
SER: Building Knowledge Intensive Service Industries	1. Increase benefits from international visitors, creative industries and information and communication technologies
SET: Sustaining New Zealand's Economic Technological Development	1. Improved well-being for New Zealanders through sustainable development of the economy and and technologies
Environmental Research Fund	
ECO: Resilient, Functioning and Restored Natural Ecosystems	1. Defining New Zealand's biota 2. Restoring the decline in New Zealand's indigenous biodiversity 3. Biosecurity – incursion management 4. Biosecurity – management of existing pests 5. Southern oceans 6. Ecosystem-based sustainable resource use
SRU: Managing Environmental Integrity for Sustainable Resources Use	1. Environmental integrity and sustained resources 2. Facilitating a shift in personal, community and society understanding and values
SCS: Building Sustainable Cities and Settlements	1. Cities and settlements that provide positive and sustainable social, cultural, economic environments
GLO: Understanding and Adapting to Global Environmental and Earth Processes Change	1. Causes and consequences of mitigation and adaptive responses to global change
Māori Knowledge and Development Research Fund	
TTW: Te Tupu o te Wananga (the growth of knowledge exploration)	1. Development of research capability aligned to FRST's Māori specific research themes and priorities

Annex 3

Definition of terms

Earth science – the study of earth including, geology, hydrology, meteorology, oceanography, physical geography, and soil science.

Earth system – the whole planetary system and all its components and interactions.

Environmental science – study of interactions among the physical, chemical and biological components of the environment. Includes the earth sciences, environmental chemistry, biogeochemistry, atmospheric sciences and ecology.

Ecology – study of the interrelationships of life and the environment.

Ecosystem – a dynamic complex of plant, animal (including humans) and micro organism communities and the nonliving environment interacting as a functional unit. Includes those relatively undisturbed ecosystems, such as natural forests, to landscapes with mixed patterns of human use, to ecosystems intensively managed and modified by humans, such as agricultural land and urban areas.

Ecosystem services and the benefits people obtain from ecosystems. These include provisioning services such as food, timber, water and fibre; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, ad spiritual benefits; and supporting services such as soil formation, photosynthesis and nutrient cycling.

Environmental technology is the application of environmental sciences to conserve the natural environment and resources, and curb the negative impacts of human activities. Examples are recycling, water purification, sewerage treatment, contaminated site remediation, flue gas treatment, solid waste management, renewable or clean energy, and energy conservation.

Informatics includes the science of information and the practice of information processing. Informatics studies the structure, behavior, and interactions of natural and artificial systems that store, process and communicate information. It also develops its own conceptual and theoretical foundations. Since computers, individuals and organisations all process information, informatics has computational, cognitive and social aspects.

Integration – the combination of parts into a whole in an appropriate way such that the resultant combination is satisfactorily fit for purpose.

Natural science – the use of scientific methods in the study of the natural world. Mathematics, statistics and computer science are not natural sciences but provide many tools and frameworks used with the natural sciences.

Modelling – the development of models which are descriptions of something which can be used to make predictions that can be tested by experiment or observation.

Social science – the use of scientific methods in the study of human behaviour and societies.

Sustainability – the sustaining (preservation or enhancement) over time of some valuable or valued condition(s) in a selected dynamic system.

ROADMAPS for SCIENCE

Ministry of Research, Science and Technology ISBN : 0-478-06150-1 Publication date : May 2007