Missing Links:

Connecting science with environmental policy

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Parliamentary Commissioner for the Environment
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Preface

> ***Most of us have begun to see the party is over. The planet is in deep trouble; we had better concentrate on bailing it out... The discrepancy between image and fact is growing too wide to be tolerated. For general sanity we need all the help we can get from our scientists in reaching a more realistic attitude to the physical world we live in.[1]***

These are the closing words of an insightful critique of science and scientists in our society written over a decade ago by Mary Midgley, a philosopher. These remarks are cited because after 224 pages of examining science, scientists and society's relationship with science, Midgley concludes with the view that, despite the many value constructs that swirl around a nation's science, including scientists' influence in and contribution to society, science is essential if we are to learn to live within our planet's physical limits.

My team and I agree with Midgley - hence our investment in this examination of environmental science/policy interactions. It is one thing to recognise the need for extensive science-derived knowledge to ensure effective environmental policy and decision-making. However, it is much more difficult to determine all the 'influences' that ensure this is the case. In this study what we have attempted to do is examine the *how* and *by whom* science and research is being done rather than just what is being done. We are interested in the issues that are driving science investment, the relationships between scientists and policy makers and, most importantly, how environmental policy and decision makers are blending the knowledge they need from a range of sources. In short, we focused on the social, political and economic constructs and institutions that shape the way we craft environmental policy and decision-making.

So why the specific focus on the importance of science as a pivotal knowledge input to environmental policy? It is largely because, increasingly, solutions to environmental issues and the development of environmentally sustainable ways of meeting society's needs and wants necessitates greater understanding of very complex ecological systems, often over long time frames. These two ingredients - complexity and long time frames - do not fit comfortably with many current human, societal, economic and governance constructs. Hence great tensions develop around what should be done, how and who pays (in today's society, but also which generation) with the result that appropriate policy responses are often glacially slow. The current controversies about what to do about the decline of water quality in the Rotorua Lakes is a local example. The manner in which nations respond to climate change is a global one. The need for policies and actions has been evident in both cases, particularly the Rotorua lakes, for many years.

One of the greatest challenges in applying science/research to environmental matters is that it invariably involves many pieces of science from a wide range of disciplines. Evidence that we need to modify our use of natural resources and our impacts on some ecosystems almost always builds up from many pieces of research. The need for action is often derived from consistent trends in a number of environmental parameters rather than one definitive ‘proof’. While this is an accepted reality by those involved in environmental research it frequently proves to be a stumbling block when it comes to using such knowledge in environmental policy-making. This is because of questions relating to how much knowledge or how strong a trend, or trends, is justification for action.

This dilemma is at the core of the concept of the precautionary principle, enshrined in environmental policy thinking by the Bruntland Report, *Our Common Future*, and subsequently at the Earth Summit 1992 and in Agenda 21. While the precautionary principle is essential to effective environmental management and policy, achieving a political and hence policy mandate to apply it is proving difficult.

In New Zealand we need look no further than the enormous debates around the use of genetic modification. One spectrum of submitters to the Royal Commission on Genetic Modification talked about the precautionary principle, or presented arguments based on scientific knowledge that supported a precautionary approach. Others presented arguments, supported by science, against undue precaution. In simplistic terms the main differences between the two groups of submitters were the time frames they were working in, the breadth of societal knowledge they were drawing from, and their beliefs about how risks and benefits would be shared across society. Those that were advancing the precautionary principle were doing so from a belief in the need to learn from history, make projections well into the future and draw from many forms of contemporary knowledge. Those that were arguing for less precaution were generally drawing from a narrower worldview and fewer forms of contemporary knowledge. Relatively short-term economic interests were central drivers to such arguments.

The debates around the application of genetic modification are just the latest in a long history of debate about the risks and benefits of applying scientific knowledge and technology. Along with other examples we have outlined in *Missing Links*, this example highlights the need to continually reassess our science-policy-society links, relationships and communication between parties. We believe the way these links are formed and maintained are crucial areas for study. The types of institutions that can assist the flow of information and knowledge between scientists, policy makers and society appear to be essential to progress. We explore the nature of such institutions, which I believe deserve much more focus and evaluation.

Finally, we conclude with some recommendations aimed at forging better links and improving processes to deal with complex environmental policy issues. Those recommendations to the Ministers of Environment and Research Science and Technology focus on the importance of regular monitoring of the state of our environment, and reviewing the adequacy of science and technological capacities in central and local government environmental policy-making agencies.

We trust that this contribution will stimulate thinking and further dialogue around environmental policy and decision-making and our current capacities to deliver good policies.

As always we welcome feedback.

J Morgan Williams

Dr J Morgan Williams
Parliamentary Commissioner for the Environment

Executive summary

> *For every human problem, there is a neat, simple solution; and it is always wrong.*[2]

Environmental policy-making is a function that imposes many demands, expectations, pressures and responsibilities on central and local government decision makers. There will be demands for neat, simple solutions, and expectations that these will provide security and certainty for all interested parties. There will be pressures to process policies and decisions with the minimum of delay and cost. Statutory responsibilities of environmental policy makers require them to consider a wide range of interests when making decisions. They have to deal with complex issues that reveal limitations in our knowledge and understanding of natural systems, and uncertainty about the extent of human impacts on those systems now and in the future.

Complexity and uncertainty have implications for deciding what scientific research needs to be undertaken, how science informs policy, and how policy makers respond to both scientific information and public concerns. These factors also affect the way in which scientists and policy makers interact, and how they both interact with the public.

This report focuses on complex issues that face environmental policy makers, and analyses ways in which science, research and technology can be used more effectively to address such issues. In doing so, it examines how the links between science, policy-making and the public interest can be strengthened to engender confidence in the way policies are developed and what they will achieve.

The report begins by identifying our target audience – environmental policy makers. It describes the science-policy interface and the various sources of knowledge that contribute to policy-making. Next we explore different ways of dealing with complex problems. The old Indian fable of the four blind men needing to share their individual perspectives of an elephant to get an overall picture of it, is used to illustrate how single perspectives of specific scientific disciplines, worldviews and stakeholder interests can lead to only partial solutions. Today's complex environmental issues require research to be more integrative across scales of time and space, and be more open to exploring the social dimensions of the issues. In addition, for scientific information to be effective in influencing environmental policy, it must be credible, salient and legitimate. In other words, the information must be scientifically accurate and technically believable, relevant to the needs of policy and decision makers, and result from a process that is procedurally unbiased and fair.

Matching scientific research to the decision needs of policy makers involves getting the 'right' science done, which is a matter of asking the 'right' questions, and using the resulting information to shape policies that are supported by stakeholders.

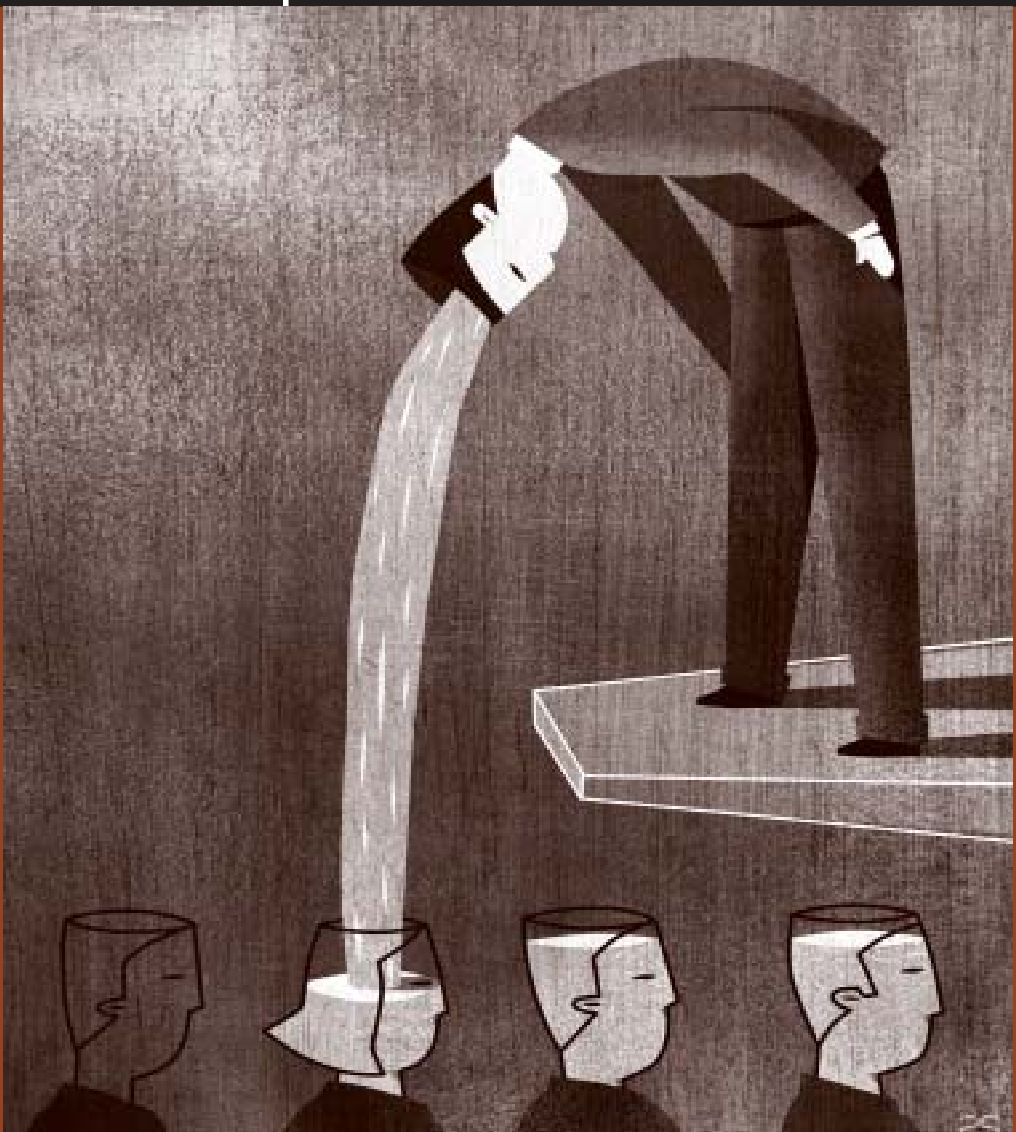
Characteristics and examples are given of organisations that have successfully used science to examine and resolve complex environmental policy issues.

We highlight some approaches to improving science-policy-stakeholder links, relationships and communication. Approaches such as adaptive management, integrating scientific perspectives, participatory and learning systems in the policy cycle, and the role of 'boundary organisations' are explored.

We conclude with suggestions for forging better links and developing better processes to deal with complex environmental policy issues. Recommendations for further action are directed towards environmental policy makers in general, and the Minister for the Environment and the Minister of Research, Science and Technology in particular.

CHAPTER 1

Introduction and background



1.1 Introduction - a sequence of questions

> ***Much of the most innovative and profound thinking about research and science for policy is emerging in the areas of environmental science and health sciences.*[1]**

This inquiry started with two assumptions and a question. The first assumption was that environmental management that leads to sustainable environmental outcomes requires a coherent framework of well-considered, effective, environmental policies. The second assumption was that scientific knowledge and research are important inputs to developing environmental policy, especially as issues become more complex and the need to understand the consequences for the environment of policy choices becomes critical.

This led to our initial question:

> What is the role that science and research play in environmental policy and decision-making, particularly in meeting the challenges of sustainable development?

In the process of exploring this question through a discussion paper, *Illuminated or blinded by science*?[2] and the analysis of submissions on that discussion paper,[3] we recognised that a number of other issues were raised, some of which we decided not to investigate at this time (see section 1.3.1). We also realised that our initial question was a simple one for a much more complex problem. As a result, the focus of our inquiries shifted and broadened. Having first determined that science is important for improving our understanding of complex environmental issues, we decided to explore the following:

> How can science provide useful solutions for complex environmental problems?

This involved examining ways in which scientists and policy makers interact and respond to the challenges of complexity, uncertainty and risk. In doing this, it became clear that there are implications for the ways in which complex science and research is undertaken and how it contributes to environmental policy-making. These are important issues for policy makers (defined in section 2.1) to be aware of and to understand how their decisions may impact on ecosystems, people and the physical environment.

However, this addresses only half the problem. Environmental policy-making is rarely determined only on the basis of scientific advice. Although policy makers need effective, reliable and relevant scientific information, they also need to consider other factors - information and values that come from stakeholders and communities, the political contexts and the expectations of various sectors of society.

This led to the second part of our inquiry:

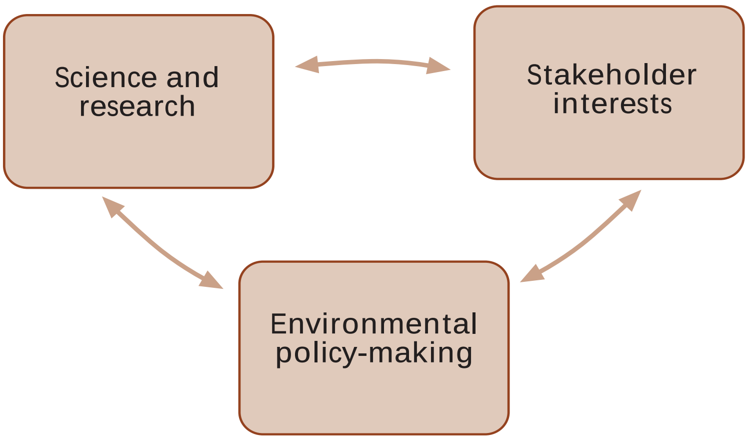
> How can more effective use be made of scientific information in the environmental policy-making process?

This raised a further question:

> How can institutional and attitudinal barriers to improving the interface between scientists, environmental policy makers and other stakeholders who have interests in environmental policies and their outcomes be overcome?

This report shows that the relationships and interfaces in an idealised diagram (see figure 1) are, in reality, more complicated. In some cases some links are strong while others are weak. In other circumstances, the relationships are constrained by systems that do not encourage knowledge sharing and learning. Such systems are inappropriate for the sort of sustainability challenges that New Zealand faces today and in the future.

Figure 1: The science-policy-stakeholder interfaces



In exploring the ways these issues have been approached overseas we identify options for achieving the objective of effective environmental policies that policy makers seek in New Zealand. These options need wider discussion since they are of significance to environmental policy institutions at central and local government levels. They have implications for institutional capacities, capabilities and resources, and for policy development processes. In identifying the characteristics of effective interfaces between scientists and environmental policy makers, the report also recognises that there are other important interfaces. Where do the various stakeholder communities fit in the process? What are the trade-offs that policy makers need to balance? These and other issues raised in this report are directed towards policy makers, scientists, resource managers and other interested parties for consideration and further analysis.

1.2 Background

A number of previous studies carried out by the PCE have drawn attention to the important role that science plays in the development of environmental policies and decisions.[4] In his 2002 report, *Creating our future: sustainable development for New Zealand*, the Commissioner identified a number of policy shortcomings and barriers to achieving sustainable development goals.[5] He noted that a major challenge for the Government is to meet its economic and social objectives while also maintaining or improving the environmental conditions, including the health of ecosystems, on which so much of our economic activity depends. Science and research have key roles to play in meeting those challenges.

An earlier study identified fundamental barriers to improving monitoring and information systems in relation to the implementation of the Resource Management Act 1991 (RMA).[6] The barriers included the costs of obtaining information and the availability of fundamental scientific information. A further significant shortcoming facing environmental policy makers is the poor quality of information on the state of New Zealand's environment and trends in environmental conditions.[7] This includes a lack of nationally consistent standards for environmental data collected by regional councils, and the absence of indicators (ecological, social and economic) specifically developed to measure progress towards sustainability.

Only one national state of the environment report has been published in New Zealand.[8] This is insufficient to determine whether and to what extent environmental conditions nationwide are changing over time, and what effect, if any, environmental and other policies are having on environmental quality and sustainability. In contrast, the Australian Government has made a commitment to prepare regular state of the environment reports. Its first report was published in 1996,[9] followed by an updated report in 2001,[10] outlining a number of changes in environmental quality that had occurred in the previous five-year period. Many other OECD member countries have made similar commitments to regularly report on the state of their environments, and several (for example, the Netherlands) make use of them in formulating economic policy.[11]

In addition to keeping track of expected outcomes of policies, past experiences of unexpected effects and consequences (for example, impacts of asbestos, lead, CFCs[i] and organochlorine compounds) have given rise to increased public scepticism of both the scientific and the policy-making processes.[12] Recent examples such as the handling of the BSE[ii] incident in Britain created a crisis of confidence in the science-policy interface that subsequently led to an overhaul of the food safety assurance system.

In New Zealand, the Ministry of Agriculture and Forestry's (MAF) handling of the painted apple moth eradication programme in West Auckland failed to address public concerns about the health risks associated with the prolonged aerial spraying

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[i] Chlorofluorocarbons.

[ii] Bovine spongiform encephalopathy.

campaign. A recent study found that a lack of information available to the public about the spray (Foray 48B) contributed to increased uncertainty and concern about the spray's toxicity, and decreased public confidence in the Government's decisions on this issue.[13] These examples of the importance of having scientific input to decision-making, but when there is diminishing trust in the processes, highlight the need to explore other ways to engage all interested parties and build better relationships.

Additional background information introducing environmental policy-making and the role that science and other sources of knowledge play in that process is outlined in chapter 2.

1.3 Scope and purpose of the report

> ***Today's quests for sustainable development pose new, deep challenges to the ways we define problems, identify solutions, and implement actions.[14]***

The first stage of this project - the release of a discussion paper on the role of science in environmental policy and decision-making - sought comments on a wide range of issues associated with science-based policy.[iii] Its purpose was to seek comments on ways to improve the quality of environmental policies and decisions. As section 1.1 indicates, our subsequent inquiries led us into new territory. Not only do we examine the role and quality of science in environmental policy-making, but also the challenges for institutions that have the task of providing effective scientific information for policy makers. There is also a growing awareness that the wider community of stakeholders need a voice in the problem definition and the solutions. Without this, the legitimacy of the resulting policy measures will be undermined. This view is supported by ongoing New Zealand research, which is investigating the links between environmental policy and outcomes in relation to the Resource Management Act 1991.[15]

This report is directed towards environmental policy makers in particular, but it may also benefit scientists who are involved in the identification and resolution of environmental policy issues, and stakeholders who have interests in the policy process and outcomes.

We outline the issues associated with science in environmental policy-making, and explore the challenges and opportunities for environmental policy makers, scientists, resource managers and stakeholder communities to:

- address environmental management challenges characterised by complexity, uncertainty and risk

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[iii] Undertaking this project is consistent with the functions of the Parliamentary Commissioner for the Environment under section 16 of the Environment Act 1986.

- make more effective use of scientific information for environmental policy-making
- improve the interfaces that are important to ensure confidence in the environmental policy-making process.

1.3.1 What this report does not cover

As we examined the relationship between science and environmental policy it became clear that it involved a broader range of issues than we could adequately address in a single report. For example:

- There are concerns about institutional capabilities, funding of environmental sciences and utilisation of scientific advice for policy purposes.
- There are questions about whether science used in some adversarial approaches to environmental policy and decision-making contribute to sustainability. For example, there is the potential for scientific evidence to be selectively used in resource consent hearings for the purpose of gaining or maintaining a particular interest or position, which could be to the detriment of the broader principles of sustainability.
- There are issues around the roles and influence of science and expert scientific witnesses in legal proceedings on environmental issues.
- Inclusive and transparent decision-making presents a number of major challenges, not the least being the expectation that policy makers will give appropriate balance to both facts and values in their decisions.
- There are many factors – scientific and non-scientific – influencing environmental policies and their outcomes.

While we touch on some of these issues in this report, a closer examination of each one may be warranted. There may be opportunities to do this at a later date.

The report is not a code of practice. It does not set out to prescribe a standard approach to the use of science in policy-making. A single set of methodological or procedural prescriptions is unlikely to produce successful outcomes in all circumstances all of the time. In most cases the issue and context will dictate whether and to what extent any scientific input is needed, and if so, the method, process and type of science required.

The report does not set out to assess the adequacy or effectiveness of science funding in New Zealand. Appendix 1 outlines some of the issues around ‘public good’ science funding, but because this funding has been undergoing changes during the course of this investigation, it was considered inappropriate to comment in detail at this stage on the implications for environmental policy-making.

It is not the intent of this report to comment on the performance of individual environmental policy agencies within central and local government. This level of inquiry and analysis was not the purpose of this project.

CHAPTER 2

Setting the scene:

environmental policy-making and its challenges

This chapter is a brief introduction to environmental policy makers and some of the challenges they face when making decisions in which both science and public interests are significant determining factors.

2.1 Environmental policy makers

In the context of this report, the term **environmental policy maker** includes:

- elected representatives such as government **Ministers**, and **councillors** of regional councils and territorial authorities. All have statutory policy and decision-making responsibilities under legislation such as the Resource Management Act 1991
- central and local government **officials** who have delegated decision-making and/or operational policy-making responsibilities within environmental management organisations such as the Department of Conservation, Ministry for the Environment, regional councils and territorial authorities. Officials also provide policy analysis and advice (including scientific advice), purchase external advice, and liase with other agencies for the overall purpose of assisting Ministers or councillors in their policy-making roles.

Other environmental decision makers who are appointed, rather than elected, and who do not have a formal policy role, but whose role is to make environmental decisions on a case-by-case basis include:

- the Environmental Risk Management Authority in relation to applications to introduce new hazardous substances and new organisms into New Zealand
- the Environment Court which, among other things, determines appeals on cases involving disputes over the management of resources.

Environmental policy makers come from a wide range of backgrounds and from within diverse occupational groups, so the range of expertise and experience relevant to the decisions they have to make will vary. Some will be more familiar with scientific principles and methods than others, and this will influence their responsiveness to scientific advice.

Appendix 2 shows the range of current institutions and their functions in relation to science and environmental policy and decision-making.

2.1.1 Environmental policy-making

An environmental policy can range from being a general principle (for example, the sustainable management of natural and physical resources), to being a response to actual or potential problems such as climate change, or a statement of intent such as a sustainable development strategy. It also includes the environmental aspects of policies in other areas such as agriculture, transport and energy. The process generally involves consulting with interested parties, evaluating and choosing from among a number of alternative courses of action, and weighing up the risks (including costs) and benefits of each before selecting a particular policy option. Environmental policy-making also involves innovative thinking - looking beyond the tried and trusted ways of doing things and exploring new paradigms.[1]

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The 'products' of environmental policy-making include:

- environmental legislation (e.g. Resource Management Act 1991 (RMA))
- national policies and strategies for environmental management and sustainability (e.g. the New Zealand Coastal Policy Statement (NZCPS), and the Sustainable Development for New Zealand Programme of Action)
- national environmental guidelines and standards (e.g. national environmental standards on air quality)
- regional policies dealing with the management of natural and physical resources (e.g. policy statements and plans of regional councils under the RMA)
- economic instruments (e.g. taxes, levies and charges)
- information (e.g. public awareness campaigns)
- non-regulatory environmental risk management strategies (e.g. the agrichemical users' code of practice (NZS 8409)).

The policy cycle

> ***In our view, New Zealand suffers from poor policy implementation, which confounds sound policy initiatives.[2]***

The formulation of an environmental policy is not an end in itself, but simply a step in the process of bringing about change in environmental quality or sustainability.

The formulation of an environmental policy is not an end in itself, but simply a step in the process of bringing about change in environmental quality or sustainability. Implementing, monitoring and evaluating environmental policies are all parts of the cycle (see appendix 3) that feeds information back into assessing the effectiveness of policies. These feedback loops are particularly important when policy decisions are initially made under conditions of uncertainty.

'State of the environment' monitoring, information from scientific research since the time of policy development, and lessons learned from implementing the policy provide the bases for evaluating, reviewing and adapting policies, if necessary. The style of working where environmental researchers and policy makers interact more frequently throughout the entire policy cycle has been described as 'sustained interactivity'.[3]

Throughout the monitoring and evaluation process science is important in the choice of indicators (what is to be measured), the methods of monitoring (how measurement will be carried out), and the accurate interpretation and analysis of monitoring results. Monitoring involves the gathering of information, but it is not limited to being a data

Assessing the changes brought about by an environmental policy (outcome evaluation) is seldom done systematically or done well in New Zealand.

collection exercise. Evaluation is primarily to determine the extent to which policy goals are being achieved, and to identify the successes or shortcomings in the policy.

The timing of policy evaluations is important to consider. Feedback information can arrive at various times and be complete or only partly useful. There is a risk that inadequate information, if wrongly interpreted, can lead to incorrect or misleading policy evaluations.[4]

Assessing the changes brought about by an environmental policy (outcome evaluation) is seldom done systematically or done well in New Zealand. This is complicated by the fact that not all environmental policies on their own will produce the outcomes intended. There will inevitably be other influencing factors, beyond the direct control of environmental policy makers, which either contribute to or detract from policy goals. Nevertheless, it is important to understand the reasons for any policy successes or shortcomings, identify any adjustments that need to be made, where gaps exist, where essential links are missing, and whether pressures on the environment are increasing or decreasing as a result of the policy.

... it is important that evaluation is regarded as an integral component of the policy cycle, and that science plays a key role in the 'learning' process.

Numerous factors, such as time and commitment of resources, will undoubtedly affect the extent to which agencies undertake outcome evaluation. However, it is important that evaluation is regarded as an integral component of the policy cycle, and that science plays a key role in the 'learning' process.

2.1.2 The science-policy interface

The relationship between science and environmental policy can be categorised in two ways: science-led policy and policy-led science. Science-led policies are those that are needed to respond to issues created by developments in science and technology. For example, the Government introduced the New Zealand Biotechnology Strategy in response to a recommendation of the Royal Commission on Genetic Modification.[5] The purpose of this recommendation was *'to ensure that New Zealand kept abreast of developments in biotechnology, and that these were used to national advantage while preserving essential social, cultural and environmental values'.*[6]

Policy-led science is the more common of the two, referring to scientific research, evidence, or opinion that policy makers may seek from science providers to help formulate appropriate and workable environmental policies. Table 1 outlines some of the characteristics of each.

Table 1: Some characteristics of and barriers to (1) science-led environmental policy and (2) environmental policy-led science

	Science-led policy	Policy-led science
Characteristics	New information uncovered by scientific research or monitoring. Science helps to define or redefine the problem. Discovery of emerging issues and new developments, such as biotechnology, requiring a policy response. Scientific research reveals the ineffectiveness of prevailing policies.	Scientific advice needed to justify and determine how policy goals and objectives can be achieved. Environmental problem recognised, but research needed to explore solutions. Scientific advice needed to forecast and monitor policy outcomes. Scientific advice needed during the review of policy effectiveness.
Barriers	Scientific advice is clear and valid but policy makers fail to act on it. Scientific uncertainties may be used as an excuse for inaction. Science unable to provide unambiguous answers.	Society knows what it wants but scientists unable to deliver the information needed. Environmental problems are dynamic, but policies are not revised. Policy decisions driven solely by ideology.

The value of science to environmental policy-making is the reliability of the knowledge gained by means of scientific research. While reliability is not the same as certainty, it is nonetheless a solid foundation for decision-making. The influence that scientific advice will have on final decisions will largely depend on the nature of the issue (the extent to which it is amenable to scientific analysis) and the context (whether scientific understanding of the issue is crucial to reaching a decision).

The value of science to environmental policy-making is the reliability of the knowledge gained by means of scientific research.

Some criticisms of the use (and misuse) of science in policy-making arise when it is selectively used to justify a favoured policy or to provide ex-post justification for a policy already adopted. Other concerns about the science-policy interface in New Zealand were highlighted in the discussion paper *Illuminated or blinded by science?*[7] This paper referred to an analysis of science inputs to Cabinet papers and a report on improving the quality of policy advice.[8] The findings of these two reports emphasised the following:

- **Framing the questions** – the effective incorporation of research, science and technology into policy advice is conditional on who defines the policy problem and how the problem is defined.
- **Transparency** – there is a lack of clear procedures that would enable the scientific input to policies to be clear and open to scrutiny.
- **Time constraints** – despite a willingness among departments to increase the use of science in decision-making, departments are often thwarted by time constraints that inhibit in-depth research.
- **Process awareness** – officials need to be aware of the potential of research and science to support their work, and scientists need to better comprehend the policy process.
- **Strategic thinking and capability** – policy issues and related research need to take into account wider strategic goals, longer-term science capability requirements, and the importance of research that is forward-looking and innovative.
- **Building relationships** – information is typically generated in departmental 'silos', and there are few incentives for departments to share information and resources.

A study of Australian and New Zealand models of government science found that restructuring of science in the late 1980s and early 1990s in New Zealand seriously weakened the science capability of many departments. This was compounded by changes in the funding of research designed to support government decision-making. Later evidence showed a small, but still limited, shift in favour of more scientific and technical research input to government decision-making and increased support for science for government decision-making.[9] Other comments on in-house science and research capacities within government agencies are outlined in appendix 4.

Unlike many other OECD countries, New Zealand's public good science funding

Unlike many other OECD countries, New Zealand's public good science funding system is fully contestable (see appendix1). This has raised concerns including the potential loss of co-operation between researchers because they have to compete for funds, and uncertainty among scientists and researchers about longer-term employment prospects. Crown Research Institutes (CRIs) see a tension between their public good role, the need to show a sense of social responsibility, and their commercial focus.[10] In some circumstances, such as the inquiry of the Royal Commission on Genetic Modification, this commercial focus has led to public mistrust of some CRIs as independent providers of scientific advice.

In Britain, weaknesses in the science-policy interface highlighted by the BSE incident prompted the Government to introduce its 'science review' process.[11] The Office of Science and Technology (OST), headed by the government's Chief Scientific Adviser, is responsible for undertaking science reviews. They involve scrutinising and benchmarking the quality and use of science in government departments in support of their policy and regulatory activities. The aim is to maintain and improve the ways in which government departments use science and manage research.

2.2 The challenges and responsibilities

> ***Science is a profoundly important part of modern life and increasingly lies at the centre of major public policy debates. In these matters of the uses of science, we scientists are drawn to relate to our wider communities. In that, we should be aware that the way we look at the world around is uniquely defined. We are united by the idea that scientific knowledge has an evidence base. We share Popper's dictum that knowledge, to be called science, must be falsifiable. We know that there are truths other than science and that, in matters of ethics or human values, the scientist's opinion has no higher status, but we do present an abiding and self-consistent way of looking at the world, and that, in itself, is of inestimable value to society at large.***[12]

Developing environmental policies and taking decisions on environmental issues is becoming increasingly complex and sophisticated in the twenty-first century. This is due to a number of factors including:

> Developing environmental policies and taking decisions on environmental issues is becoming increasingly complex and sophisticated in the twenty-first century.

- advances in science and technology that increase or reduce environmental risks
- the emergence of unprecedented, complex environmental problems (e.g. climate change)
- the discovery of cause-effect links that were previously unknown (e.g. endocrine disruptors)
- an increasing awareness of scientific uncertainty, especially in the areas of health and the environment
- changing relationships between civil society and democratic governments (e.g. expectations of inclusive and transparent decision-making processes).

Other countries have recognised that environmental issues facing governments are increasingly complex and require decisions that have profound impacts on societies and economies. Many environmental management decisions involve risk assessments that arouse public concerns about their health, safety and long-term well-being, and the long-term sustainability of ecosystems. There are also increasing concerns regarding the accountability and liability of scientists and decision makers. With increased access to information, there is heightened public interest in science-based issues and greater emphasis on active public involvement in decision-making. At the same time, there is greater scepticism of science, government, industry, and the interactions among them.

This has prompted some countries to introduce principles or guidelines for scientific advice in policy-making such as those developed by the UK Office of Science and Technology and Industry Canada.[13] Both countries' guidelines address similar issues, such as:

- **Issue identification** – anticipating and identifying early on issues needing scientific advice, drawing information from a variety of sources, networking among science and policy staff. Using interdisciplinary co-operation to address issues that cut across areas of expertise or need input from a range of viewpoints.
- **Asking the right questions** – consulting with scientists when framing the questions that science is expected to address to ensure that the questions are capable of being answered, that scientists clearly understand what is required of them, and that the advice ultimately given will be of value and relevant to addressing the issue.
- **Quality assurance** – employing measures to ensure the quality, integrity and objectivity of scientific advice being used.
- **Transparency** – establishing procedures for obtaining scientific advice that is open and transparent, and ensuring the evidence upon which advice is based is published and accessible by interested parties.
- **Uncertainty and risk** – recognising that science in public policy will contain uncertainties, and the importance of making uncertainties explicit so that they can be assessed and managed by using an appropriate risk management framework.
- **Implementation and review** – the importance of reviewing and assessing how successful the process of incorporating scientific advice into policy has been, whether the expected outcomes have been achieved, or whether there is a need to review key decisions in light of new scientific knowledge.

The state of knowledge about the environmental consequences of the choices that environmental policy makers face may be incomplete or uncertain at the time when decisions have to be made. In addition, policy makers and their advisers will be operating under time constraints, and on time scales that may be considerably shorter than those required to undertake the necessary scientific research. They will be faced with various demands and expectations of interested parties, statutory requirements, and other pressures and constraints. Their decisions can have long-lasting and potentially irreversible impacts. For these reasons environmental policy makers carry a heavy burden of responsibility.

Science, politics and public concerns

Bovine spongiform encephalopathy (BSE or 'mad cow disease') is a 'classic' example of a situation where science became embroiled in the political debate. A comprehensive investigation led by Lord Phillips was published in 2000 detailing numerous failures in terms of the management, interpretation, and communication of science. These have been blamed for severely eroding public trust in both politicians and scientists.

In February 1985, the first cow died in Britain from BSE, but it was not recognised as a new cattle disease until November/December 1986. This information was withheld from the public for six months. In October 1987, BSE was found to be a prion disease,[i] which is thought to have infected other cattle through the common practice of rendering the remains of dead animals into meat and bone meal for use as cattle feed. Following this discovery, it was assumed, but not tested that BSE was the bovine form of scrapie, a disease of sheep. Since scrapie is not known to infect people, it was assumed that neither would BSE.

This uncritical acceptance that BSE could not affect humans, meant that early reassurances were taken as fact. This aided public acceptance that British beef was safe to eat and slowed scientists' reactions to warning signs. That BSE could infect people with a form of Cruetzfeldt-Jacob disease (vCJD) only emerged 10 years after the first official case of BSE.[14]

When BSE was first identified as a potential risk to human health there was little scientific information, let alone scientific consensus. Many important aspects of BSE policy were based not on 'sound science' as proclaimed, but on assumptions, or use of 'managed science' that supported the status quo. Repeated reassurances from two scientific advisory committees, Britain's Chief Veterinary Officer, the Chief Medical Officer and politicians that *'beef is safe to eat'* rang out for nearly a decade even though sufficient evidence to support these claims was not available.[15]

Because of repeated official pronouncements that beef was safe, the eventual discovery that BSE was linked to vCJD led the public to believe that they must have been deliberately misled. The result was severe erosion of trust in both government and scientific expertise. Phillips stated, '*Public trust can only be established if communications about risk are frank and objective [and] in particular, there must be openness about uncertainty'.*[16]

The role of scientists is to provide information regarding cause and effects. Politics is the art of deciding how to act on this information.[17] These roles became blurred during the BSE saga, with scientists expected to provide all the answers even when it was not their proper role. It demonstrated how inadequate knowledge and understanding can lead to false reassurances. It also highlighted how unnecessary delays in undertaking research, and a lack of scientific and political openness can lead to a major erosion in public trust, not only in politicians, but in the integrity and trustworthiness of scientists.[18]

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[i] Prions are known to cause four human diseases including Cruetzfeldt-Jakob disease. Other prion diseases affecting animals include scrapie in sheep, chronic wasting diseases in mule, deer and elk, and BSE.

Environmental policy makers need to have regard to the process of environmental policy-making, as well as the outcomes they expect to achieve. The process is important for gathering information, eliciting values and attitudes, comparing options and enabling stakeholders to contribute to and participate in policy-making. It is also important for ensuring that decisions are made in an open and transparent way.

The responsibilities of environmental policy makers have been described as applying 'principles of good governance'. These include:

- **Openness** – institutions should adopt greater transparency
- **Participation** – there should be greater public participation in policy development, from creation to implementation
- **Accountability** – lines of responsibility should be clear, with general understanding of the different roles of institutions and decision makers
- **Effectiveness** – policies need to be effective, timely, with clear objectives, evaluating future impacts and past experience
- **Coherence** – policies and actions must be coherent and easily understood.[19]

2.2.1 Science, values and other sources of knowledge in the environmental policy process

> ***The existence of ethical limits highlights the fact that science in itself can say nothing about values, although values can influence the interpretation of scientific results.***[20]

In a democratic society, the primary role of science in the environmental policy process is to inform policy makers and guide policy, not determine it.

In a democratic society, the primary role of science in the environmental policy process is to inform policy makers and guide policy, not determine it. Science is important in environmental policy-making because it enhances the evidence base for, and provides rigour to, policy formulation. It identifies and analyses environmental risks, and contributes to the management of those risks. In other situations the pace of scientific advances, such as in biotechnology, is so rapid that public policy (for example, oversight and regulation to manage risks) has difficulty keeping up with the issues that new technologies often raise. Such issues also generate debate centred on the values, traditions and choices that society (or sectors within society) wishes to uphold. Values include those expressed by individuals or groups, and the values that individual scientific advisers and policy makers bring to bear on their opinions or judgements.

While science cannot always provide all the solutions to environmental problems all of the time, it makes a significant contribution to improved knowledge and understanding. Awareness of the nature and extent of consequences, intended or otherwise, of policy and decision choices is a major contribution that science can make.[21] However, this is not to say that science-based environmental policies will not be controversial. Both the science and its interplay with non-scientific components, such as economic, trade, ethical and cultural considerations, can be the subject of intense scrutiny, criticism and debate, as demonstrated in issues associated with genetic modification.

Crater Lake

Mt Ruapehu with its Crater Lake situated within Tongariro National Park is one of the world's most active volcanoes. Tongariro is New Zealand's oldest National Park, established in 1887 following the gift of the mountain peaks to the nation by the paramount chief of Ngati Tuwharetoa, Horonuku Te Heuheu Tukino. The rohe (tribal area) of Ngati Tuwharetoa includes the central-northern area of Tongariro National Park, but the iwi (tribe) consider the entire mountain sacred. The outstanding natural and cultural values associated with this area have been internationally recognised through the awarding of World Heritage status.

Eruptions of Mt Ruapehu in 1995 and 1996 built up a 7m thick deposit of tephra[ii] on the crater rim at a former rock outlet. Natural filling of the Crater Lake has since raised levels to this barrier, meaning the lake levels have risen above the normal overflow level. A concern is that this overflow could burst out, resulting in a lahar,[iii] in a manner similar to the one that caused the Tangiwai rail disaster of 1953.

A large lahar can present a significant natural hazard. In 1997 the Department of Conservation (DoC) began preparing an Assessment of Environmental Effects (AEE) for the Minister of Conservation and the regional and district councils. DoC staff, engineering and scientific consultants researched and presented 23 options for mitigating the effects of a lahar. Strategies presented fell into two broad categories: (1) strategies to reduce the hazard and (2) removal of the hazard. Options considered included engineering options at the crater rim, dams and diversion walls downstream, and alarm systems.

Options to reduce the hazard were based on technical and scientific information, which was then placed in the context of other considerations, including the extremely high natural, cultural, and scientific values associated with the area. Active engineering intervention would run counter to the National Parks Act 1980 and the World Heritage status of the area. The decision by the Minister of Conservation highlights the significance given to social and cultural considerations in this case.

Environmental policy makers often face questions such as:

- Should knowledge that is based on current scientific understanding and evidence prevail over other kinds of knowledge?

[ii] Tephra is comprised of ash, scoria and rocks.

[iii] Lahar refers to the rapid flow of a mix of rock debris and water from a volcano.

- Are there ways to effectively integrate different kinds of knowledge to help decision makers achieve good environmental outcomes?
- To be consistent and fair, should the merits of each source of knowledge be evaluated on some common basis?

Science is a rigorous process of sharing as well as testing knowledge and ideas, but it is inherently incomplete because it is continuously tested and superseded by superior science.[22] Scientific evidence and the divergences of views among scientists can be challenged, defended and assessed through well established experimental and peer review processes.

Some people also gain knowledge and understanding of natural resources and processes through traditional and other 'non-scientific' ways. This is often based on years (and sometimes centuries) of experience, trial and error, and knowing what does or does not work without necessarily understanding the scientific reasons why. Sometimes strongly held beliefs about managing the environment, based on traditional knowledge, are later given a scientific explanation. Information needed to make wise environmental management decisions may, therefore, be derived from many sources of knowledge including those that are scientifically verifiable and defensible, and those that are not, but which are nonetheless policy-relevant.

Managing relationships is a critical role for policy makers.

Inclusive decision-making should not presuppose the priority of expert over lay, or scientific over non-scientific, knowledge.

Managing relationships is a critical role for policy makers. This means having the capacity to interact with a wide range of science providers and other experts, communities, various stakeholders and the legal system.[23] Policy makers' understanding of the science underpinning the choices they face, as well as the values that are important to communities, are key to promoting inclusiveness in decision-making and improving the public's confidence in the decisions being made on their behalf. Inclusive decision-making should not presuppose the priority of expert over lay, or scientific over non-scientific, knowledge. *'Rather, it should provide a forum which acknowledges, amongst other things, the provisional, uncertain, value-laden and contestable nature of knowledge; which respects the diverse and sometimes incommensurable discourses voiced by different stakeholders; and which allows for differences to be debated in a spirit of openness and mutual trust.'*[24]

Maori and science - lessons from successful collaborative relationships

An examination of three successful case studies of research collaborations between science providers and tangata whenua, summarised in appendix 5, revealed the following lessons:

- It was clear from the research undertaken that scientists enter into relationships with tangata whenua with sometimes little understanding or appreciation of tangata whenua values and knowledge.

- When embarking on a collaborative research proposal in conjunction with tangata whenua, scientists need to think about and address the worthiness of their research for tangata whenua.
- Tangata whenua have more knowledge than scientists give them credit for and they are happy to share their knowledge with scientists. Scientists often fail to acknowledge the significance of tribal knowledge that is held by tangata whenua. This includes the knowledge within an iwi or hapu of a river or coastline that it has inhabited, interacted with and observed for centuries.
- The value of collaboration to tangata whenua is not necessarily the scientific knowledge they gain but the technology they learn.
- Establishing meaningful, collaborative relationships between scientists and tangata whenua takes time and resources, and involves the sharing of benefits, accountability, risk and responsibility.
- The principle of tino rangatiratanga, or self-determination, is about having meaningful control over one's own life and cultural well-being. The maintenance of tino rangatiratanga within research relationships is imperative to the survival of Maori cultural rights and responsibilities.
- It is important to hui early in the project to ensure that there are opportunities for views to be expressed, heard and taken into account before any research commences.
- In some cases, having a scientific intermediary who has the confidence of the tangata whenua, can be useful for translating and interpreting the scientific data being presented, and helping to determine whether such data add anything to the knowledge that already exists among the tangata whenua.

The success of the three case studies examined has been put down to the fact that they were primarily based on the terms set out by tangata whenua - on the ways in which tangata whenua groups chose to interact. This highlights the point that, when such collaborative research initiatives are being considered, mutual respect and the processes of negotiation, testing, trust-building and knowledge-sharing are essential components of building the necessary relationship.[25]

In this chapter we have described, in general terms, environmental policy makers, their responsibilities and some of the challenges they face. In the following chapter we explore the particular problems that complexity and uncertainty create for those involved in the environmental policy-making process.

CHAPTER 3

Understanding the elephant

There is an Indian fable about four blind men who, having no experience of an elephant, encounter one and try to work out what it is. The one that touches its side thinks he has walked into a large wall, the one exploring the legs believes the unfamiliar object is some strange tree, while another touching the trunk thinks he has discovered a novel kind of snake. The fourth man held the elephant's tail and was sure he had found a rope. One of the fable's lessons is that from different perspectives we see things very differently, and sometimes in contradictory terms. One version of the fable has the blind men asking the zoo keeper what the thing is in front of them, given their different understandings of what it is. She responds by telling them that the only way to know what it really is, is to do what they have done. *'Only by sharing what each of you know can you possibly reach a true understanding.'*

This chapter explores different ways of understanding a very complicated 'elephant'. In this case the analogy operates at three levels:

... single perspectives of specific scientific disciplines to complex environmental problems are likely to lead to partial solutions...

1. It refers to how the single perspectives of specific scientific disciplines to complex environmental problems are likely to lead to partial solutions that lack the necessary integration to be effective.

2. It shows how different ways of 'seeing' and responding to complexity and uncertainty have implications for scientists and for environmental policy makers.

3. It can characterise the different perspectives on what is meant by 'consultation and communication' by scientists, policy makers and the various parties to environmental issues and management problems.

The chapter starts with a very brief account of the economic, social and political causes behind today's global and national environmental problems. Many are the consequence of complex, poorly understood relationships between socio-economic factors and natural systems. There have been various international responses to these issues and civil society is also exerting its own pressures for solutions, and calling for a different relationship with policy makers in the process.

3.1 Causes of, and responses to, unsustainability

There are numerous international assessments of the global declines in biodiversity, losses of soils, forests and grasslands, pollution impacts, urbanisation pressures and fresh water problems, to name a few of the obvious signs of the unsustainability in the current human-resource relationships.[1] There are direct causes that have led to this situation, for example, habitat degradation, invasive species, unsustainable rates of exploitation, as well as pollution and climate change. Most of these direct causes are the result of complex underlying socio-economic factors. Four of the major underlying threats to sustainability are:

- human population dynamics
- consumption patterns

- market failures and policy distortions
- wealth, poverty and inequity.

One key example of an economic policy with adverse impacts on many environments is production subsidies. The global subsidies in three sectors - fisheries, forestry and agriculture - amount to billions of dollars annually and have a direct impact on biodiversity. Many of these subsidies have been variously described as economically inefficient, trade-distorting, ecologically destructive and socially inequitable, sometimes all at the same time.

Over the past 30 years, there has been a range of responses to the emerging environmental problems. Some countries sought international as well as national solutions as they realised environmental mismanagement was undermining human aspirations as well as global life-support systems. The 1980 World Conservation Strategy marked the first appearance of the 'sustainable development' concept.[2] Considerable effort went into developing multi-lateral environmental agreements (MEAs). By 2000, there were about 240 binding accords, as well as many non-binding agreements and declarations, such as Agenda 21. Many countries established environmental agencies for the first time.

What difference have these initiatives made? MEAs have increased the dialogue between countries, and benefits can be cited for some, such as CITES.[i] On balance, however, the gains have not been impressive. In 1997, five years after the Rio Earth Summit, the Special Session of the UN General Assembly tasked with reviewing progress, concluded that reforms had been inadequate and too slow. Problems have included the under-funding of new environmental and conservation departments, the dominance of older and more powerful agencies and negative environmental impacts of international trade regimes, such as the World Trade Organization. In April 1998, environment ministers from the leading economic powers issued a communiqué that expressed '*grave concerns about the ever-growing evidence of violations of international environmental agreements'*.[3]

While global environmental problems were receiving increasing attention (if not resolution), there were also other developments that would have an increasing effect on how decision makers responded to these issues. Environmental policy makers are now operating at a time when the relationships between civil society and democratic governments (for example, expectations of open and transparent decision-making) have changed considerably. This is affecting environmental, as well as other policy issues, such as health. Advances in science and technology and the emergence of unprecedented, complex environmental problems have meant that the relationship between scientific experts and civil society is a matter of considerable attention and social concern. People also have a greater awareness of scientific uncertainty, especially concerning complex issues in the areas of health and the environment.

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[i] CITES (1973): Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Scientists, however, already know more now about the behaviour of natural and physical systems than at any previous time.

3.2 Sustainable development: enter science

At the same time as work on the conceptual and policy framework of sustainable development was underway in the mid-1980s, scientists started to explore the linkages between global ecological and geophysical systems on the one hand, and industrial and resource development activities on the other, in policy terms.[4] Finding out more about the state of global biodiversity also developed into a co-ordinated international effort. The 1995 initiative of the United Nations Environment Programme[5] has been followed by an even larger exercise, the United Nation's Millennium Ecosystem Assessment that is currently underway.[6]

But will more global assessments of the state of the world's environments be enough? Will better information lead inevitably to better policies or are these issues beyond resolution using the analytical tools developed for a time when problems seemed simpler? A common response to problems has often been to call for more studies to gather more information. Scientists, however, already know more now about the behaviour of natural and physical systems than at any previous time. Why, therefore, has there been limited progress and repeated failures in managing major environmental problems? Some well-researched international examples of environmental management failure include the following:

- Some major fisheries have collapsed despite public support for sustaining them and a highly developed theory of fisheries management.
- Moderate stocking of cattle in semi-arid rangelands has increased vulnerability to drought.
- Pest control (e.g. spruce budworm in eastern Canada) has created pest outbreaks that become chronic.
- Flood control and irrigation developments have created large ecological and economic costs and increased vulnerability.
- The threats to Lake Taupo water quality were identified by scientists decades ago, but no effective action was taken.

...the tested insights developed in the fields of economics, ecology and social systems are partial perspectives when applied individually to the complex issues of sustainable development.

In analysing why these management problems repeat themselves, despite having an understanding of the critical factors involved, Gunderson and Holling identify 'the trap of the expert'.[7] In summary, they argue that the tested insights developed in the fields of economics, ecology and social systems are partial perspectives when applied individually to the complex issues of sustainable development. Each of these separate disciplines, they argue, approaches sustainable development based on a particular worldview and theoretical base. As a consequence:

> *The conservationists depend on concepts rooted in ecology and evolution, the developers on variants of free-market models, the community activists on precepts of community and social organisation. All these views are correct, in the sense of being partially tested and credible representations of one part of reality. The problem is that they are partial. They are too simple and lack an integrative framework that bridges disciplines and scales.*[8]

While the partial views of experts can be an important part of the problem, and one that we focus on in this report, there are other reasons too, of course. There is also a history of unequal tradeoffs between economic development and environmental protection, real or perceived costs of solutions, opposition by vested interests, an absence of appropriate institutional arrangements, and the fact that costs and benefits of effective management are not evenly distributed.

3.2.1 Implications for environmental policies

The point argued by Gunderson and Holling, and by others seeking to develop testable ideas about the behaviour of linked ecological, social and economic systems, is that we need to do better at integrating relevant theories in two different ways. The first target is *'... to integrate the dynamics of change across space from local to regional to global and over time from months to millennia'.* Research usually focuses on one scale. The extent of human impacts are now such that to understand influences across scales, such as climate change on regional ecosystems and local human health, requires this broader approach. The second integration that Gunderson and Holling seek is a need to integrate *'...across disciplines to better understand systems of linked ecological, economic and institutional processes'.*

This has major implications for the way that environmental policies are developed and for the research that is necessary to inform and illuminate policy options. Short term, narrow focused, quick-fix 'solutions' are increasingly unlikely to address the sort of global and local environmental issues that New Zealand faces now and in the future. Solutions need to be more integrative across scales and, as will be argued below, open to models of policy development that are more flexible and interactive with a wider variety of legitimate perspectives.

Short term, narrow focused, quick-fix 'solutions' are increasingly unlikely to address the sort of global and local environmental issues that New Zealand faces now and in the future.

Sustainable development, science and government policy

In January 2003, the Government released its *Sustainable Development for New Zealand. Programme of Action.*[9] Most of the accompanying principles for policy and decision making, as well as four of the five action programmes, will require significant investment in science, integrated across disciplines and scales, to achieve the Government's objectives.

The principles include:

- looking at long-term implications of decisions
- seeking innovative solutions
- using the best information available to support decision-making
- addressing risks and uncertainty and taking the precautionary approach
- considering the global implications of decisions
- decoupling economic growth from pressure on the environment
- respecting environmental limits.

To be effective in policy development these operating principles need to be closely linked to a scientific capacity to deliver the underlying research that will inform the policy process in the relevant action programmes.

The programmes that will rely extensively on environment-related research are concerned with:

- quality and allocation of freshwater
- sustainable and efficient energy future for New Zealand
- sustainable cities
- measuring progress via indicators and statistics.

Sustainability first arose as a theme in funding allocations by the Foundation for Research Science and Technology (FRST) in 1999. Following this emergence, three research strategies were developed with a focus on sustainability. These were: 'sustainable cities and settlements' 'maintaining environmental integrity for sustainable resource use', and 'sustainable productive systems'. Funding allocations were made under these research strategies in 2003.

3.3 Complexity, uncertainty and science

Some efforts to achieve this 'double integration' of understanding across scales of time and space, as well as across disciplines, have already been made. They exposed another difficult reality for scientists, policy makers and decision makers – the problems of dealing with complexity and uncertainty. The way that scientists respond to these particular challenges has implications for both scientists and policy makers. This section looks at complexity and uncertainty in terms of the implications for science and research. The consequence for policy makers is the need to consider different types of risk and determine appropriate responses to them.

3.3.1 Complexity

Environmental policy issues and their resolution can be complex, particularly when they incorporate a range of characteristics, such as being:

- **multi-dimensional** – varying in extent and significance over time and space, and rationalised in many different ways (e.g. on the basis of science, culture or religion, as in the GM debate)
- **multi-scale** – varying in spatial scale of effects from local to global (e.g. waste, biodiversity losses, climate change), and over time scales ranging from weeks to millennia
- **multi-disciplinary** – needing a variety of approaches and sources of knowledge to resolve (e.g. sustainable development).

For most of the last century, most scientists undertook what has been called 'normal science'. The majority continue to do so today, especially in the applied physical sciences. The term 'normal science' has been used to refer to problem solving within the paradigms of the discipline, testing hypotheses, and generating new understandings of structures, materials and how things work.[10]

By training and by the nature of science, researchers seek to identify and test component parts of the larger whole, controlling all other variables so that the effects of one can be tested and understood in isolation. The results have led to spectacular advances in technologies, transportation, computing, energy generation, medicine, human welfare and improved understandings of the natural world.

Population options - Australia's six dilemmas

In 2002, the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) Future Dilemmas study was released.[11] In this complex study, that has few international equivalents (and no New Zealand equivalent), the researchers constructed a computer model that went beyond the usual demographic statistics. They examined three population scenarios and included all the physical transactions that underpin the Australian economy as well as impacts on the environment. A short paper by the report's authors spells out the six 'dilemmas' that emerge for national decision makers.[12]

Using the dictionary definition of a dilemma as a choice between two, or several alternatives, which are, or appear, equally unfavourable, the six dilemmas that emerged were categorised as: population aging, physical trade, physical flows underpinning the economy, greenhouse gas emissions, resource use and environmental quality. The key insight that emerged by looking beyond a single dimension of the problem (and including several disciplines) was the complexity of the linkages between the dilemmas. Studying one dilemma in isolation (as is often done in many countries) may 'solve' one problem without appreciating the ripple effect it will have elsewhere.

Researchers concluded that unless discussion on population (including immigration) options focused on the '... *six linked dilemmas as an interacting set, then national population policy will remain at the beck and call of marginal policy decisions and lobbyists promoting their own causes'.*[13]

Normal science continues to be a relevant form of inquiry for routine research on small-scale problems. This might be developing sampling techniques for invasive marine organisms, or quantifying relationships between agricultural runoff, water quality, and changes in species composition. It is when we move from the routine to major questions of how humans interact to transform natural systems that complexity dominates and single scale, single discipline inquiry is often inadequate.

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Such transformations can result from the sheer scale of human consumption of natural resources. The collapse of the Atlantic cod fishery is one such example.[14] Other examples include the overloading of natural systems with pollutants (for example, the ecological degradation of Lake Taupo and the Rotorua Lakes), the unexpected impacts of technologies on natural systems (for example, the destruction of atmospheric ozone by chlorofluorocarbons), and the combined impacts of several human-induced changes on a single major ecosystem (for example, reduced resilience of coral reefs to overfishing, pollutants and climate change impacts).

Then there are complexities in relationships where subtleties are discovered by accident. Examples are the capacity of pesticides (including DDT) and some industrial chemicals to seriously disrupt the endocrine systems of vertebrates. There will be impacts of new technologies that have yet to be investigated. Possible impacts of genetically engineered organisms on ecosystems is such an example. Another topical, but better understood complex transformation of natural systems by human behaviour is the phenomenon of climate change. Understanding these transformations is not 'rocket science'; it is much more complicated.

Understanding these transformations is not 'rocket science'; it is much more complicated.

These types of complexity have implications for policy at three levels:

1. There are implications for the conduct of science itself. Partial approaches to understanding these large interacting systems, as Gunderson and Holling (and others) have demonstrated, will not be enough if the objective is to identify management options that have a reasonable likelihood of success (see section 3.2). How uncertainty is recognised and addressed in the process can become a divisive issue (as in the British BSE controversy). The BSE case raised doubts about the ability of both the United Kingdom Government to understand and make best use of proffered scientific advice, and of the scientific community to reach a consensus when the evidence was still uncertain.[15]

2. There are implications for ways that policy makers respond to complexity and how they interact with science providers. Although research may reveal considerable insights into how complex nature-human system transformations work, there is also likely to be considerable uncertainty attached to those insights. This has considerable

implications for the policy process. Nature-human systems that are complex are not merely complicated, but by their nature they involve deep uncertainties and many legitimate perspectives, some of which will be values based. Scientists can live comfortably with uncertainty for it is at the heart of the scientific approach, but policy makers much prefer certainty. This places considerable pressure on the nature and the quality of communication between scientists and policy makers. Does New Zealand have the capacity for analysis, and the long-term analytical framework for environmental policy work that is required? Is there general agreement on the models and options, such as sustainable development, that set the policy directions? Without a much better measure of environmental trends, how will success or failure be measured and policy makers held to account?

Scientists can live comfortably with uncertainty for it is at the heart of the scientific approach, but policy makers much prefer certainty.

3. There are implications for the policy-public interactions, since the complex nature-human transformations and new technologies, such as biotechnology, and energy generation, are of significant interest to many affected parties. Stakeholders and public interest groups are demanding, more insistently than previously, to be involved in the development of policy on major issues affecting human health and welfare. Acknowledging complexity and uncertainty as relevant dimensions in the policy debate requires greater sophistication of both the process and the players.

Acknowledging complexity and uncertainty as relevant dimensions in the policy debate requires greater sophistication of both the process and the players.

These implications and the resulting tensions between scientists, policy makers and stakeholders will be discussed after we explore the concept of uncertainty in more detail.

Water quality in Rotoiti

Rotorua is one of New Zealand's most visited tourist destinations. The eleven major lakes of the area form a focal point for tourists, particularly those visiting for recreation and trout fishing.

Water quality issues in Lake Rotoiti were brought to the fore following considerable concern about large blooms of blue-green algae, particularly over the summer of 2002-2003.[ii] This algal growth meant that the lake was closed to swimmers for the whole summer. The underlying problem is excess nutrient availability (particularly nitrogen and phosphorus), which stimulates algal growth, cyanobacteria blooms and weed growth. Algal growth in Lake Rotoiti is fed by nutrients from a range of sources, including lake sediments, farm runoff, septic tanks and groundwater.[16]

Water quality in Lake Rotoiti has been the subject of scientific analysis since 1955. Scientific evidence has been available for more than 20 years that illustrates the gradual degradation of water quality in Lake Rotoiti.[17] Why has the degrading quality of Lake Rotoiti, and many other lakes, only recently been brought onto the political agenda when scientific evidence of the degradation has existed for more than 20 years? Is it too late for Lake Rotoiti? There are concerns that Lake Rotoiti could lose its remaining oxygen within the next year or two, becoming anoxic,[iii] killing off most of the life in the lake.[18]

[ii] The declining water quality of Lake Rotoiti is certainly not occurring in isolation. Many other New Zealand lakes could have been chosen as the subject of this case study.

[iii] Deficient in oxygen.

This case study is an example of inaction by policy and decision makers, despite the availability of scientific information for more than 20 years in this case.[19] It raises questions about the relationship between the different parties over this time period and the importance and transfer (or lack of transfer) of scientific information.

Science is not a matter of certainties but of hypotheses and experiments. It advances by examining alternative explanations for phenomena, and by abandoning superseded views. It has provided very powerful tools for gaining understanding of complex environmental processes and systems... In a scientific assessment of an environmental issue there are bound to be limitations and uncertainties associated with the data at each stage... decision-making procedures should recognise that.[20]

3.3.2 Uncertainty

uncertainty ...often reflects the intrinsic indeterminism of complex dynamic systems

The examples cited above of complex nature-human systems involve considerable uncertainty in understanding how the factors work and their many interactions. Sometimes this reflects limitations in our current understanding, but it often reflects the intrinsic indeterminism of complex dynamic systems (involving natural, human-made and human components). It may seem paradoxical that at a time when scientists have a better grasp than ever before of natural phenomena as complex as climate change, that scientists are also arguing that it is essential to acknowledge the uncertainty that remains.

There is not necessarily a consensus viewpoint within science on the argument that uncertainty and its attendant surprises are dominant features of the scientific enterprise. Nor is a consensus necessarily required. In fact, consensus can be limiting when it resists efforts to shift an outdated paradigm. It may be more important to bridge what can be characterised as two different scientific ways of seeing the world.

The first is an analytical stream of biology, represented by molecular biology and genetic engineering, that is essentially experimental, a science of parts, reductionist, and disciplinary in character. The second way of seeing the world, represented by ecology and evolutionary biology, is integrative, broad and explorative. It presumes that knowledge of the ecosystems and societies it investigates will always be incomplete.

Both the science of parts and the science of the integration of parts are essential for understanding and action.

The bridge, identified by ecologist C.S. Holling, comes with the realisation that neither view is complete in itself: *'Both the science of parts and the science of the integration of parts are essential for understanding and action.'* Each has a responsibility to understand the other. *'Otherwise the science of the parts can fall into the trap of providing precise answers to the wrong question and the science of the integration of parts into providing useless answers to the right question.'*[21]

Gallopín and colleagues reached a similar conclusion when looking at the consequences of investigating complex systems. They argued that a new approach to science was needed when investigating complex systems and their associated 'irreducible uncertainty'.[22] Certainly retain scientific rigor, they argued, but include in the initial definition of the issue a wider range of factors, including ones involving non-scientific analysis. *'It is better to get an approximate answer for the whole problem/issue, than a precise answer for an isolated component.'* The argument that complexity and uncertainty require a re-evaluation of how scientific inquiry is done has far reaching implications. What it might mean for the model of how scientific research is developed, especially when linked to environmental policy issues, is explored in Chapter 4.

...retain scientific rigor, but include in the initial definition of the issue a wider range of factors, including ones involving non-scientific analysis.

Uncertainty - scientific and political perspectives

In contrast to the approach taken to the BSE crisis in the UK, in which the Government gave the public unequivocal assurances of safety in the face of considerable uncertainty, the Bush administration in the United States has been accused of manipulating documents to give the impression of considerable uncertainty where there is little. The Union of Concerned Scientists (UCS) released a report in March 2004 detailing numerous examples of the suppression and distortion of scientific based information that conflicts with the administration's political agenda.[23]

In a case detailed in the report, the Bush administration was found to have attempted to force the US Environmental Protection Agency (USEPA) to *'substantially alter'*[24] a section on climate change in its draft *Report on the Environment.*[25] The White House Council on Environmental Quality and the Office of Management and Budget are reported to have demanded alterations to the document, including:

- The deletion of a 1000-year temperature record in order, according to a USEPA internal memo, to emphasise *'a recent, limited analysis [which] supports the administration's favored message'*.[26]
- The insertion of a reference to a discredited study of temperature records that was partially funded by the American Petroleum Institute.
- The removal of any reference to a review undertaken by the National Academy of Sciences (NAS) that confirmed human activity is contributing to climate change.[iv]
- The removal of a statement, uncontroversial in the climate change science community, that *'climate change has global consequences for human health and the environment'.*

Further, White House officials are reported to have demanded the inclusion of so many qualifying words such as 'potentially' and 'may' that the result would have been to insert *'uncertainty... where there is*

[iv] NAS was asked by the Bush administration to review the findings of the Intergovernmental Panel on Climate Change and provide further assessment on the climate science.

essentially none'.[27] Rather than comply with these demands, the entire section on climate change was deleted from the USEPA report prior to its release for public comment. *'Agency staff chose this path rather than compromising their credibility by misrepresenting the scientific consensus.'*[28]

This example highlights the vulnerability of scientific uncertainty to being overplayed or underplayed in order to attain political advantage.[29] Such manipulation could have disastrous implications not only for environmental sustainability, but also for the health and safety of people. It is crucial that political agendas do not lead to the manipulation of scientific research and analysis. Policy and decision makers must have access to *'rigorous, objective scientific research and analysis'* in order to make informed decisions.[30]

3.3.3 Matching risks and responses

Before looking at the implications of uncertainty for scientific research in relation to environmental policy, we turn briefly to another aspect of uncertainty – classifying different types of uncertainty and associated risks. Dealing with uncertainty on a day-to-day basis, as well as for questions of policy, is the basis of risk management, which is a large part of management practices in the public and private sectors.

Risk management is a systematic method of identifying, analysing, assessing, treating, monitoring, and communicating risks associated with any activity in a way that enables decision makers to minimise losses and maximise opportunities. Risk management is as much about identifying opportunities as avoiding or mitigating losses.[31] It is a principle on which important statutes are based, including the Hazardous Substances and New Organisms Act 1996, the Biosecurity Act 1993 and the Building Act 1991. Among other things, the Resource Management Act 1991 (s.3) defines 'effect' in terms of probability and impact, thus introducing the concept of risk.

Surprises and public risks

Understanding linkages between cause and effect may not become clear until decades after a product has been widely used without awareness of its potential risks, either to people or to natural systems. Asbestos and chlorofluorocarbons provide two such examples.

Asbestos products were first promoted in the late 1800s as a great scientific advance, a *'miracle fibre of great versatility and usefulness'*. Asbestos has been incorporated into thousands of products such as insulation, roofing tiles and cladding, cement pipes, ironing boards, paint, cement board, brakes, clutches, fireproof clothing. It has been used extensively in New Zealand's rail, building, shipping, saw milling and motor vehicle industries.

However, asbestos use has also created chronic health hazards in many countries. Significant exposure to any type of asbestos fibre creates a hazard, which may lead to the development of scar tissue (asbestosis) or to the development of lung cancer. It was not until 1934 that the link between asbestosis and lung cancer was established. It took more than 50 years following this recognition before the United States Government took some protective action, but with strong (and successful) opposition from asbestos companies.

Occupational standards were set for New Zealand in 1964 for asbestos fibres in the air. Asbestos regulations were first introduced in New Zealand in 1978 and then amended in 1983. Increasing public concern surrounding the effects of asbestos on exposed workers and their families and the environment led to the establishment of the Asbestos Advisory Committee in October 1990. The Committee reported to the Minister of Labour on issues relating to the use and health effects of asbestos in New Zealand and on the adequacy of controls and legislation surrounding asbestos use.[32]

From their discovery at the end of the 1920s until the 1970s, **chlorofloruocarbons** (CFCs) were regarded as a 'miracle substance' by the chemical industry.[33] They were developed in the 1930s as refrigerants. CFCs were ideal for this purpose as they are stable, non-flammable, non-toxic, cheap to manufacture and easy to store. CFCs were used in New Zealand as solvents in the electronics industry, as a propellant in aerosol spray cans, and for refrigeration and air-conditioning.

Then in 1974, scientists discovered, fortuitously, that chlorine released from the breakdown of CFCs destroys stratospheric ozone. The depletion of the ozone layer, leading to increased UV exposure, gained international prominence with the unexpected discovery of the ozone 'hole' above Antarctica in 1984. Scientists called for rapid action to stop the production of CFCs. The outcome was the development of the Vienna Convention for the Protection of the Ozone Layer in1985 and its Montreal Protocol in 1987 that detailed specific commitments for countries to meet.[34] New Zealand meets its commitments to the Protocol through the Ozone Layer Protection Act 1996 and the Ozone Layer Protection Regulations 1996, with rules relating to specific substances.

In summary, scientific advances created useful products that later research showed to have serious and unintended consequences. The assessment of risks associated with these products varied substantially over time. Commercial interests hindered political responses, sometimes for decades, but increasing public concern as well as further scientific understanding and reduction of uncertainties, eventually led to more stringent and effective controls and reduced risk.

This report does not examine the science of risk management in relation to policy development, but it is important to recognise that 'risk management' concepts need to be applied appropriately. Acting in a risky situation can mean acting across a range of circumstances from knowing the consequences clearly (for example, when to cross a road safely) to situations of unknowability. Policy makers may press risk analysts to assign a probability to such events, but to do so would go beyond the knowledge required for realistic risk assessment. Even when probabilities are assigned, it does not necessarily simplify the development of policy, because 'acceptable' levels of risk still have to be determined. But by defining different risk situations, based on levels of knowledge or ignorance, different types of action can be defined and evaluated to determine which are most likely to be appropriate in the circumstances.

The following table, adapted from the European Environment Agency[35] and Hilborn,[36] shows the relationship between different situations of risk, states of knowledge and examples of appropriate approaches for different situations.

Table 2: Relationships between different situations of risks and examples of action

Situation	State of knowledge	Examples of action
Risk (statistical uncertainty)	Known impacts and known probabilities. Example: setting environmental quality standards for air and water.	Prevention: action taken to reduce known risks, e.g. avoid exposure to asbestos dust. Probabilities can be assigned.
Uncertainty (model or system uncertainty)	Known impacts but unknown probabilities. Connections between variables are uncertain. Example: behaviour in novel environments of known invasive pests.	Precautionary prevention: action taken to reduce potential hazards. Cannot assign probabilities to specific outcomes.
Ignorance (fundamental uncertainty)	Unknown impacts and therefore unknown probabilities. Novel situations that existing models do not explain. Example: discovery of the ozone hole.	Precaution: action taken to anticipate, identify and reduce the impact of surprises, e.g. use of the broadest possible sources of information, including long-term monitoring. No predictions or probabilities are possible.

The temptation for scientists and policy makers is to operate at a more certain level of knowledge than scientific understanding warrants at the time. There will always be pressures to do so. For example, setting import health standards in relation to biosecurity policy must acknowledge that for many situations and species, especially when considering threats to indigenous biodiversity, the scientific knowledge at the time is often less certain than policy makers would prefer.

There is also a warning at a deeper level about an over reliance on the science of risk management. The uncertainties that can be recognised scientifically are only the known uncertainties. As Brian Wynne has warned: *'This totally and silently excludes from consideration the unknowns, which result in unanticipated consequences...'*[37] These are the unknowns underlying our current ignorance. The existence of prions was unknown at a time that scientists were assuming they knew what to test for with respect to effects related to BSE. The behaviour of endocrine disrupters (themselves a product of science) that can skip a generation before showing an effect is completely outside the traditional dose-response relationships of risk assessment. An appropriate compensatory mechanism might not exist. Public concerns about these issues recognise that there is more uncertainty about the phenomena than is often admitted by scientists.

'No satisfactory way has been devised of measuring risk to the natural environment, even in principle, let alone defining what scale of risk should be regarded as tolerable'.

The United Kingdom Royal Commission on Environmental Pollution made the following observation that sets a high barrier for assessing risk. In its 21st Report, on Setting Environmental Standards, the Commission concluded: *'No satisfactory way has been devised of measuring risk to the natural environment, even in principle, let alone defining what scale of risk should be regarded as tolerable'*.[38]

Setting limits for resource exploitation is an example of where pressures, both political and commercial, have often overridden the limited scientific understanding of the system or species and led to unsustainable exploitation. In 1993, Donald Ludwig and colleagues argued in the journal *Science* that history shows us that the uncertainty and complexity inherent in biological and physical systems precludes a reductionist approach to management.[39] Trial and error will best determine the optimum levels of exploitation, while large levels of natural variability often mask the effects of overexploitation. It can even be difficult, they argued, for scientists to achieve consensus, after the event, as to the causes of some collapses. This was the situation with the collapse of the Peruvian anchoveta fishery when yields decreased from a high of 10 million metric tonnes to near zero in a few years.

... it is extremely difficult to perform controlled and replicated experiments in large-scale systems, such as fisheries.

The great problem is that it is extremely difficult to perform controlled and replicated experiments in large-scale systems, such as fisheries. Understanding the interactions of major pests in New Zealand (possums and red deer, for example) with physical and ecological systems to improve management requires large-scale experimentation, which is costly and time-consuming. Nonetheless, some efforts are underway (see section 4.6).

3.4 The importance of precaution

One response to scientific uncertainty about environmental proposals, and the recognition that it is difficult to remedy environmental injury, has been the elaboration since the 1970s of the legal concept of precaution. The 'principle of precaution' has since become a cornerstone of environmental law. It relies on techniques such as risk assessment and environmental impact assessment of the potential effects of a planned activity followed by a decision to allow it or prohibit it. Now widely known as the 'precautionary principle', it has been incorporated into international agreements, including the United Nations Rio Declaration on Environment and Development in 1992. Principle 15 states:

> ***In order to protect the environment the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.***

There has been controversy over how precaution should be implemented and, in particular, whether to refer to the 'precautionary principle' or the 'precautionary approach'. While the debate has relevance for determining whether or not there is an established and agreed legal principle involved, the concept of precaution is intrinsically useful. The Rio Declaration version of precaution appears in a modified form in the Convention on Biological Diversity and again in the Cartagena Protocol on Biosafety.[v] Proponents for including precautionary provisions in the Cartagena Protocol argued that even with proper risk assessment, some uncertainty may still remain and that in such circumstances countries should have the right to adopt precautionary measures to protect biodiversity and human health.[40]

Orange Roughy

Orange Roughy *(Hoplostethus atlanticus)* is a deep-sea species that has been subject to intensive fishing for more than 25 years in the southern hemisphere.[vi] Orange Roughy is an extremely long-lived species that is very slow growing, with low fecundity and low levels of recruitment. In addition, Orange Roughy, like numerous other deep-sea species, typically form dense aggregates for spawning and feeding, making them vulnerable to exploitation. Orange Roughy is taken by demersal trawling, which involves the towing of a trawl net along, or immediately adjacent to, the ocean floor.

Management of Orange Roughy takes place in an uncertain environment. Fishing for Orange Roughy (and other deep-sea species) developed before there was a reasonable understanding of the

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[v] The 2000 Cartagena Protocol on Biosafety is an independent instrument, related to its 'parent' treaty, the Convention on Biological Diversity.

[vi] Orange Roughy are found from the southwest Pacific to the northeast Atlantic Ocean.

biology/life history characteristics of the species being targeted, and also prior to formal stock assessments being done, resulting in initial overestimations of biomass. Acoustic surveys allow greater confidence in determining current biomass and estimates of the size of pre-fished biomass. However, other parameters are still subject to much uncertainty.

A report produced by TRAFFIC Oceania and WWF highlights the uncertainty faced when trying to determine fundamental biological information such as stock structure and mortality of Orange Roughy.[41] Further uncertainty persists when trying to establish the true extent and scale of fishing, and the accuracy of methods used to determine the age of Orange Roughy. The ability of stock assessment models to account for the variable nature of species recruitment has also been questioned. Knowledge about the ecosystems in which Orange Roughy are found is also limited at a fishery-specific level.

Orange Roughy is a species that is particularly vulnerable to over fishing. In the light of all the uncertainties, sustainable management of the fishery is more likely to be achieved if a precautionary approach is taken to the stock assessments and the level of exploitation.

3.5 Reducing uncertainty and capturing new knowledge

Through research, we can improve our understanding of how things and complex systems function and reduce, if not eliminate, uncertainty in understanding. When the state of knowledge shifts, for example, from a situation of ignorance to one of uncertainty, so the policy options change. It may then become easier to identify a better policy or management option. This has been one of the functions, and successes, of the Inter-governmental Panel on Climate Change (IPCC). This international scientific initiative has been instrumental in assessing and summarising the evidence of climate change for policy makers and making increasingly clear the need for action on adaptation strategies and mitigation targets, despite the uncertainties that remain.[42] The IPCC has provided scientific advice that is relevant to policy, without being policy-prescriptive. Through its meetings and reports, the IPCC provides policy makers with relevant information at the various Conferences of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC).

In other fields of environmental science the transfer of new scientific knowledge to the policy system is less structured, or even haphazard. Capturing the results of public good research for policy purposes, funded in New Zealand by the Foundation for Research Science and Technology (FRST), should be fairly straightforward. In practice, the extent and effectiveness of this transfer and its contribution to policy is less clear. There are certainly examples of contract research results from studies into pest control methods by Crown Research Institutes leading directly to improvements in management practices.

...marine scientists are concerned that fishing industry pressure seems to be having more influence on fishing policy than their research findings.

On the other hand, marine scientists are concerned that fishing industry pressure seems to be having more influence on fishing policy than their research findings. The Ministry of Research, Science and Technology (MoRST) is currently examining the relationship between the environmental research community and users of research. This includes looking at the attitudes of regional and territorial authority personnel to this relationship.

Capturing new research from universities or the private sector in an appropriate way for use in policy development is more of a problem. The importance of this 'capture and assessment' function has been formally recognised in other countries, particularly in Europe. Over a dozen European countries have created technology assessment bodies to provide scientific advice on emerging or existing technologies, often to government and parliamentary systems. A review of six such European bodies concluded that they were of increasing value for policy analysis and that by putting technological issues into a broader social and environmental context, such bodies were becoming *'an indispensable tool of democracy'*.[43]

While New Zealand has an agency for assessing new health technologies (mostly for the Ministry of Health),[44] it does not have one that assesses environmental technologies. This 'horizon scanning' or 'futurewatch' function was identified in the 2003 New Zealand Biotechnology Strategy. It proposed that biotechnology futurewatch activities will *'...scan for emerging biotechnologies and develop early assessments of issues and opportunities'*.[45] It follows a recommendation by the Royal Commission on Genetic Modification to develop mechanisms for supporting community awareness and engagement on biotechnology issues.[vii] Keeping up with technologies that affect the environment applies to other fields as well. For example, transportation and energy systems, industrial processes, environmental contaminants and the built environment are all areas where new research holds promise, or perhaps threats, for environmental policy.

As well as the importance of tracking new and emerging technologies and their implications for policy, is the issue of how advances within scientific disciplines might also affect policy and management. Take as an example the findings of the Royal Commission on Genetic Modification, which finished its hearings in mid-2001. Since then, significant advances in genetics have been identifying new functions for RNA (ribonucleic acid), including RNA-only genes that can play major roles in the health and development of plants and animals. Conventional wisdom defines genes as those sections of the DNA that encode functional proteins. Such sequences constitute only about two percent of the human genome. The rest, long regarded by geneticists as 'genetic junk' contains many non-coding genes that *'...give rise to surprisingly active RNAs, including varieties that can silence or regulate conventional genes'*.[46] Molecular biologists are now paying more attention to what is called a separate 'epigenetic' layer of heritable information that resides in the chromosomes, but outside the DNA sequence. This separate code, about which relatively little is known, can have

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[vii] This led to the establishment of the Bioethics Council.

dramatic effects on the health and appearance of organisms, and may play crucial roles in growth, ageing and cancer.

The message from this example is that policy makers run risks if they rely on occasional 'snapshots' of the conventional wisdom within rapidly changing scientific disciplines. Scientific understanding often undergoes significant change, which can have important implications for policy. If governments lack effective mechanisms to keep in close touch, not only with emerging technologies, but also basic advances in relevant sciences, they run the risk of developing policies based on inappropriate science and outmoded technologies. While science and policy institutions in New Zealand are well aware of the importance of keeping up with scientific and technological developments, it is difficult for a small, isolated country to do so in all spheres. International organisations such as the OECD can, and do, play a useful role in this respect.

... policy makers run risks if they rely on occasional 'snapshots' of the conventional wisdom within rapidly changing scientific disciplines.

3.6 Perspectives on consultation and communication

To return to the analogy posed at the start of this chapter, 'understanding the elephant' has much to do with how the different parties to an issue communicate with one another. This section will address the needs, while section 4.4.1 considers communication as part of the systems that provide effective scientific information.

A review of science communication and public attitudes to science in Britain identified the main issue in science communication policy was how best to develop a dialogue between scientists, policy makers and the public, and to bring public opinion into the development of policy.[47] Understanding the wide range of views held by the public and the variety of ways that they could be engaged in dialogue is important to avoid the situation where only the views of the scientifically assured will be heard. The report found that science is communicated to the public in many different ways, but there is a skew towards more activities that provide facts about science compared with activities that highlight the ethical and policy issues raised by science. The communication of science involves much more than a one-way process of only telling people about science and research. This is an important and necessary condition for the policy-public dialogue, but is not sufficient by itself.

There is a clear role for governments in the development of effective dialogue between scientists, policy makers and the public. An OECD study on engaging citizens in policy making distinguished three levels in government-citizen relations in policy making:[48]

- **Information** is a one-way delivery of information to citizens. It is a necessary stage in policy-making and is a shared objective by all OECD countries.
- **Consultation** is a two-way relationship in which citizens provide feedback to government. It is based on the prior definition by government of the issue on which citizens' views are being sought.

- **Active participation** is a relationship based on partnership with government, in which citizens actively engage in the policy-making process. It acknowledges a role for citizens in proposing policy options and shaping the policy dialogue, although responsibility for final decisions rests with the government. At the time of the report (2001), active participation was rare and confined to a few OECD countries.

... a 'science for science's sake' approach seems the one least likely to generate public engagement and therefore public understanding.

People are interested in the *context* of science and how it affects their lives

The news media play a role in informing people about science. One British report examined the relationship between the public understanding of science and the media coverage of science, focusing on what and how people learn about science from the media.[49] The study focused on three contemporary issues: climate change, the MMR[viii] vaccine controversy and cloning/genetic medical research. It concluded that there is little evidence to support the idea that the presence of more science, scientists and science specialists in the media will increase the public understanding of science. On the contrary, a 'science for science's sake' approach seems the one least likely to generate public engagement and therefore public understanding. What matters is not so much the science itself, but establishing clear connections between science, policy and the broader public interest. People are interested in the context of science and how it affects their lives. Emphasis needs to be placed on information that is necessary for people to make a valid contribution to the issues.

In the light of this finding that the public are more interested in the *context* of science than in the science itself, a survey of scientists in Britain is relevant.[50] The survey identified a number of issues concerning science communication for policy purposes. While the majority of scientists felt it was their duty to communicate research and its implications to policy makers and the public, many felt they lacked the time and skills to do so. (Nor are scientists necessarily trained to assess the ethical and social dimensions that might be involved.) The importance of having the right processes for effective scientific input into environmental policy is discussed in section 4.3.

Challenges for effective science communication

New Zealand research into what the public knows, thinks, and feels about science found that a majority of New Zealanders are interested in at least some aspects of science and technology, and are most interested in those areas where personal and societal benefits are most evident.[51]

Some of the relevant findings of the study included:

- New Zealanders are not inclined to take scientific claims on trust. They are likely to judge research as irrelevant or unconvincing if they do not understand the research methods and/or the meaning of evidence is not immediately apparent.

[viii] Measles, Mumps and Rubella.

- New Zealanders appear to have gaps in their understandings of basic science theory in areas that underpin contemporary research and debate. When basic principles are misunderstood, misleading views of the nature and significance of research can develop.

- People recognise that new developments in science and technology are important to New Zealand's economy. However, there is concern about the consequences of new developments in science and technology, which may be partly related to personal values positions.

- There appears to be a high level of awareness about past dishonesties in science internationally, particularly in relation to the reporting of health effects of smoking. Public relations approaches to socio-scientific issues are treated with suspicion.

- Openness about uncertainty is seen as evidence of honesty on the part of scientists. Open acknowledgement of areas of uncertainty and new questions are preferable to bland assurances of safety or predictability.

- Health and environmental issues are both areas of high interest to New Zealanders. Some see a role for the government in funding basic research, and for government control over scientists and their accountability to the public.

- People are discriminating of the sources of scientific information they will trust. Professionals are trusted above all media sources. Politicians and lobby groups are the least trusted sources of information about science issues.

Openness about uncertainty is seen as evidence of honesty on the part of scientists.

3.6.1 Debate or dialogue?

> ***Decisions about biotechnology cannot be left solely to government, business or science. Every New Zealander needs to be involved.***[52]

The way that societies consult and communicate is influenced by their history and social mores. Some societies put more effort into public discussion and the airing of different perspectives than do others. In other countries issues seem to quickly degenerate into polarised and angry debate between opposing positions. Developing environmental policies can do the same, as witnessed in New Zealand by the lead-up to the decision on the importation of Rabbit Calicivirus Disease (see box *The RCD decision - science, uncertainty and process issues* in section 4.2).

Consultation on complex and contentious science-policy issues to do with environmental management is more likely to succeed through dialogue rather than debate.

Successful consultation requires open minds, mutual respect, knowledge sharing and building relationships between scientists, policy makers and stakeholders that establish trust. That takes time and effort. Consultation on complex and contentious science-policy issues to do with environmental management is more likely to succeed through dialogue rather than debate. Dialogue provides the opportunity to explore a wider range of ideas and perspectives to address potentially complex connections and, in particular, uncertain environmental outcomes. It enables each party to acknowledge, listen to and respect the other's viewpoint, and to move forward in a way that is mutually constructive.

Table 3: Some features that distinguish debate from dialogue[53]

Debate	Dialogue
Pre-meeting communication between participants is minimal.	Pre-meeting contacts and preparation of participants are essential elements of the full process.
Participants adopt a position or commitment to a point of view, approach or idea.	Participants express uncertainties as well as deeply held beliefs.
Participants listen in order to refute the other side's data and to expose faulty logic in their arguments. Questions are asked from a position of certainty. These questions are often rhetorical challenges or disguised statements.	Participants listen to understand and gain insight into the beliefs and concerns of the others. Questions are asked from a position of curiosity.
Statements are predictable and offer little new information.	New information surfaces.
Success requires simple impassioned statements.	Success requires exploration of the complexities of the issue being discussed.

Despite the benefits of dialogue, discussions on contentious issues in New Zealand involving science and technology are often dominated more by a debating approach, than by in-depth dialogue. In the absence of structures and attitudes that encourage dialogue, the default option, which is often encouraged by the media, is generally debate with little opportunity for exploring common ground and the broader context of the issue. MoRST is currently funding a programme, 'Dialogue between science and community', which seeks to address New Zealanders' concerns over science issues. To quote from the MoRST website description of the Dialogue programme: *'These concerns have been highlighted in recent years by the rapid development of biotechnology, increasing commercialisation of research... These issues are linked to trust and to values'.*

A comment on the benefits of dialogue

The experience of a dialogue held on the topic of genetic engineering (GE) in April 2004 was described as follows:

'What was unusual was that participants represented viewpoints from across the board, and did not just debate with one another. Instead we talked both in large and small groups about motivations, shared values, personal experiences and responsibilities. Technical details were offered, prejudices were confronted.

This process of dialogue humanised the concerns of all sides in the issue and wandered through technical, spiritual, metaphysical and political matters ... A lack of trust was acknowledged around science, business, activism and the media - and trust was built among representatives of these sectors during the four days of dialogue. Participants also acknowledged the roles of both gut instinct and rationality in the way positions are formed.

There were no grand resolutions to be passed to, and perhaps ignored by, officials. But important and valuable connections were made, connections which might have previously been regarded as impossible.

What changed? What difference will it make? All the participants will be asking that question. Certainly impressions of the 'other' changed. The conversations will no doubt continue among individuals who were there and with their wider communities.'[54]

New Zealand remains some distance from the concept of 'active participation' outlined in section 3.6. This is a quite different issue from that of addressing public concerns over what scientific research is undertaken. Active participation in the policy making process is consistent with the views of Funtowicz and Ravetz that the new environmental policy problems require new processes, a proposal explored in section 4.4.[55] Active participation is also implicit in the idea of a 'public ecology' and different models for approaching research into complex systems that are explored in the next section.

... new environmental policy problems require new processes ...

3.7 Towards a public ecology

If large complex systems involving ecosystems, societies and the physical world are characterised by complexity, uncertainty and occasional surprises, what are the implications for the way science is done, and for the interface between science and policy-making? How do we factor in the concerns of a scientifically literate citizenry who, while appreciating the benefits science brings to their lives, are increasingly aware of the 'problems of unintended consequences'? We need to recognise and respond to the fact that careful science can reduce, but not eliminate, such uncertainties. Research on this scale is, however, often expensive as the work on understanding climate change has shown. Nor should policy makers rely too much on past experience. The current human domination of the earth has defined a new

We need to recognise and respond to the fact that careful science can reduce, but not eliminate ... uncertainties.

geological epoch for which historical studies are not necessarily useful analogues for future conditions.[56]

In calling for a different model for scientific research into complex systems Gallopín *et al*. proposed that it would have the following features:[57]

- Include policy relevant indicators at the beginning of the problem definition.
- Involve policy makers and stakeholders in the initial problem characterisation.
- Clearly distinguish between the knowledge base (including scientific uncertainties) and the political decisions (incorporating social values).
- Consider the possible behaviour of the whole system as broadly as possible. Thereby prepare for novelty, structural change and surprise.
- Value the information generated by the responses of the system to policies and human actions.

There are overlaps here with the principles of effective management listed by Ludwig *et al*.[58] They argued for a more cautious approach to resource exploitation as follows:

- Include human motivation and responses as part of the system to be studied and managed.
- Act before scientific consensus is achieved. Calls for additional research on topics, such as depletion of fossil fuels, may be only delaying tactics.
- Rely on scientists to recognise problems, but not to remedy them.
- Distrust claims of sustainability. Given the lack of specificity over many references to 'sustainability' of resource use, scepticism is appropriate.
- Confront uncertainty. Effective policies are possible under conditions of uncertainty, but they must take uncertainty into account.

The suggested way to proceed is: '*Consider a variety of plausible hypotheses about the world; consider a variety of possible strategies; favour actions that are robust to uncertainties; hedge; favour actions that are informative; probe and experiment; monitor results; update assessments and modify policy accordingly; and favour actions that are reversible'*.[59]

The common features of these lists suggest some guidelines for developing a more effective relationship between science and policy development for complex human-nature systems. For instance:

- Involve scientists and stakeholders when defining the policy problem that needs to be studied.

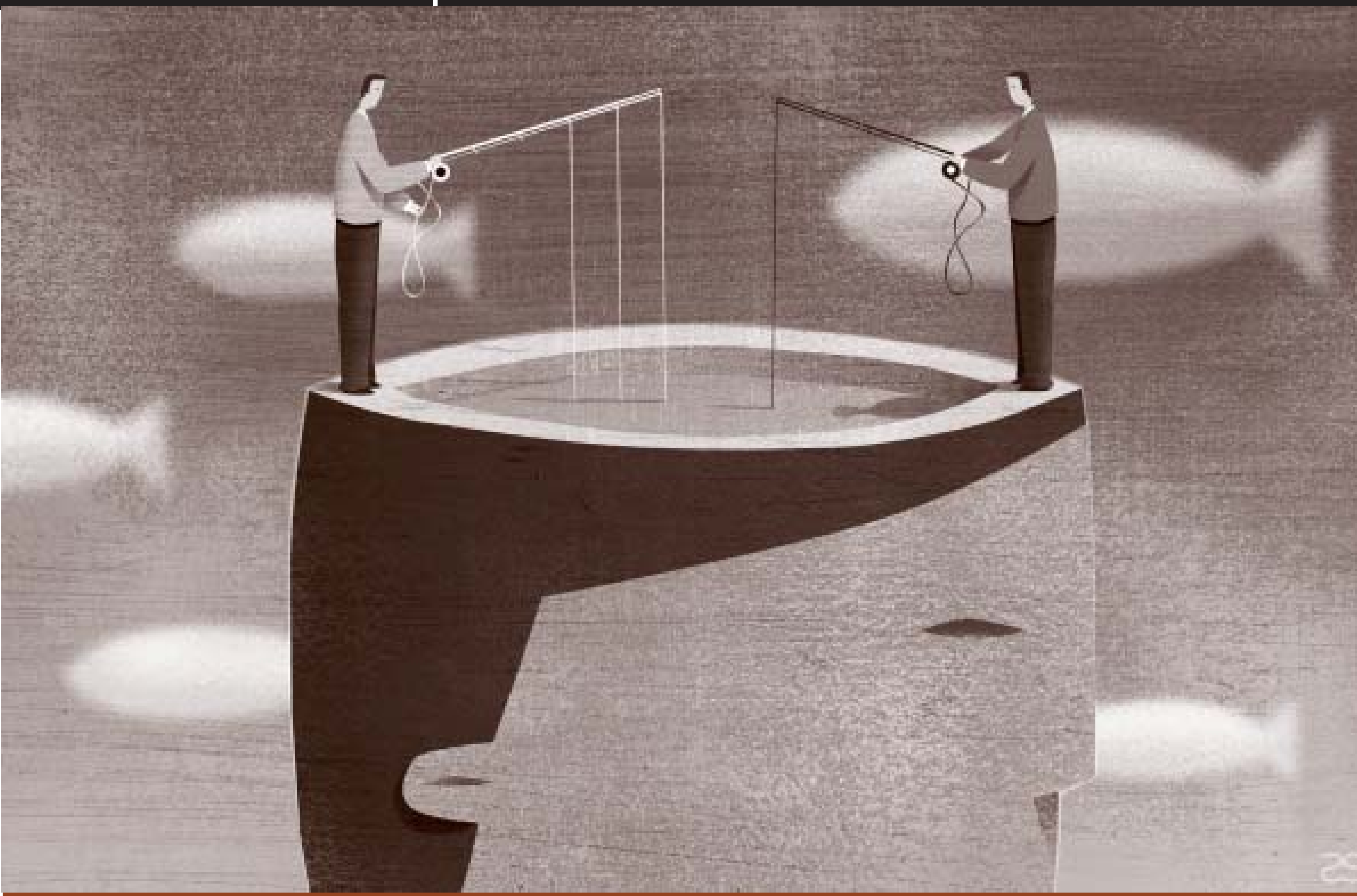
- Seek an understanding of the whole system, rather than the workings of the parts. This is more likely to reveal uncertainties and possible surprises.
- Recognise uncertainty and surprises and experiment with ways to take them into account in open and transparent ways.
- Separate the scientific knowledge from social values that need to be considered in developing policy and taking decisions.
- Build in frequent feedback loops, including communications, to experiment, monitor results, and, if necessary, modify policies accordingly.

Putting this approach into effect requires a shift in environmental inquiry that Robertson and Hull described as 'public ecology'.[60] This approach does not expect scientific knowledge to be perfect or complete. However, it requires that science be produced in collaboration with a wide variety of stakeholders in order to construct a body of knowledge that will reflect the context of the decision, while continuing to maintain the rigor and accountability expected of scientific research. The goal is to build common ground among competing beliefs and values through participatory, democratic processes.

The goal is to build common ground among competing beliefs and values through participatory, democratic processes.

Public ecology asks that professionals share with a larger community of stakeholders the responsibility of defining the problems, the research needs, the decision process, and the content of the deliberation surrounding environmental issues. In this science/policy arena, uncertainty is not banished but is managed, and values are not presupposed but are made explicit. How this might be done is explored in the next chapter.

CHAPTER 4 Responding to new dynamics



There is no bias-free position; there is no knowledge untainted by the institutions that promote it; there is no cosmic exile. But what we can do is concede that this is how things are, and that the inevitable contradictions and contentions in this state of affairs lead not to chaos but to an essential pluralism.[1]

In Chapter 3, the concepts of complexity and uncertainty as they relate to environmental science and policy were described. We proposed that the complexity of large human-nature systems is such that they involve deep uncertainties, a variety of legitimate perspectives and are rarely amenable to effective analysis using the standard research of single-discipline, reductionist science.

Further, there is an intrinsic indeterminism about such systems, which means there will always be degrees of uncertainty about any scientific understanding of how such systems behave, and therefore might be managed. The lesson for doing science, from well-known failures in managing environmental problems, was straightforward, if rather challenging. Science needs to be able to integrate 'the dynamics of change' across broader scales of time and space and to also integrate across disciplines. This is the most likely way of understanding processes that link ecological, economic and institutional responses.[2] Achieving sustainable development requires nothing less. How we go about harnessing science in the process remains a challenge.

Science needs to be able to integrate 'the dynamics of change' across broader scales of time and space and to also integrate across disciplines.

In this chapter we start by revisiting the way policy makers treat uncertainty and suggest an attitudinal change would help. This could improve the way policy is developed and improve the political-public dialogue over contentious issues when uncertainty is a concern. We then examine the broad question of how to make scientific information effective for the development of environmental policy. This leads to considering the roles of institutions. They play a particularly important role by providing the right (or wrong) kind of interface between science and environmental policy makers. From overseas examples we identify the key functions of institutions that deliver effective scientific information. We conclude by examining a specific approach to environmental management (adaptive management) that incorporates many of the ideas on how to research complex environmental problems while using good science and addressing the different needs of policy makers, managers and stakeholders.

4.1 Incorporating uncertainty

Uncertainty, as already discussed in this report, is both a driver for researchers to find out more about the phenomenon under consideration, and a source of tension between scientists, policy makers and citizens. The '*improper inference of scientific uncertainty*' may be a major reason for this tension and behind examples of inaccurate translations from science to policy.[3] Scientists, and policy and decision makers, generally approach uncertainty from potentially conflicting perspectives and backgrounds, which reflects their different functions and obligations, as well as different behaviours and attributes. Scientists are familiar with conditions of scientific uncertainty, whereas policy and decision makers often seek certainty and deterministic solutions. The latter are operating under shorter time frames, less willing to accept failure and risk, and are more oriented to service and satisfying specific clients, than are scientists.

There is an alternative to treating scientific uncertainty as a negative element to be marginalized and ignored, if possible, or else used as an excuse for bureaucratic inertia: *'realign the definition of scientific uncertainty as perceived by the public and policy makers with that of the science community'*.[4] This would mean that scientific uncertainty would be treated in the policy arena as it is in scientific circles – as information for hypothesis building, experimentation and decision-making.

What does this realigned approach to uncertainty imply? Policy makers would more readily acknowledge the intrinsic uncertainty about science and knowledge, and would more frequently review policies based on new information, including better monitoring and evaluation information. Decisions would be made based on the best available science and other relevant information, while acknowledging the wider context of uncertainty. They would also recognise that calling for 'faster and better' science for resolving policy dilemmas is inconsistent with the nature of scientific inquiry. Policy makers would need to adopt a more self-critical, reflective, learning approach to policy development. This repeated questioning is a feature of the adaptive management approach described in section 4.6.

There are significant institutional and attitudinal barriers, as well as matters of self-interest, to achieving such a *rapprochement* between science and policy. If these can be addressed, policy makers would have the benefit of new technologies and better tools for decision-making that are emerging. This includes more sophisticated approaches to the use of statistics.[5] There could also be an unintended, but beneficial spin-off from efforts to have policy makers develop more scientifically aligned approaches to formulating policy. It could serve to de-mystify the techniques of science (if not the jargon) that can disempower otherwise powerful and intelligent policy makers and stakeholders.

This approach proposes that we embrace uncertainty, work to reduce it where possible, incorporate uncertainty more transparently in the policy process and recognise the need to develop more sophisticated self-critical policy models in the process. Ravetz developed a similar argument over a decade earlier, in his proposal that we recognise the increasing need to develop policy and take decisions based on what he calls 'usable ignorance'.[6] Rather than posing a Zen riddle by inverting the usual term 'usable knowledge', Ravetz is pointing out something else. He is saying that the big environmental problems of today make it difficult, and often impossible, to rely on science providing unequivocal 'facts' on which to base policies. Instead, we need to respond intelligently to the imperfections of science in forming policy decisions, but in a way that makes sensible use of the available scientific knowledge,

... the big environmental problems of today make it difficult, and often impossible, to rely on science providing unequivocal 'facts' on which to base policies.

in the context of other information.

Ravetz also proposes that, paradoxically, science has led to an exponential increase in knowledge, but at the same time has contributed to our relevant ignorance (see box below). Again his argument is not to delay or procrastinate on decision-making (often by calling for more research), but to have a better policy process with wider engagement, procedures for self-criticism and quality control. Proceeding when ignorance is severe means it is necessary to bring in considerations of prudence, costs and benefits. How these considerations are weighted will depend on values, and those values need to be made explicit. *'In terms of a dialogue between opposed interests, this effectively takes the form of a burden of proof: in the absence of strong evidence on either side do we deem a system safe or do we deem it dangerous?'*[7]

The paradox of science generating ignorance

In the Victorian age, people were totally ignorant of the problem of disposing of long-lived radioactive wastes. They had no such things and could not have imagined their existence. But many countries now have stockpiles of such wastes, thanks to scientific advances. Along with the stockpiles they have the problem of guaranteeing secure storage of them for hundreds of thousands of years. Unfortunately, there remains considerable ignorance about how to do this, and simultaneously resolve the societal, economic, technological and physical issues. Thus we have removed a former ignorance, our knowledge of radioactivity, but in the process created a new ignorance, of how to manage it in all its dangerous manifestations.

In a similar vein, ignorance of the genetic code was replaced by knowledge of the structure of DNA fifty years ago. Subsequent advances ultimately led to genetic engineering and a new ignorance - the possible environmental consequences of releasing genetically modified plants into ecosystems. As with the problem of disposing of radioactive wastes, this new ignorance comes with a range of societal, economic and environmental dimensions.

Official admissions of uncertainty can be more favourably received and trusted by the public than efforts to deny risks exist.

There is another important reason to revisit the way policy makers and agencies respond to uncertainty - the response of the public. Official admissions of uncertainty can be more favourably received and trusted by the public than efforts to deny risks exist. Lord May, President of the Royal Society of London, made the following observations during his address to science and government leaders at Parliament in March 2002. In a time of increased public scrutiny the best way forward is through open and honest public discussion and debate. *'Lay it all on the table, uncertainty and all, and let the individual choose,'* said Lord May.

This approach is exemplified by the way Sir John Krebs, head of the Food Standards Agency in the United Kingdom, handled the question of whether the BSE prion (see box in section 2.2) has got into the sheep population in Britain. His constant response was: *'There is no indication that it has, from the knowledge we currently have. But that doesn't rule out the possibility, because we don't know enough and all I can tell you is that the risk level is relatively low. It's not in many sheep, but it could be there - you choose.'*

Lord May noted: *'Interestingly, the outcome is people trust him because he seems to be telling the truth and this has had very little impact on the lamb industry'.*

As much as this approach may appeal as being intellectually honest and scientifically correct, it is still vulnerable to adverse political environments where uninformed, spurious arguments may derail carefully developed policy.

4.2 Appropriate science for quality policy-making

The challenge is to improve the quality of policy and decision-making in the face of uncertainty and complexity. In this section we look at the kind of science that is needed for these new challenges. At this point we need to acknowledge a difficulty over terminology. The sort of science that is needed in this new environment has been called 'post-normal science' in contrast to the 'normal science' described in Chapter 3.[8] The term implies a qualitative change in the way science and policy-making is approached. It draws attention to aspects of uncertainty and values that tend to be neglected in traditional research. However, the term is not one that is in common use by the science community although it does convey the need to think about science differently. Instead of 'post-normal' science we will use the term 'integrative science' which might be more easily appreciated in the context we are addressing here.

In a later paper Funtowicz and Ravetz argue that the need for a new approach to science comes from the insight that in the sorts of issue-driven science common to environmental debates the facts are typically uncertain, stakes are high, and decisions are urgent. They suggest: *'... the previous distinction between "hard", objective scientific facts and "soft" subjective value-judgements is now inverted. All too often, we must make hard policy decisions where our only scientific inputs are irremediably soft'.*[9]

One way of explaining the perceptual changes that are needed is to look at the role of science along a continuum as decisions become more important, but the amount of uncertainty increases. Thus when 'systems uncertainties' and 'decision stakes' are small, (for example, testing for chemical residues), we are in the realm of 'normal' science, or applied science, and expertise within a single discipline is sufficient. When the system uncertainties and the decision stakes are both medium (for example, major engineering works) then the application of routine techniques needs to be bolstered with skill and professional judgement. It is when system uncertainty is extreme and decision stakes are very high (for example, climate change policy) that an 'integrative science' perspective is more appropriate. The important guiding principle at this point in the policy context is quality, in relation to outcome, rather than an expectation that 'truth' will be achieved through science.

It is when system uncertainty is extreme and decision stakes are very high ... that an 'integrative science' perspective is more appropriate.

Achieving a quality decision when the stakes are high, values are in dispute, and the facts are uncertain, (for example, MAF's decision on whether to import Rabbit Haemorraghic Disease) requires paying as much attention to the process as to the science. There is increasing evidence that for policy making on complex environmental issues that lack neat solutions and require support from all stakeholders, *'the quality of the decision-making process is absolutely critical for the achievement of an effective product in the decision'*.[10]

The RCD decision - science, uncertainty and process issues

In an attempt to reduce the high costs of rabbit control a new and highly contagious virus (called Rabbit Calicivirus Disease (RCD) or Rabbit Haemorrhagic Disease (RHD)) was extensively researched in Australia (in co-operation with New Zealand scientists). This occurred between 1991 and 1995. Two earlier applications by New Zealand farmers to import the myxomatosis virus for rabbit control had been declined.

In 1993, the second decision by the government not to import myxomatosis was linked to the potential of introducing RCD as a more humane biocontrol of rabbits. This was a clear signal to farmers, long frustrated by high control costs and a lack of action on biological control, that more research on RCD, followed by an application to import RCD, was a more acceptable policy option. In October 1995, the RCD virus escaped from Wardang Island, off the South Australian coast where it had been undergoing trials for six months, and spread rapidly on mainland Australia. Its inevitable arrival in New Zealand, accidentally or illegally, was quickly recognised by officials and Cabinet.

The decision to import RCD rested with the Ministry of Agriculture and Forestry (MAF), not with government ministers. MAF was responsible for developing a process for considering the application to import RCD under the Animal Act 1967. There were significant problems with the process MAF eventually used. The outcome of the process included:

- rulings by the Ombudsman ordering release of information
- farming and conservation groups with strongly polarised views
- no public dialogue over the scientific issues
- public confusion over scientific aspects of postulated risks to kiwis
- changes to the process half-way through
- considerable public and private antagonism for many of the people involved.[11]

The first time that all the scientific issues were actually discussed in a public forum involving all the parties, and many scientists, was in March 1998, at a conference organised by the NZ Association of Scientists. This was eight months after MAF had ruled against the application to import RCD in July 1997. *'Significant uncertainty as to* *the likely effectiveness of the virus*' and concerns over how risks might be managed were two of the three principal reasons for MAF declining the introduction. At this time it is highly likely that the virus had already been imported illegally, for it was discovered on Otago farms, less than two months later, in August 1997.

With hindsight, the RCD saga had the classic features of an issue common to 'post-normal' or 'integrative science' - the stakes were high, there was uncertainty about the facts, and a decision was urgent. In such circumstances, quality of process is essential for good outcomes. However, the reality was quite the reverse. This case study also provides a good example of the problems that arise in communicating risk issues when there is strong conflict of interest, a perceived inequality of the distribution of risks and benefits, and high uncertainty both in the risks and the benefits. It also illustrates the difficulty in communicating complex scientific information when positions have already become entrenched.

Funtowicz and Ravetz take the idea of stakeholder input in situations that call for integrative science beyond a matter of simply broadening democratic participation. This proposes a significant break from past practice. They suggest that complex policy problems require new processes. Quality, in this context, requires open dialogue between all those affected, something they call an 'extended peer community'. Although this would involve non-scientists in addition to those from institutions and agencies, it should not be seen as diluting or politicising science. The varied structures that constitute extended peer communities have an important element in common: *'They assess the quality of policy proposals, including a scientific element, on the basis of whatever science they can master during the preparation period. And their verdicts all have some degree of moral force and hence political influence'.*[12]

Forms of extended peer communities have already been used, such as citizen's juries, focus groups, multi-stakeholder working groups or consensus conferences, in a number of countries, particularly in Europe. A limited version of an extended peer community was the Climate Change Working Group set up by the Government to review the range of policy options for least cost means to meet New Zealand's net emission reduction commitments. It included private sector members as well as officials, to consider complex policy issues as well as economic analysis.[13] Likewise, stakeholder participation is a complex process of ongoing engagement that has required research agendas of its own. In New Zealand, participatory processes have been explored, for example, to influence people's behaviour to improve environmental management[14] and to enhance the contribution by scientists to the sustainability of farming systems.[15]

The proposed integrative science approach, involving non-scientists, should not be taken as an attack on recognised scientific experts, nor on the importance of research, but as providing assistance to help deal with the class of extraordinary problems now facing environmental policy makers. This new approach, exemplified also in the later section on adaptive management and boundary organisations (section 4.5 and 4.6), indicates some of the innovative ways in which science and policy makers are addressing complex issues. In doing so, they are helping to change the way we view, and respond to, complexity and uncertainty in the real world.

4.3 Making scientific information effective

What are the characteristics of information that is most effective for linking science and decision-making? A growing body of international research on the role of science and technology in environmental and sustainable development issues suggests there are three critical characteristics necessary for scientific information to be effective in influencing social responses to public environmental issues.[16] The information needs to be:

... information needs to be ... credible, salient and legitimate

1. **Credible**. The information is perceived by relevant stakeholders to be scientifically accurate and technically believable.
2. **Salient**. The assessment is relevant to the needs of policy and decision makers.
3. **Legitimate**. The information is the outcome of a process that is seen as procedurally unbiased and fair.

The challenge to the policy maker comes in achieving a balance, or trade-off, between these attributes of scientific information. Bringing more stakeholders to the table may well increase salience, but could decrease credibility if scientists question why non-scientists are involved. These three characteristics of effective scientific information are briefly elaborated, and then the organisational question of which systems promote credible, salient and legitimate information will be explored in section 4.4.

Credibility of information is essential for setting policy and decision-making, but attaining it is becoming an increasingly difficult task. The relevant stakeholders include scientists as well as the non-science stakeholders. Credibility of scientific information to the relevant science community has been achieved historically by publishing research findings in peer-reviewed scientific journals and by a number of scientists working on, and testing, the same ideas.

Including scientists as stakeholders requires some elaboration. Usually, scientists and technologists are regarded as separate from the process, in the sense that historically they have been seen as providing the science that others use. By regarding them instead as players in a more iterative process, they are both doing science and contributing to the dialogue with other stakeholders about what science should be done. In this context scientists can be regarded as a particular class of stakeholder.

Establishing the credibility of scientific information for non-science stakeholders is more complex and difficult, but no less essential. Indeed, given recent lessons from biotechnology, a perceived lack of credibility on the part of relevant stakeholders has been at the heart of public concerns and suspicions over major environmental issues, sometimes including public suspicions of the credibility of science.

Establishing the *salience*, or relevance, of information to policy and decision makers is an obvious requirement that is not always met. Failure to provide salient information can often be traced to poor communication between experts and policy makers and a lack of understanding between experts, stakeholders and policy makers. When the linkages between scientists and policy-making communities are poor, the outcome is likely to be scientists who assume they know what questions are salient to decision makers, or decision makers who assume that the questions that are relevant to them are ones that scientific experts can credibly answer. 'Hit-and-miss' outcomes, with information of low relevance, are more likely when the structural linkages between the providers of scientific research and the policy/decision-makers are filtered, occasional, and competitive.

'Hit-and-miss' outcomes ... are more likely when the structural linkages between the providers of scientific research and the policy/decision-makers are filtered, occasional, and competitive.

Establishing the *legitimacy* of scientific information in this context is not to question the competence or integrity of research scientists and their results. Rather, it is to ask if the process that determined what research should be done was transparent and inclusive, directed to the issue, and 'fair' in the sense of not favouring the interests of a particular party. This is consistent with some of the critiques of adaptive management discussed later in section 4.6.

Christchurch and air quality - the politics and the science

Concern about air quality in Christchurch has a considerable history. The first known press report published on smoke nuisance in Christchurch was recorded on 9 August 1869.[17] The problem is worst during the winter, exacerbated by the geography of the region and the resultant temperature inversion that occurs. Air pollution comes from a number of sources. The one most relevant to human health is 'suspended particulates' (PM_{10}). Excessive concentrations of PM_{10} are associated with numerous health problems, ranging from increases in the number of colds, to the worsening of existing respiratory and cardiac problems (particularly among small children and the elderly). PM_{10} accounts for up to 70 premature deaths every year.[18] Ninety percent of Christchurch's measured PM_{10} is from burning coal and wood in open fires, coal burners or log burners.

Reports and studies on the causes and effects of Christchurch's poor air quality in winter go back to 1959. They all indicate a problem of smoke (particulate matter or PM_{10}) from domestic fires. Despite Environment Canterbury (Canterbury Regional Council) having extensively researched, monitored and analysed the problem, since the Resource Management Act 1991 reformed the management of air quality, there has been no significant reduction in levels of particulate matter in Christchurch air. The guideline limit of 50 micrograms per cubic metre continues to be exceeded on 30 occasions per year, on average.

Environment Canterbury published and sought comments on two discussion papers on air quality issues in 1993 and 1997. The Council then adopted a draft air plan in June 1998. A decision by Environment Canterbury in 1998 to introduce a ban on the use of coal was challenged in the Environment Court and subsequently referred to the High Court for a judicial review. The High Court quashed the Environment Canterbury decision to ban coal, not on the merits of such a ban but on the basis that the process used by Environment Canterbury (section 369(11) of the RMA) was invalid.[19]

In May 2001, Environment Canterbury decided not to receive or adopt the draft air plan and associated s32 RMA report (cost benefit analysis). The council asked for further reports on the social and economic impacts of the proposals in the draft plan (i.e. solid fuel ban and the phase out of solid fuel burners by 2020 and whether this was necessary). The council also wanted further consultation on the proposals.

Despite the scientific and medical evidence, social and economic factors continue to dominate the debate. A firm commitment to a plan of action remains in the future. It could be 2020 before any improvements in Christchurch's air quality become evident.

4.4 Systems that provide effective scientific information

> ***A key constraint to the emergence of strong sustainability institutions is the fragmentation of research into disciplines, government units into sectors, and so on.***[20]

Environmental policy is made within organisations. In New Zealand, these range from central government departments, such as the Ministry for the Environment (MfE), the Department of Conservation (DoC), the Ministry of Agriculture and Forestry (MAF) and the Ministry of Fisheries (MFish) to the regional councils. The research capacity of each of these organisations varies considerably, as does the extent to which they rely on in-house or contracted research (see appendix 4). However, they all face the same two challenges - getting complex science done for complex problems (section 3.2) and making the scientific information effective in assisting the policy and social responses. The latter challenge requires getting the 'right' science done and using it to shape environmentally sustainable policies that stakeholders and decision makers support and implement.

... getting the 'right' science done and using it to shape environmentally sustainable policies

What sorts of organisations or systems are best able to provide effective scientific information for decision-making? (Some examples of science-policy systems are outlined in appendix 6.) The goal is information that is recognised as credible, salient and legitimate to providers (scientists), users (policy/decision makers, management agencies) and stakeholders (for example, landowners, environmental advocates). As part of the Harvard University's Social Learning Project, 30 international case studies of efforts to mobilise science and technology for sustainable development were analysed.[21] The analysis suggested that efforts are more effective when they manage boundaries between knowledge and action in ways that enhance the credibility, salience and legitimacy of the information they produce. Three specific functions were identified as making the most important contribution to 'boundary management', namely communication, translation and mediation.

4.4.1 Communication

> ***Active, iterative and inclusive communication between experts and decision makers proves crucial to systems that mobilise knowledge that is seen as salient, credible, and legitimate in the world of action.***[22]

One-way communication, in either direction, reduces effectiveness, as does communication that is infrequent or only occurs at the beginning of a project. The latter situation means that scientists address yesterday's problems (and provide non-salient, irrelevant information) or else policy makers get yesterday's knowledge (and receive non-credible information). There is also a decline in effectiveness when stakeholders feel excluded from relevant discussions on how the knowledge is to be used. *'Excluded parties often questioned the legitimacy of the information that emerged from the ensuing conversations, regardless of the information's salience or credibility'*.[23]

Science-policy relationships

A report on the integration of science and policy in Canada's public service emphasised the need for a strong relationship between the science and policy decision-making capacities within government.[24] The best way to achieve this was considered to be by integrating science and policy functions around key issues to encourage joint efforts to solve problems. The report uses the analogy of scientists and policy analysts needing to function as a sports team. In this way they support each other to achieve goals, rather than operate as individuals in a relay event in which the scientist completes a piece of work and then passes it on to a policy person to complete the next leg, and so on. Science-policy communication, the report points out, needs to be regular and informative, and in pursuit of shared goals.

An example of an effective science-policy relationship, which we came across during the course of this project, was that between Environmental Science and Research Ltd (ESR), as the science provider, and the Ministry of Health, as science purchaser. Not only does this combine both biophysical and social sciences in controversial topics such as fluoridation of community water supplies,[25] but the Ministry's contractual arrangement (or partnership) with ESR for scientific services means that the ESR's areas of expertise are always available to the Ministry.

Effectively, ESR becomes the technical arm of the Ministry's environmental health policy group. In this relationship policy-relevant science is produced, emerging environmental health issues are identified enabling polices to be proactive, and the implementation of policies (and the associated science) is monitored and assessed for their effectiveness.

This partnership approach, linking scientific research to environmental health policy-making needs, has resulted in initiatives such as:

- Guidelines for preparing public health risk management plans for drinking water supplies. It is proposed that such plans will become mandatory under new legislation to strengthen drinking water management.[26]
- Guidelines, jointly prepared by the Ministry of Health, Ministry for the Environment and ESR, for managing the health effects of radio-frequency transmitters. These provide guidance for decision makers on such things as the siting of cell phone towers and other radio-frequency transmission facilities.[27]

4.4.2 Translation

While good communication channels between scientists and decision makers are crucial, it is also a given that the participants in the resulting discussions can understand each other. This is not always easy or straightforward. Scientific jargon, as well as different experiences and presumptions about what constitutes a persuasive argument, often combine to obstruct mutual understanding. When these differences are recognised, it is necessary to provide the 'translations' that lead to mutual understanding. Part of this problem is the gap that exists between the views of scientists and policy makers on what information is credible.

For example, fishers might believe from their catch records that fish are relatively plentiful, which leads them to distrust the computer models of scientists that suggest that fish stocks are on the verge of collapse. At a deeper level than disagreements about 'facts' is an inability to understand the other side's claims to knowledge or criteria of credibility. Issues of translation are often more pronounced when managing boundaries is also required to take place between different cultures.

Issues of translation are often more pronounced ... between different cultures.

4.4.3 Mediation

Translation helps the flow of information between experts and policy/decision makers when languages, histories and usages divide them. The next stage beyond that is to recognise the common need for environmental policy and decision makers to make tradeoffs among salience, credibility and legitimacy. Conflicts in the effort to reach acceptable balances will not necessarily be resolved just by improving understanding.

The research shows that getting to workable and effective outcomes often requires active mediation of those conflicts. In the international case studies, mediation appeared to be the most important function in making the role of science 'legitimate' while also retaining adequate levels of salience and credibility to various interests. Mediation worked by '*improving the legitimacy of the process through increasing transparency, bringing all perspectives to the table, providing rules of conduct, and establishing criteria for decision making'*.[28]

Mediation can be a difficult process.[i] In this model the connecting link has ongoing obligations. When it works well it acts as a selective filter for the boundary between scientists and decision makers (for example, getting the research needs of users to researchers), while keeping it closed to others (for example, keeping politics out of research activities). Failed mediation might create too rigid a boundary that keeps scientists too segregated from decision makers. Scientific credibility is retained, but the results can lack salience with local decision makers. Alternatively, the boundary might be too loose. For example, assessments of Canadian fish stocks have been questioned as to their scientific credibility because they were widely seen as excessively vulnerable to the influence of the decision makers.[29]

New Zealand may soon be facing a similar challenge to the credibility of fisheries research with the transfer of significant research responsibilities to the fishing industry to determine fish stock levels. Questions about the credibility of the science as well as the legitimacy of the process have already been expressed by conservation organisations.

How these three functions can effectively work in practice is summarised in the following case study on the management of water resources in Nebraska. The agency managers and agricultural extension agents helped to *mediate* between the hydrological modellers and the farmers. They also made information *salient* to users while making sure that scientists could use peer review to maintain the *credibility* of their research. This mediation led to a process that was accepted as *legitimate* by most of the stakeholders, and gave different interests and perspectives standing in the scientific endeavour of finding solutions for better management of critical water resources.

Effective management of the High Plains Aquifer

Stretching over 1,300 km north to south, and covering eight States, the High Plains Aquifer in the central USA is a critical groundwater system to the economic and ecological health of the region. It is a central concern to the well-being of Nebraska.

In the early 1970s, to address various threats to groundwater (over-pumping, contamination, and droughts), Nebraska formed Natural Resources Districts (NRDs). Each NRD is a local management agency, based on watershed boundaries, with broad authority to research and regulate natural resource use and to provide environmental protection.

[i] This is not 'mediation' in the common meaning of resolving a dispute between two parties. It is related more to the dictionary meaning of mediation as 'forming a connecting link'.

Harnessing science to aid decision-making is an integral feature of each Natural Resource District. In addition to their own scientists, there are legislative requirements to avoid duplication of surveys and research by co-ordinating such studies in co-operation and co-ordination with the University of Nebraska. There is also close collaboration with the scientific resources of the U.S. Geological Survey, the U.S. Department of Agriculture's Agricultural Research Service, and private firms. Use of the USDA's extension system is central in many of the initiatives that help to translate research results for end users.

How does this work in practice? To study ground water depletion and resolve related management issues in one area, the local NRD convened meetings of many players with different perspectives - farmers, feedlot owners, managers, economists and hydrologists. The NRD helped parties who normally don't communicate with each other to share ideas. NRD staff translated information, mediated discussions about how to establish credibility of information and helped the different parties to agree on methods for proceeding. In this case, they decided the US Geological Survey would use its standard peer review process, the university researchers would publish in their respective fields and the outputs from the scientific model-building efforts would be vetted by the elected NRD board and at public meetings.

The result is an evolving management model that is felt to be salient, credible and legitimate. This means that it answers the questions that matter to managers and water users. It accurately reflects the small-scale and large-scale dynamics of the aquifer as judged and tested by the scientists. The process was transparent and inclusive, with the stakeholders engaged at appropriate times. *'The model has been effectively used to determine regulations, test the impacts of regulations, educate water users and decision makers, and plan future management efforts.'* The result is a learning system in which the specific interests and contributions of the different players are acknowledged and integrated into a well-defined, accepted and transparent process.[30]

4.5 Improving the interface: boundary organisations

The Natural Resource Districts in Nebraska play the intermediary role of what have been described as 'boundary organisations', i.e. organisations that are able to provide the 'boundary management' functions described above - communication, translation and mediation. These are organisations that can act as effective intermediaries, providing the connecting link between science and policy-making, and as a conduit of information to and from stakeholders, as illustrated in figure 2.

... boundary organisations ... the connecting link between science and policy-making

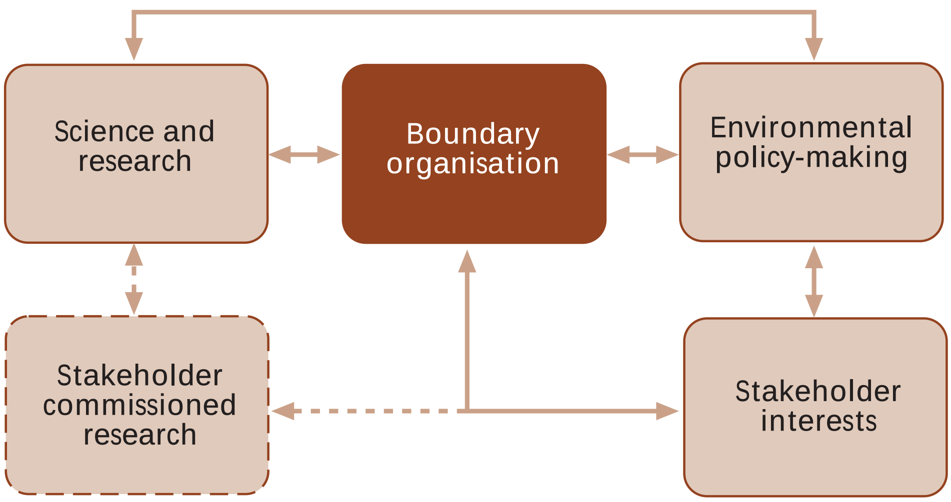
Boundary organisations perform work that is useful to both sides of the science-policy boundary. They have been described as '*institutions that straddle the shifting divide between politics and science*'. Their incentives for action and the demand for their outputs come from both the political and scientific communities. Consequently, they act to *'facilitate the transfer of useful knowledge between science and policy'.*[31] The role that boundary organisations play is distinctive and would be difficult, if not impossible, for organisations in either community to fulfil.[32] Some of the varied functions that successful boundary organisations perform include:

- negotiating the boundary between science and policy
- providing accountability on both sides of the boundary
- translating scientific information from scientists to policy-makers
- communicating research needs from policy makers to scientists
- protecting scientists from accusations of bias or illegitimacy, while protecting policy makers from accusations of technocratic intrusions
- coordinating information production
- transferring information, but avoiding ‘doing policy’ or telling users what to do with the scientific data
- providing neutral forums for debate and dialogue
- facilitating the long-term development of trust between the policy and scientific communities by being factual and empathetic
- encouraging adaptive management.[33]

Boundary organisations have three particular features:

1. There are specialised roles within the organisation for managing the boundary.
2. They have clear lines of responsibility and accountability to interested parties on both sides of the boundary (i.e. science providers and policy makers).
3. They provide a forum in which information can be jointly produced by parties on different sides of the boundary, through what is termed ‘boundary objects’ (see over).

Figure 2: The boundary organisation



Boundary organisations demonstrating the full range of functions ... do not yet exist in New Zealand

Making the connections

Boundary organisations play a key role facilitating effective communication between parties, performing tasks useful to both sides and ensuring that information provided to parties is credible, salient, and is gathered via a legitimate process. The European Environment Agency (EEA) is an organisation that regards itself has having a boundary-like role. The EEA provides decision makers, such as the European Commission, with information to enable sound, effective policies to be made that protect the environment and support sustainable development throughout Europe. The EEA aims to produce timely, targeted, relevant, and reliable information to policy makers and the public resulting from a process that involves accumulating, analysing and reporting on data regarding the state and direction of environmental quality in the European region.[34]

Technology assessment bodies (discussed in section 3.5) can also fulfil boundary functions. The former congressional Office of Technology Assessment (OTA) in the USA built a reputation as a politically neutral institution that provided technical advice on policy problems. It survived without being politicised through having dual accountability to both Republicans and Democrats on its governing board and to its congressional users. Being equally responsive to both political parties, OTA was able to internalise partisan differences, negotiate them for each study and produce a 'boundary object' or standardised package that either party could use for its own purposes.[35]

Boundary organisations demonstrating the full range of functions described in this chapter do not yet exist in New Zealand (to our knowledge). However, there are undoubtedly organisations that exhibit boundary-like functions, facilitating better relationships between the science community and the user communities. Two such examples are provided here.

The Royal Society of New Zealand is accountable to government and the wider public to whom it provides advice and promotes awareness, knowledge, and understanding of science and technology.[ii] The Society is also directly accountable to its membership of scientists and technologists and has a role in encouraging, promoting and recognising excellence in science and technology. The Royal Society provides an independent voice for New Zealand science and technology research and practice, and enables scientifically credible and salient advice to be provided to the government on important public policy issues.[36]

Landcare Trust is a non-governmental organisation that facilitates sustainable land management and biodiversity enhancement through community involvement, throughout New Zealand. Landcare Trust is accountable to the Ministry for the Environment to facilitate the Sustainable Land Management programme, and to the private sector and communities that are involved in achieving *'real action on the ground for biodiversity enhancement in New Zealand'*.[37] Responsibilities of Landcare Trust in undertaking this work in 2004/05 include:

[ii] The Royal Society was first established in 1867 as the New Zealand Institute. The most recent statute relating to the organisation is The Royal Society of New Zealand Act 1997.

- assisting and encouraging the establishment and maintenance of landcare groups by providing support through trained coordinators, developing information networks and working with industry groups
- fostering links between research providers and research users with an interest in sustainable land management research
- providing opportunities for, and encouragement of the dissemination and exchange of technical and scientific information.[iii]

These examples illustrate some boundary-like functions already being performed by New Zealand organisations.

A survey of organisations that were most effective at managing boundaries between experts and policy/decision makers found that the most important institutional features were:

1. **Treating boundary management seriously**. If this was done well, by investing in communication, translation and mediation functions, the outcome was a more effective balance between salience, credibility and legitimacy in the information they produced.
2. **Dual accountability of boundary managers**. Institutionalising accountability of boundary managers to key actors on both sides of the science/decision making boundary was found to be crucial in building effective information flows. Dual accountability meant that boundary managers were forced to address the interests, concerns and perspectives of actors on both sides of the boundary. For example, Nebraskan agricultural extension officers were duly accountable by working under contracts (which could be cancelled) to the local management district, while also answering to the academic departments and universities with which they were affiliated.
3. **Use of boundary objects**. The third important feature for managing the boundary between experts and decision makers involves the joint production, by experts and decision makers, of models, scenarios and assessment reports. Producing these 'boundary objects' requires collaboration across the boundary. The outputs '*are both adaptable to different viewpoints and robust enough to maintain identity across them*'.[38] The process of collaboration engages end-users early on in defining what information is needed and is therefore more likely to produce salient (relevant) information. It can also enhance legitimacy by providing multiple stakeholders with more transparent access to the process of producing information. The complex management of acid rain problems in Europe provides a useful example of the value of boundary objects.

[iii] Landcare Trust's responsibilities are outlined in Vote Environment in the 2004 Budget.

Developing a boundary object

During the 1980s, European countries with acid rain problems used their own experts to defend their own negotiating positions and to cast doubt on the expertise of others. Scientific assessments of the problem were not accepted between countries, and consequently, political agreement on appropriate action remained elusive. As a way forward the International Institute of Applied Systems Analysis (IIASA) worked with policy makers and scientists from several countries to construct and apply the Regional Air Pollution INformation and Simulation (RAINS) model. Constructing the model required the efforts of researchers from various disciplines to work together to produce a more credible model of acid rain deposition and impacts. The country delegates who were negotiating emission reduction protocols were also linked into the model development process.

The outcome was the production of scientific information that was more salient to the policy debate. The RAINS model became a boundary object that helped the discussions among parties with multiple interests regarding differences in perspectives, methodology, values and desired outcomes. The numerous iterations while the RAINS model was constructed, revised and then applied, required a level of communication between the scientists who produced the model and the users of the model. This meant its information outputs *'... were salient to negotiators, credible to scientists of all nations, and legitimate in not favouring the interests of any particular country'*.[39]

In summary, these case studies show that large, complex, environmental issues that cut across local jurisdictions, and even across countries, can be amenable to resolution in practice. They also show that producing effective scientific knowledge that policy makers will use is a complex process that goes well beyond the traditional sequence of problem-identification, followed by research, leading to findings that go directly to policy and management decisions. Scientists, policy makers and decision makers are required to play more diverse roles to produce credible, salient and legitimate information on which decisions can be taken with confidence.

One of the challenges is achieving adequate levels of acceptability for all three criteria. This may require a careful balancing of trade-offs. If this can be achieved, then it is possible to produce effective scientific information for complex environmental policy issues that also has the support of stakeholders.

4.6 The adaptive management approach

Many of the issues involved in researching complex environmental problems and providing effective scientific knowledge are features that suit the adaptive management approach to environmental management. This has been developed over the past 30 years. It is not the only approach to underpinning environmental policy with science, but it does demonstrate, in its strengths and weaknesses, many of the central ideas that we have discussed in this report.

In order to incorporate science into policy when systems are complex and research cannot provide all the facts, two conditions need to be met. First, is the goodwill of individuals from science and policy communities. Secondly, an openness to work across boundaries needs to be agreed to by both scientific disciplines and political institutions. The latter condition is more complex and difficult to meet. This is especially the case when resolving some problems that can threaten not only institutional or discipline values, but may also undermine the institutions themselves. One way of working across scientific boundaries and political agencies is adaptive management.

The idea of adaptive management as applied to natural resources began at a workshop in 1974. It was as a deliberate attempt to use interdisciplinary teams of scientists and resource managers to develop an adaptive approach to environmental impact assessment and management. The focus was on the needs of policy makers and managers.[40]

A decade later, the approach was further refined and described.[41] Carl Walters, one of the founding fathers has described the term as referring to '*a structured process of "learning by doing" that involves much more than simply better ecological monitoring and response to unexpected management impacts'.*[42]

There are two steps in the adaptive management process:

The first step is to integrate existing interdisciplinary experience and scientific information into dynamic models that attempt to make predictions about the impact of alternative policy options. There are three important functions that the computer modelling phase is intended to serve. First, it aims to clarify the problem and improve communication between scientists, managers and other stakeholders. Second, it can screen out policy options that are least likely to be useful. Third, it identifies key gaps in knowledge that make the model predictions suspect.

The second step in the adaptive management process is to design management experiments. This generates a whole new set of management issues about how to deal with the costs and risks of large-scale experimentation. The normal prerequisites of experimental design (replication, randomisation of treatments and untreated controls) have to be part of these experiments. It is important to note that the range of players that should be involved in these steps, including policy staff and stakeholders, extends well beyond the scientists that may ultimately carry out the field experiments. This phase therefore explicitly recognises the value of scientific information and techniques and also acknowledges the relevance of the differing perspectives and values of stakeholders.

...the range of players that should be involved ... extends well beyond the scientists that may ultimately carry out the field experiments.

The adaptive management model has now been applied widely to a diverse range of problems. These have included: testing effects of fishing on Great Barrier Reef ecosystems, policy planning for major river systems, restoration of the Florida

Everglades, fisheries management, restoration of lake systems, and the manipulation of forest dynamics.[43]

In New Zealand, adaptive management experiments are underway to help identify optimal strategies for possum management, following the development of computer models of the interactions between the pest, its forest foods and management.[44] Adaptive management has sometimes been misinterpreted as simply a type of experimental management, but to do so fails to acknowledge the social and political perspectives of a problem. It also has applications in the agricultural sector. For example, the dairying business has been concerned about issues of water quality, impacts on riparian values and water extraction for pastoral development.

Adaptive management has sometimes been misinterpreted as simply a type of experimental management.

Adaptive management experiments will include a monitoring component to determine the effectiveness of the experimental treatment over time. Ideally, this will lead to new and more effective management interventions. At that point, monitoring of environmental conditions, at appropriate scales, will determine the overall benefit of such experiments. Monitoring of adaptive management experiments will also contribute to 'state of the environment' reporting, which in turn informs policy-making. However, as indicated earlier (section 1.2), state of the environment reporting at a national level is not being done on a regular, systematic basis in New Zealand.

4.7 How adaptive is adaptive management?

Despite its theoretical soundness, integrative appeal, and emphasis on maintaining the rigor of scientific experimentation, the actual process of implementing adaptive management approaches has not had a high success rate. Walters analysed 25 exercises in adaptive management of riparian and coastal ecosystems, few of which eventually led to well planned, large-scale experiments.[45]

Implementing adaptive management can be costly. However, the four barriers that Walters identified were mostly institutional, not scientific. They were:

- a failure to move from modelling to large-scale field experiments
- the costs and risks of large-scale management experiments
- self-interest in research and management organisations
- deep conflicts over values within the community of ecological and environmental management interests.

Over a 20-year period, Walters had found that agencies often had *'the belief that the pretence of certainty is necessary to maintain agency credibility'*. Admitting uncertainty was apparently viewed as an admission of weakness and agency staff assumed that, as a consequence, the outcome would be inaction or ineffective compromise policy. Both positions reflect the normal view of uncertainty as something to be ignored or minimised, a fear that uncertainty is likely to induce paralysis. We discussed the benefits of changing institutional responses to uncertainty in section 4.1.

Interestingly, the conflict over ecological values was stronger among interest groups representing different ecological values than with development interests. These value conflicts were particularly intense where historical development had created new ecological values. A well known New Zealand example of clashes over ecological values is the conservation debates over the most appropriate management of introduced mammals. Some hunting organisations, on the grounds of recreational values, have strongly opposed science-based recommendations for the management policies for Himalayan thar and red deer, while conservation organisations have condemned the same policies as not rigorous enough, arguing from values focused on protecting indigenous biodiversity.

In a review of adaptive management from a social scientist's perspective, Lee suggested that one reason for the low success rate might be the sequence of setting up the collaborative structure between affected interests after the agenda for the adaptive approach has been set.[46] Lee proposed that the disputing parties should agree on the agenda of questions to be answered before moving any further into the technical process of devising the experiments. While it may place the process at risk by complicating the initial bargaining phase, it may also increase the legitimacy of the process, an important criterion we discussed in section 4.3. Processes that are not perceived as legitimate by all affected parties are less likely to lead to acceptable outcomes, regardless of the quality of the science.

This is also consistent with the plea for a public ecology (section 3.7) that values the participation of extended peer communities in policy debates while maintaining the rigor and accountability of scientific knowledge. What is needed, suggests Lee, is *'... creative thinking about how to make adaptive management and social learning an irresistible opportunity, rather than a threat to various established interests'.*[47] An interesting and thoughtful effort to work in this way is the adaptive co-management research into the sustainability of a traditional harvest of titi (sooty shearwaters, muttonbirds) by Rakiura Maori. Muttonbirders initiated this study, which has been underway since the early 1990s.[48]

In a similar vein, a number of critique papers indicate that the challenges to improving the application of adaptive management are not scientific, but more clearly social and political.[49] Johnson identified three main challenges that emerged from those critiques.[50]

1. **Integrating stakeholders more effectively into decision-making**. A lack of well-defined objectives that reflect stakeholder values seems to result in less support for the process. (Refer to the earlier discussion on the importance of legitimacy of the process - section 4.3.) In addition, managers need to find ways to incorporate the non-scientific knowledge and data that stakeholders possess

into the adaptive management process.

2. **Developing institutions that are amenable to adaptive management**. The tendency in most management agencies is to resist change and seek control of the management functions as much as possible. What might be called for is a new institutional paradigm that sees management agencies not as providers of solutions, but as facilitators and partners with other players to help find joint solutions.

3. **Embracing risk as a part of management**. Adaptive management can help to determine the level of risk involved under different actions and incorporate that knowledge into policy options. This links to the earlier discussion on the attitudes of organisations to uncertainty (section 4.1).

...adaptive management approaches have tackled big environmental problems, have worked across scales of time and space, as well as across interdisciplinary boundaries

In summary, adaptive management approaches have tackled big environmental problems, have worked across scales of time and space, as well as across interdisciplinary boundaries to address ecological as well as economic and social processes, while maintaining scientific rigor and peer credibility. These are all features of the integrative science appropriate for investigating the complex issues of sustainable development. Adaptive management practitioners recognise that complexity, uncertainty and risk are inherent parts of these problems and that most answers will be partial, requiring ongoing testing and modification.

At the same time, shortcomings in the application of adaptive management serve to underline a number of useful points. First, adaptive management requires organisations to be sufficiently self-critical and reflective, and have a willingness to reform and reinvent themselves, as circumstances dictate.[51] This might be a big ask for the larger New Zealand resource-management bureaucracies. Nonetheless, given the relatively small number of our resource-management agencies and their wide policy roles it is a pertinent responsibility.

Secondly, the question of values held by different parties to the issue can be a blockage to progressing a research agenda. This underscores the earlier point that complex environmental issues are not 'just' scientific issues, but also have social, cultural, political and economic dimensions. Unless these are part of the problem definition phase, the process is likely to lack legitimacy for important stakeholders and the outcomes, regardless of their scientific credibility, are less likely to be accepted.

Thirdly, the shortcomings that Lee identified reinforce the importance of the quality of the policy-making process when policy solutions are unlikely to be neat and widespread support is needed.[52]

CHAPTER 5

Forging the links:
conclusions and reccommendations

In science, how much knowledge you give is much more important than how much knowledge you have.[1]

This report has attempted to show that effective environmental policy-making needs to be both scientifically robust and reflect the needs and aspirations of society. In previous chapters we outlined some of the challenges and opportunities facing environmental policy makers, particularly when dealing with complex scientific issues, uncertain environmental outcomes, and significant public and other stakeholder interests.

Responding to these challenges and opportunities is the next step. In this chapter we summarise our findings with reference to the three issues raised at the outset (section 1.1):

- How can science provide useful solutions for complex environmental problems?
- How can more effective use be made of scientific information in environmental policy-making?
- How can institutional and attitudinal barriers to improving the interface between scientists, environmental policy makers and other stakeholders who have interests in environmental policies and their outcomes be overcome?

The chapter concludes with some recommendations for further action.

5.1 Science providing useful solutions for complex environmental problems

Environmental policy-making can be complicated. This is not only because the sometimes complex nature of environmental problems require detailed scientific analysis, but because policy decisions also have to take into account competing social, cultural and economic factors. Each of these is likely to have a major influence on policy choices.

Science and research contribute to environmental policy-making by evaluating risks and identifying options for managing risks. We have discussed examples of situations where science has identified environmental problems, assessed their significance and helped to formulate measures to address them. These problems range in scale and significance from global (for example, climate change and ozone depletion) to local (for example, water quality in Lake Rotoiti and air quality in Christchurch). Scientific activities that contribute to the policy process range from new or ongoing research to operational research, modelling and forecasting, statistical reports and surveys, and environmental monitoring.

Simple solutions to complex problems are invariably wrong.

We have highlighted the important role that science plays in helping to frame the problem. If the problem is poorly defined the subsequent search for solutions may be misdirected. Simple solutions to complex problems are invariably wrong. It is important that relationships between environmental policy makers and science providers is such that it encourages constructive dialogue, well targeted research and useful information at critical times in the policy process.

Structural and funding reforms of the early 1990s, which eroded the science capability of many government departments (appendix 4), need to be kept under review to ensure that the quality and effectiveness of environmental policies are not compromised by any lack of scientific input or scrutiny. It remains to be seen what impact, if any, there will be on environmental policy-making as a result of recent changes to science funding for Crown Research Institutes (appendix 1).

In section 4.4.1 we presented examples of science-policy relationships that promote better policy-making and implementation. We believe that relationships between environmental policy makers and their science providers need to move beyond the simple project specific contractual arrangement and aim for more strategic, long-term alliances. This would enable agencies and their external scientific advisers to operate as a mutually supportive partnership throughout the policy cycle (appendix 3), rather than in a piecemeal fashion. This is particularly relevant to sustainable development policies in which there are multi-dimensional, multi-scale and multi-disciplinary factors to consider (section 3.3.1). As mentioned in section 3.5, relying on occasional ‘snapshots’ of conventional scientific wisdom to develop policy runs the risk of those policies becoming obsolete or disconnected from broader sustainable development goals.

Ways in which science can provide useful solutions to complex problems in the future, and the implications for the science-policy interface, need to be explored further by policy makers, scientists, resource managers and other interested parties. Specific issues to consider include:

- **Reviewing the scientific skills and capacity** needed to carry out the sort of environmental research across the scales of space and time that the complex problems of today and tomorrow require. Where appropriate, further studies on the scale of ecosystems should be undertaken and the information fed back into environmental policy reviews.

- **Exploring opportunities for integrating research across disciplines** to better understand the systems that link ecological, economic, social and institutional processes. This includes examining the present science funding model and whether it inhibits or encourages integrative research. Examples include integrative research into urban sustainability, population-resource scenarios, climate change impacts on primary production industries, and non-point sources of pollution of waterways.

- **Undertaking regular ‘state of the environment’ monitoring and reporting** at the national level to better understand the pressures on the environment, and policy priorities. Managing the environment, like managing the economy, needs to be based on sound information that enables environmental managers to understand what policies and programmes are needed and whether existing ones are working. Without comprehensive, scientifically rigorous and regular monitoring regimes in place, agencies cannot assess the effectiveness of environmental policies or meet international reporting obligations.

5.2 Using scientific information more effectively in environmental policy-making

As outlined in section 4.2, a major challenge for environmental policy makers is to improve the quality of policy-making in the face of uncertainty and complexity. We pointed out in section 4.3 that scientific information for policy-making must aim to be credible, salient and legitimate. We recognise that to achieve all three criteria will be especially difficult in the case of complex problems. This is further complicated by the fact that scientists' and policy makers' interests in each criterion will differ.

In general, scientists will be interested in the credibility of the scientific analysis for policy-making to ensure that it meets accepted standards of scientific inquiry. Policy makers will be interested in the salience of the scientific advice and whether it is relevant to the policy issue under consideration. Where scientific analysis and advice for policy-making occurs within policy agencies, the interest is likely to focus on whether such advice is legitimate (i.e. perceived to be fair from political and stakeholder perspectives).

Once the credibility, salience and legitimacy of scientific advice for policy-making has been established, the next crucial stages are the communication of that advice to policy makers, and the interpretation of the advice during policy development. Misunderstandings and misinterpretations can be avoided by encouraging 'sustained interactivity' (section 2.1.1) between scientists and policy makers throughout the policy cycle. The aim is not simply to have *more* knowledge at the outset, but to provide policy makers with *better* knowledge at all stages of the policy cycle.

The aim is not simply to have more knowledge at the outset, but to provide policy makers with better knowledge at all stages of the policy cycle.

We discussed the benefits of an 'integrative science' approach (section 4.2) for dealing with environmental policy issues where the facts are uncertain, the stakes are high, and decisions are urgent. These are characteristics of situations that generate a great deal of public interest and require processes that not only rely on the effective use of scientific information, but also need to offer opportunities for 'dialogue' to occur (section 3.6.1).

'Sustained interactivity', 'integrative science' and 'dialogue' are terms we have used to describe ways of forging better links between science, policy-making and the public interest, and making effective use of information in the policy process. The strengths of these links and the influence that one sector has on another will vary. For example, while the public have little influence on the type of research that scientists undertake, opportunities exist for them to be involved in how research is undertaken (for example, through ethics committees) and to influence policy makers' use of research.

5.3 Overcoming institutional and attitudinal barriers to improving the science-policy-stakeholder interface

Some of the barriers to a better interface between scientists, policy makers and various sectors' stakeholders, and better policy-making generally, have been outlined in section 2.1.2.

We also mentioned in section 2.2 some principles of good governance that can be used to assess the extent to which environmental policy makers are fulfilling their responsibilities. But above all, the most important aspect of the science-policy-stakeholder interface is the nature and quality of communication between them. We discussed this in section 4.4.

... the most important aspect of the science-policy-stakeholder interface is the nature and quality of communication between them.

Good communication helps to disseminate knowledge, improve understanding and build relationships within organisations, between organisations, and between organisations and affected parties. Examples have been given of methods such as translation (section 4.4.2), mediation (section 4.4.3) and dialogue (section 3.6.1) that help to break down communication barriers and improve the channelling of information.

Institutional options for improving science-policy communication include the boundary organisation idea (section 4.5). Boundary organisations (or organisations with boundary-like roles) are accountable to both policy makers and the science community. They help to maintain scientific credibility while assuring policy saliency, and facilitate the transfer of usable knowledge between science and policy. They enable scientists to maintain an appropriate separation from politically-driven policy processes. A driving factor in these organisations is that, in politically controversial issues, they endeavour to keep facts relevant. However, securing the credibility and authority necessary for an organisation to take on a boundary-like role and attain the respect and trust of scientists, policy makers and stakeholders alike is a major challenge. The concept needs to be explored further and tested in appropriate decision-making situations.

Earlier reports have been critical of the scientific and technical research input to government decision-making in New Zealand (section 2.1.2), and issues have been raised in appendix 4 about the decline of in-house science and research within central government agencies. This suggests the need to take a closer look at the scientific capacities and capabilities within central and local government environmental agencies, particularly with regard to complex science-policy issues. Among the matters to consider are:

- Identifying the range of core scientific skills and capabilities that enable environmental agencies at central and local government to function effectively.
- Reviewing from time to time the scientific skills and capabilities within environmental agencies to determine whether they meet the core attributes necessary to ensure credible, salient and legitimate scientific input to environmental policy-making.
- Reviewing the effectiveness of consultation between scientists, policy makers and stakeholders.
- Reviewing the public accessibility of scientific information used for policy-making.

The Ministry of Research, Science and Technology would be best placed to further explore the ideas mentioned above, and to carry out a systematic review of science capacities and capabilities within environmental agencies, similar to the 'science reviews' mentioned in section 2.1.2. This should include the scientific and technical capabilities within regional councils and how they link with central government environmental agencies to work towards national goals.

5.4 Conclusion

From the outset, this project has been a learning experience. Initially it proved difficult to decide on which aspects of the science-policy-stakeholder interface we should focus in order to encourage dialogue. While we started by examining the role that science plays in environmental policy and decision-making, we soon realised that it was not a question of *whether* science had a role, nor *why* science was important in environmental policy-making. In the last century, science, research and technology made important contributions to identifying serious environmental problems created by human actions, improved the understanding of the causes and effects of these problems, and developed ways to overcome them. Policy responses to scientific findings have ranged from international co-operative efforts to local environmental initiatives. Science and research are, therefore, critical components of environmental policy-making, particularly when dealing with highly complex issues and uncertain outcomes.

We decided that the important question to address was *how* to make better use of science and research, combined with other sources of knowledge, to develop better policies that strive towards environmental sustainability.

We learned that a lot of the issues centre around the need to improve relationships and communications between environmental policy makers, scientific advisers and stakeholders, all of whom have an interest in the inputs to, and the process and outcomes of, environmental policies and decisions. Communication is central to conveying and understanding scientific advice and the concerns of stakeholders. Effective communication fosters better relationships, builds trust, improves dialogue between parties, and contributes to increased public confidence in the policy-making processes. Central and local government institutions have key roles to play in this regard.

In common with other studies that have examined the interface and interaction between science and policy making in a number of countries[2] we conclude that there is no single panacea, best practice, process or institutional arrangement that guarantees an effective science-policy-stakeholder interface in all circumstances. However, we have highlighted a number of approaches to improving the interface and interactions needed to understand and deal with complex and uncertain environmental issues ('understanding the elephant'). They require a commitment by environmental policy makers to developing more effective relationships with science providers and stakeholders, better use of knowledge for policy-making and policy evaluation, and maintaining the capacities and capabilities necessary for environmental policy-making. Accordingly, our recommendations are along these lines and are outlined below.

5.5 Recommendations

It is recommended that:

1. The **Minister for the Environment** establishes a process whereby changes in the state of New Zealand's environment are identified and reported on at regular intervals (at least every five years).

   Explanatory note: Co-ordination of regional information on the state of New Zealand's environment, and regular reviews of such information, are essential for identifying trends in environmental quality and targeting environmental policies. Just as information on factors affecting economic growth is essential for managing the nation's economy, so knowledge of the state of the environment and environmental trends is critical for prioritising and formulating new environmental policies, as well as monitoring and evaluating the success of existing ones.

2. The **Minister of Research, Science and Technology** establishes a process to undertake regular and systematic reviews of central government environmental agencies and regional councils to assess the effectiveness of their scientific and technological capacities and capabilities for environmental policy-making. The results of such reviews should be published.

   Explanatory note: Structural and funding reforms of public good science and research in the early 1990s eroded science capabilities of many government departments. While there have been attempts to redress this, there has not been a comprehensive review of environmental agencies' core scientific needs to undertake their functions. Nor has there been a comprehensive review of whether their systems are effective for ensuring that quality science and research feeds into *environmental policy. Systematic science reviews of environmental agencies would enable deficiencies as well as good practice to be identified.*

3. **Environmental policy makers** (such as central and local government elected representatives and their advisers) consider developing strategic, long-term, formal alliances with science providers to encourage scientific input throughout the policy cycle - from problem identification through to monitoring and evaluation of policy outcomes.

   Explanatory note: We have given an example of an initiative in which the short-term, project-specific contractual relationship between a science purchaser and a science provider has been replaced with a longer-term, partnership arrangement between the parties. This has proved to be largely successful in bringing together the sort of inter-disciplinary research needed to address complex, sustainable development issues that environmental policy-makers face. It also ensures an on-going scientific commitment to the success of policies.

4. **Environmental policy makers** explore options for improving accountability and communication links between scientists, policy makers and the public, including the use of ‘boundary organisations’.

   Explanatory note: Communication is a critical factor in ensuring that, in relation to environmental policy-making, the appropriate science and research is undertaken and that it is policy-relevant. The characteristics of boundary organisations enable them to facilitate the effective transfer of information between scientists and policy makers. In doing so they separate political interests from scientific research, while ensuring that credible, salient and legitimate scientific knowledge flows into the policy-making process.

Appendix 1: Science funding

This project has not set out to undertake an in-depth analysis of the science funding system, nor has it assessed whether the level of environmental research funding is adequate to meet the needs of those who rely on scientific advice for environmental policy and decision-making. However, during the course of this investigation, we noted a number of concerns about some aspects of the funding system, primarily from those who work within the science sector. This is a brief outline of the main concerns, and the Government's recent response to those concerns.

Appendix 2 of the discussion paper *Illuminated or blinded by science?* outlined examples of sources of funding for research and other activities relevant to environmental policy and decision-making. The discussion paper also provided some background to the system of funding environmental research in particular. In New Zealand the public good science funding system is 100% contestable. In contrast, trends in some other OECD countries show that contestable funding (referred to as grants and contracts) in 2000 ranged from about 37% in Canada to 65% in the UK.[1]

Fully contestable funding in New Zealand has raised concerns. These include the potential loss of co-operation between researchers as they have to compete for funds, and uncertainty among scientists and researchers about longer-term employment prospects if their bids fail.[2]

Although overall investment in research and development within New Zealand has continued to rise, New Zealand still lags behind other OECD countries. Total research and development activity in New Zealand is 1.15% of GDP, compared to the OECD average of 2.25%. Research and development funding in New Zealand comes from two main sources: 53% from the Government and 37% from the private sector. Business undertakes 37% of research, tertiary education institutions 30%, CRIs 29% and Government departments 4%.[3]

Total appropriations for Vote Research, Science and Technology in 2003-04 are $556.9 million for the output classes delivered. About 16% of this ($88.62 million) is the environmental research investment. 'Non-specific output funding', which provides institutional funding to CRIs for public good science and technology, amounts to $28.5 million, or 5% of the total Vote Research, Science and Technology.

On 8 April 2004, the Minister of Research Science and Technology announced changes to the science funding system. These changes are expected to provide more stable long-term funding to maintain key research capabilities.[4] The Minister acknowledged the concern about how the lack of long-term certainty over funding can undermine the science sector's ability to develop and maintain particular research capabilities of strategic value to New Zealand, and the difficulty of recruiting and retaining top researchers.

The Government's response was to announce the introduction of a progressive increase in institutional funding ('non-specific output funding') over the next several years. This increase was initially only applicable to CRIs as they rely heavily on FRST funding and have fewer alternative funding sources than tertiary institutions.

Among its 2004 Budget announcements on 27 May 2004 of new funding in research, science and technology, the Government outlined two areas relevant to science in environmental management that will see increases in funding. One is an increase in 'Organisational Capability' funding to help CRIs maintain strategically important new research capabilities. This will increase by $4 million in 2004-05 to $32 million, and by up to $10 million in reprioritised funding in 2005-06, conditional on further policy development.

The other area is 'Environmental Research' funding, which increases by $21 million over four years, with an increase of $6 million in 2004-05 bringing the total for the year to $94 million. Priorities for this new funding include research into sustainable development opportunities, updating nationally important collections and databases, and ecosystems research.[5] Whether or not this level of funding is sufficient to meet current and future needs remains to be seen.

An article in the Royal Society of New Zealand's 'Alert', referring to a presentation by Professor Paul Callaghan to the APEC Forum in March 2004, talked about a *'smart approach to managing the taxpayer investment in science and technology'* being 'capability funding' rather than the current programme funding.[6] Professor Callaghan's suggestion was that *'it is better to invest in organisations to enable them to employ people in long term career paths (with suitable performance measures in place) than to fund proposals for programmes driven by the current fashion of the fund managers. Capability funding provides the base of most New Zealand university funding while programme funding drives the CRIs.'*

Appendix 2: Science in environmental policy and decision-making - institutions and functions

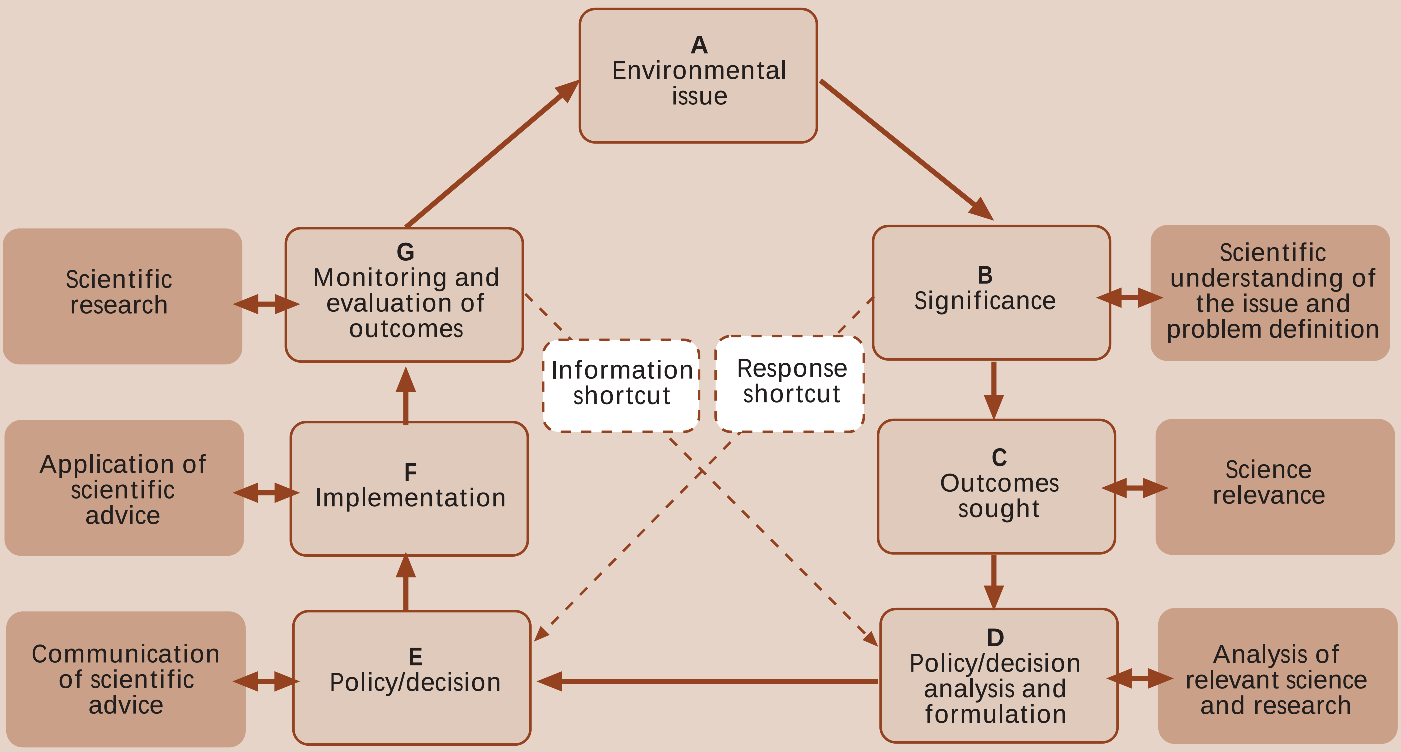
Institutions	Research funds manager	Operational research purchaser	Science provider	Environmental policy	Environmental decisions	Science policy	Resource manager	Sources of additional advice
MfE		x		x				
DoC		x	x	x	x		x	
MAF		x		x				
MFish		x		x			x	
MoH		x						
MoRST		x				x		
Regional councils		x	x	x	x		x	
Territorial authorities		x		x	x		x	
ERMA					x			
Environment Court					x			
FRST	x							
RSNZ	x							x
HRC	x							
CRIs			x					x
Private researchers			x					x
Universities			x					x
Iwi	x			x			x	x
NGOs								x
Industry								x
Regional public health services								x
Professional groups								x
Public submissions								x

Appendix 3: The policy cycle

Figure A3 shows the various roles that science and research play in the policy cycle. Science funding, capacity, capability, structures, and relationships influence the extent to which these roles are carried out. Uptake of scientific advice will depend on identifying the problem, correctly framing the questions for science to address, communication and trust between scientists and policy makers, understanding the capabilities and limitations of science, and time pressures.

The cycle can be regarded as a learning process in which use is made of feedback systems to continually strive towards improving environmental policy-making and environmental outcomes.

Figure A3 Science inputs to the various stages of policy-making



A Identification of the environmental issue

The focus is on identifying issues that impact on environmental sustainability, and may need a policy response, highlighting gaps in knowledge or deficiencies in environmental management, and endeavouring to pre-empt or anticipate problems. Questions that need to be answered include:

- What is the issue and why does it need to be addressed through environmental policy?
- What concerns are being expressed and why?
- What is the primary driver of the issue (e.g. regulatory requirements, international obligations, emerging issues, public outrage, etc.)?

B Examination of the significance of the issue

The purpose is to examine the underlying causes, context and significance of the issue to clarify what is involved and what, if anything, needs to be done about it. Questions include:

- How significant is the issue to environmental sustainability?
- What information already exists, and what additional information is needed?
- What are the consequences of doing nothing?
- What questions need to be asked of whom, and how should the questions be framed?

C Defining the outcomes sought

In some cases, clearly defining the desired environmental outcomes help to determine whether (and how) science can make a contribution. Matters to consider include:

- What needs to be done about the issue?
- Is a policy response required and, if so, what outcomes (or changes) are expected?
- Is scientific advice crucial to formulating a policy and achieving the outcomes sought?

D Policy analysis and formulation

This stage involves gathering information and, where appropriate, commissioning new scientific research, and analysing all relevant information in order to develop policy options. Questions include:

- What is the scientific evidence, knowledge or understanding?
- What additional information is needed (e.g. social, economic, cultural, ethical views, etc)?

- Has all available information been critically analysed?
- What consultation is necessary, with whom and when?
- What are the policy choices?

E Policy-making

This involves consideration of the policy options, the advice and comments received, including scientific advice, uncertainties, other views, experiences and values, and costs and benefits. Matters that policy makers need to consider include:

- What needs to be done and what choices are available?
- Is the scientific advice well communicated, understood, credible and reliable for policy-making purposes?
- What can science not address and what are the implications for policy-making?
- How will the policy account for aspects of scientific uncertainty?

F Implementation of policy

During this stage the implications of putting into effect the policy is determined. Issues to be addressed include:

- How is the policy being applied?
- What difficulties have arisen from implementation?
- What are scientists and policy-makers learning from policy implementation?

G Monitoring and evaluation of outcomes

Monitoring and evaluating the changes brought about by the policy provides feedback to policy makers and their advisers on the success or otherwise of their efforts. Matters to consider include:

- Has the policy achieved the outcome(s) intended?
- Has the policy brought about any unintended effects?
- Has the scientific input been valid and valuable?
- Does the evaluation indicate the need for further scientific research?

In some circumstances a shortcut from B to E may be necessary to respond to an emergency situation, for example, an oil spill or biosecurity incursion. An information shortcut between G and D may be useful to feed up-to-date monitoring information into policy analysis and formulation.

Appendix 4: In-house or contracted science and research within government

Following the public sector restructuring of the 1980s and 1990s, only the Department of Conservation (DoC) retained its previous in-house scientific research functions and capacity. Other departments had their scientific workforce considerably diminished (for example, the previous Ministry of Agriculture and Fisheries), or lost completely to the Crown Research Institute structure (as with the Ministry of Forestry, now part of the Ministry of Agriculture and Forestry).

DoC successfully argued that the nature of its broad management responsibilities justified retention of a strong, in-house research capacity that was essential to underpin and sustain improvements in management functions, such as weed and pest control, threatened species management and ecosystem restoration. Yet DoC is also obliged to purchase a considerable amount of research, particularly from Landcare Research, given its limited capacity in key disciplines, such as mammalian pests and plant ecology. These areas of research had been centred in the Forest Research Institute, the research establishment of the New Zealand Forest Service, and in the Ecology Division of the Department of Scientific and Industrial Research. Both of these research institutions ended up in the Crown Research Institute structure.

Agencies such as the Ministry of Agriculture and Forestry (MAF) rely extensively on contract operational research for scientific advice in support of policy initiatives. MAF's new and additional responsibilities for the overall coordination of biosecurity functions, under the 2003 Biosecurity Strategy,[1] may place further demands on its needs for scientific advice and research. The Ministry for the Environment (MfE) was established in 1986, without an in-house research capacity and needs to purchase any research it requires to underpin its environmental policy work. It is difficult to estimate the level of reduction in scientific capability that occurred across the public sector departments as a whole during the 1980s. Clearly there was a significant move from science and research capability within government departments, to contracted science advice and research.

While DoC is the only central government agency with the combined functions of science provider, environmental policy-making, environmental decision-making and conservation management, the regional councils also have this suite of functions as well (see appendix 2). Since the regional councils have a much greater focus on natural resource management, as prescribed in the Resource Management Act, there are significant differences in the areas of science, as well as some overlaps, that are needed to underpin the work of regional councils, compared with DoC. Like DoC, regional councils are also purchasers of operational research, often from the CRIs.

It has been argued that external sourcing of scientific advice can have the advantages of flexibility (different providers for different issues), choice (contestable advice from a wider number of sources) and cost efficiency (if duplication is thereby avoided between agencies). Alternatively, arguments in favour of building an in-house science capacity include: a closer linkage between scientists and management needs (increased salience of research); more current scientific and research knowledge base; easier access to scientific advice by management and decision makers; and retention of scientific institutional memory. How a department is structured will have a major bearing on the degree to which these benefits are realised in practice. Under the right structure, a strong in-house science capacity could lead to the development of a science-backed culture of environmental management.

Does the in-house or contracted research question matter? There can be negative consequences when 'scientific literacy' is lost within a department. In 1996, a potentially disastrous infestation of the White Spotted Tussock Moth (Orgyia thyellina) occurred in Auckland suburbs. At the time, the government agency responsible for deciding what to do was the Ministry of Forestry. It had lost all its qualified scientists in the reforms of the 1980s and the policy process was vulnerable to 'capture' by scientists.

A study of the events leading to the decision to eradicate the moth suggested there had been a serious imbalance between the contracted researchers and the ability of the Ministry staff to set the policy and decision-making directions.[2] Some senior staff didn't see a need for research in developing a strategy to eradicate the moth, nor was there any anticipatory research in place. With an absence of in-house scientific capability the Ministry's policy analysts and decision makers were effectively unable to define the research questions that needed to be asked. It followed that they were also unable to effectively question the research findings of the contracted researchers. The research scientists, therefore, had a powerful influence on the Ministry's research agenda.

While the final outcome was positive (the White Spotted Tussock Moth was eradicated), this case identified the importance of having scientific capacity within departments with environmental policy and management responsibilities. Without it, who is to effectively judge the adequacy of the science or research in question? This is particularly important for major science and technology issues, when the issue is contentious or a large amount of funding is involved. In these circumstances, salient and acceptable scientific knowledge is critically important for decision makers. It is more likely to meet these criteria when there is in-house expertise to review science and technology for its scientific vigour, usefulness and currency.

Appendix 5: Maori and science

The following is a brief outline of the findings of research carried out by Dr Fiona Cram (formerly of the University of Auckland's International Institute for Maori & Indigenous Education) and written up in Maori and Science: three case studies.[1] The aim of this research was to capture the lessons learned from three examples of successful research collaborations between science providers and tangata whenua. The case studies were conducted with three Maori groups that had been engaged with science/technology and matauranga Maori (indigenous knowledge) to solve three particular problem situations. The findings were intended to help facilitate better interactions between tangata whenua and the scientific community.

More details of each case study, including comments from tangata whenua participants, can be found in the full report.

Case studies

The case studies comprised:

1. Experiences between tangata whenua in the rohe of Ngati Kere and scientists primarily from the National Institute of Water and Atmospheric Research Ltd (NIWA) to better understand the roles of rahui, taiapure and proposed mahinga mataitai in the protection and restoration of kaimoana. The relationship between Ngati Kere and NIWA scientists developed out of a need by NIWA to trial a marine field resource kit. Developing the relationship involved hui, workshops and the training of Rangatahi.

   The outcome of the collaboration was overall acceptance of western scientific tools being applied to protect and enhance kaimoana species along with their habitat, and the abatement of factors that impact on the health and habitat of freshwater kai.

   Ngati Kere are now equipped with the basic scientific techniques and are conducting their own shore-gathering data collection.

2. Te Ropu Raranga Whatu o Aotearoa (Maori Weavers of New Zealand) and Landcare Research (Maanaki Whenua) worked together to explore the properties and uses of the various types of harakeke. This included examining their individual fibre and strength capabilities. The project planted a number of pa harakeke throughout New Zealand and documented how each variety of harakeke grew in the various regions.

   This case study highlighted two important considerations:

   - the need for tangata whenua to be aware of their own needs before engaging with scientists

- the need for scientists to be respectful of the knowledge already held by the kairaranga.

The initial engagement with scientists was perceived to be more for the benefit of the scientists than the kairaranga. There was a perception that that the scientists had driven the agenda, and the kairaranga were not in a position where they felt they had a united opinion from which to challenge or present questions to the scientists.

Among the lessons learned from this case were that both tangata whenua and scientists need to evaluate their positions in terms of the following:

- The timing of their interactions (are specific agenda items/questions clear?)
- The type of interaction that would best meet the needs of both parties (do both parties share the same interests and outcomes?)
- Both parties need an initial opportunity to negotiate how the interaction will be successful for both stakeholders.

3. The third case study was of the interaction between Otaraua hapu and Fletcher Challenge energy scientists to map the hapu's kaimoana (seafood) beds. The relationship between both parties arose as a result of a series of spills of hydrocarbon products from an offshore oil exploration rig. The spills ended up affecting beaches along the Taranaki coastline. Fletcher Challenge agreed, in a public meeting, to undertake a survey of kaimoana along the affected coastline.

   Among the features highlighted by this case study were the following:

   - Early in the relationship differences between the worldviews, and therefore values, of both tangata whenua and scientists were obvious, particularly in relation to water quality. From a Western scientific viewpoint, sewage can be discharged when scientific measurements of the quality of the receiving water show it to be 'safe'. In contrast, for Maori, human waste remains human waste even after treatment, and should not be discharged into water.
   - Relationships are built on an understanding of and respect for each other's values. Scientists wishing to build relationships with tangata whenua need to develop an understanding of their worldviews and cultural values.
   - The scientific findings need to be communicated in a way that enables tangata whenua to engage in meaningful discussions with the scientists. To facilitate this, tangata whenua engaged a trusted environmental scientist to help translate scientific information. Fletcher Challenge covered the costs involved.

- Tangata whenua are often very knowledgeable about their local environment to the extent that scientific findings do not necessarily add to their knowledge or understanding.
- The conducting of the survey was set within a cultural context whereby the significance of the area being surveyed was explained to the scientists before the work began.
- The involvement of young people from the hapu in the study was valuable from the point of view of the things they learned about their local area and the skills that they developed.
- The collaborative effort was valuable in improving the relationship between the tangata whenua and Fletcher Challenge.

Summary of the overall findings from the case studies

Kaitiakitanga

Maori have long protected the environment for future generations through the practice of kaitiakitanga (guardianship) for the purpose of ensuring ongoing existence of the mauri or life force of all things, inanimate or animate. Strict rules or tikanga, including the use of rahui and tapu (restrictions) at appropriate times, help prevent adverse effects on the people and the places. The role of tangata whenua as kaitiaki was prominent in the research undertaken, and underpinned the depth of knowledge of tangata whenua about their environment and resources.

Matauranga Maori

It was clear from the research undertaken that scientists often enter into relationships with tangata whenua with little understanding or appreciation of tangata whenua values and knowledge. The case studies demonstrated that tangata whenua had more knowledge than scientists gave them credit for, and they were happy to share their knowledge with scientists. The value to tangata whenua was not necessarily the scientific knowledge they gained but the technology they learned.

Matauranga Maori should not be considered as an interesting aside to western scientific knowledge, but as a way of understanding the world in its own right. Scientists often fail to acknowledge the significance of tribal knowledge that is held by tangata whenua. This includes the knowledge within an iwi or hapu of a river or coastline that it has inhabited, interacted with and observed for centuries. If there are to be opportunities for the building of bridges between matauranga Maori and scientific knowledge, then these are most likely to arise within the context of long-term collaborative relationships.

Collaborative relationships

Establishing meaningful, collaborative relationships between scientists and tangata whenua takes time and resources, and involves the sharing of benefits, accountability, risk and responsibility. It is important to hui early in the project to ensure that there are opportunities for views to be expressed, heard and taken into account before any research commences. In some cases having a scientific intermediary, who has the confidence of the tangata whenua, can be useful for translating and interpreting the scientific data being presented, and helping to determine whether such data add anything to the knowledge that already exists among the tangata whenua.

Tino rangatiratanga

The principle of tino rangatiratanga, or self determination, is about having meaningful control over one's own life and cultural well-being. The maintenance of tino rangatiratanga within research relationships is imperative to the survival of Maori cultural rights and responsibilities. Terms such as ‘collaboration’, ‘consultation’ and ‘partnership’ can all too often conceal important power differentials beneath their egalitarian façade and, for Maori, the lack of tino rangatiratanga.

Conclusion

When embarking on a collaborative research proposal in conjunction with tangata whenua, scientists need to think about and address the worthiness of their research for tangata whenua. Questions that scientists need to ask themselves, the responses to which will indicate whether they have been reflexive and will demonstrate their understanding of the concerns of tangata whenua, include:

- What research do we want to carry out?
- Who is that research for?
- What difference will it make?
- Who will carry out the research?
- How do we want the research to be done?
- How will we know it is a worthwhile piece of research?
- Who will own the research?
- Who will benefit?

The success of these case studies has been put down to the fact that they were primarily based on the terms set out by tangata whenua - on the ways in which tangata whenua groups chose to interact. When such collaborative research initiatives are being considered, mutual respect and the processes of negotiation, testing, trust-building and knowledge-sharing are essential components of building the necessary relationship. This view is supported by a science provider's perspective that identifies the following criteria as the basis for any successful collaborative research with iwi:[2]

- Research proposals and collaborative research can only happen once a meaningful relationship is established.
- Credible relationships take a long time to build, but are critical to successful collaborative research.
- A very clear understanding of future relationships needs to be articulated at an early planning stage, and may follow certain protocols.
- Research and project management capability, and human capacity, are prerequisites for starting collaborative research projects.
- Building human capacity and developing collaborative research go hand in hand.
- Developing collaborative research with iwi and hapu requires adequate resources.
- Characterising important Maori issues at a national level will help identify collaborative research opportunities.
- Collaborative projects with iwi need to be evaluated using a wider set of criteria than just research or science outcomes.

Appendix 6: Review of other science-policy systems

In New Zealand, only the Ministry of Research, Science and Technology (MoRST) is recognised as providing formal science policy advice to government. This appendix describes a variety of different systems that other countries have established to provide governments with science input to policy. While such advice extends beyond the input of science for environmental management the broad objectives are the same. The focus is on the science-government linkages, but the importance of public and stakeholder connections is also recognised in some of these systems.

Scientific advice in government decision-making

Smith and Halliwell reviewed scientific advice in government decision-making by examining case studies from various countries, including New Zealand.[1] They found that no country is confident that it has the institutional arrangements or processes that assure the promotion of the best practices in the use of science for public policy. They identified the need for policy makers to be more science literate and for scientists to better understand and respect the policy process. Better integration of the social sciences in the decision-making processes was considered important, as often the analysis of physical science data is only policy-relevant when translated into decisions designed to promote social or behavioural change. Governments had to deal with risk and uncertainty, and with the challenge of effectively communicating scientific advice.

The report identified two main features that increase the quality of advice while assuring public confidence in the science decision-making process: greater openness and explicit guidelines. Greater openness requires that policy-making processes are inclusive and transparent. Guidelines can be a useful means of establishing and assessing such processes, as well as providing quality assurance in the credibility and robustness of scientific advice. However, the simple propagation of guidelines is inadequate to ensure their success. The publication of the findings of scientific research used in decision-making was an important means of ensuring the quality of the science met recognised standards.

Science-policy structures

An examination of the interaction between decision makers and expert advisers within a number of countries[i] concluded that there is no best practice for seeking scientific advice.[2] However, the report went on to state that it is increasingly important for decision makers to draw on expert advice that is independent from stakeholder interests. As with the Smith and Halliwell report, this report adds that the openness of advice is a key factor in its robustness. There is a growing expectation that advisory

[i] UK, France, Germany, Sweden, Italy, US and Japan.

bodies will publish details of their information. This is especially true in France and the United Kingdom where public scepticism towards scientific advice grew after secretive systems became associated with public health scandals such as contaminated blood supplies in France, and the link between BSE and vCJD in Britain.

Efforts to achieve independence of advice vary. In France it is preferred that government advisers do not have any financial links with industry, while in the United Kingdom industry advisers are not excluded, but they are expected to declare any interests. Transparency in the advisory system is becoming more important, and advisory structures are expected to publish information, minutes and reports. It was hard to assess the impact that scientific advice has on policy, as science is only one aspect of decision-making.

A variety of advice structures exist in other countries, including the following:

High level policy-making

In the United States and United Kingdom an individual (Chief Scientific Adviser) is responsible for advising the head of Government on scientific issues. In each case, a high-level scientific panel can have input to strategic policy-making. The Chief Scientific Adviser is usually a distinguished non-government scientist appointed for a temporary period. In the United Kingdom, advisory committees set up by government departments to deal with specific issues are also involved in policy-making, in dialogue with officials, and in regulatory risk assessment.

Advisory structures for government departments

In countries such as the United Kingdom and France, expertise and the job of providing advice has been externalised from policy Ministries to dedicated agencies, such as the Environment Agency in United Kingdom. These are statutory bodies with their own staff who can be involved in research and supplying advice to the government. Other advisory structures include scientific committees. Ministries that deal with technical matters may have their own permanent scientific committee composed of experts who are nominated by the Ministry.

In the United Kingdom, the Head of the Office of Science and Technology, Sir David King, is also the Government's Chief Scientific Adviser (CSA). Appointed in October 2000, Sir David has subsequently appointed chief scientific advisers in each government department. These advisers are responsible to him and responsible to the secretary of state in that department. As Sir David has commented: *'...the government is very evidence-based in terms of the policy it receives and it recognises that science and technology is a very key part of evidence-based policy advice going to ministers'*.[3]

Research organisations constitute another important source of advice. They tend to operate independently, and policy makers may use the results of their research programmes or they may be commissioned to do a specific piece of work. Advice on scientific issues can also come from other types of organisations such as research councils, national academies and non-governmental organisations.

The Netherlands has developed innovative approaches to environmental planning that have strong parallels with the boundary organisations described in section 4.5. Considerable effort has been invested in developing workable models that bring together government, business interests and citizens to work out long-term approaches for sustainable development.[4] Much of this work is underpinned by science. The government funds a scientifically autonomous institute with the function of producing annual reports on the state of the Netherland's environment. The institute also comments on the successes and failures of environmental policy and has expertise to cover environmental, social and economic planning.

Advice to the legislature (Parliament)

The United States Congress and its various committees are supported by numerous and well-funded expert staff, and Congressional hearings can call upon expertise from the United States and abroad. Parliamentary select committees in United Kingdom (and New Zealand) can hold inquiries into specific issues, call witnesses and can appoint specialist advisers to assist them.[5] The United Kingdom's Parliamentary Office of Science and Technology (POST) carries out studies and provides analysis and brief summaries of science and technology-based issues.[6] The French Parliament has its own science and technology assessment office that acts as an intermediary between Parliament and researchers. It collects information, carries out assessments and launches study programmes to inform Parliament about scientific issues in order to aid decision-making.

Independence of advice

Some countries have established systems, such as independent[ii] panels of experts to consider scientific matters associated with public policy development, and for evaluating any competing scientific claims being put forward. In some cases members of such bodies have to declare any interests that have the potential to influence their judgement.

Transparency

In most countries surveyed by the European Commission report, transparency is increasingly recognised as an important means of improving confidence in the science advisory process.[7] Several reports and guidelines have recommended that all evidence upon which advice is based should be published. The report acknowledges that where processes are informal, transparency may be more difficult to maintain, but if processes are too prescriptive it may lead to inflexibility and an inability to quickly respond to particular issues.

[ii] In the context of this report independent advice means a source (or sources) of scientific advice that has no direct interest in (i.e. does not stand to gain or lose by) the outcome of the decision under consideration.

Glossary

biodiversity	the variety of all biological life (plants, animals, insects, fish, birds, invertebrates and micro-organisms), the genes they contain and the ecosystems and habitats in which they live
biosecurity	the exclusion, eradication and effective management of pests and unwanted organisms into New Zealand
biotechnology	any technological application that uses biological systems, living organisms or derivatives thereof (whether genetically modified or not) to make or modify products or processes for general use
boundary organisation	an organisation that acts as an intermediary between science providers and policy makers, contributing to better communication between the two
capability	the knowledge, skills and ability to successfully perform an activity
capacity	the competence and resources within an organisation to undertake certain functions
civil society	the set of institutions, organisations and behaviour situated between the state, the business world, and the family. Specifically, this includes voluntary and non-profit organisations of many different kinds, philanthropic institutions, social and political movements, other forms of social participation and engagement and the values and cultural patterns associated with them
drivers	driving forces; pressures, circumstances or actions that initiate change
ecology	broadly, the study of organisms in relation to their environment
ecosystem	a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit
endocrine disruptors	a generic term used to describe natural and synthetic chemicals in the environment, exposure to which can interfere with the

	endocrine systems of humans and wildlife by mimicking natural hormones and giving rise to reproductive disorders, immune system dysfunction and other disruptions of the body's natural processes
horizon scanning	the systematic examination of potential threats, opportunities and likely future developments which are at the margins of current thinking and planning. Horizon scanning may explore novel and unexpected issues, as well as persistent problems or trends
nature-human systems	various situations, including human-modified environments such as urban areas, where the natural world and humans co-exist and interact
outcome	end result; visible effect; consequence
public policy	a role of public authorities within central and local government responsible for managing issues that involve a strong element of public good. Public good describes issues that are of interest to or affect society as a whole (for example, air quality)
PM_{10}	fine dust particles less than 10 micrometres (or microns) in diameter, which can be inhaled into deeper parts of the lungs
reductionist	a description of an approach to scientific analysis that is based on the belief that complex situations may be explained by reducing them to their component parts and explaining these
research	an organised and systematic way of finding answers to questions
science	science is both a process of gaining knowledge and the knowledge gained by this process

Maori glossary

hapu	family or district groups, communities
harakeke	flax
hui	gatherings, discussions, meetings, usually on marae
iwi	tribal groups
kai	food, produce
kaimoana	seafood
kairaranga	weavers
kaitiaki	iwi, hapu or whanau group with the responsibilities of kaitiakitanga
kaitiakitanga	the responsibilities, passed down from the ancestors, for tangata whenua to take care of places, natural resources and other taonga in their geographical territory
mahinga mataitai	a fisheries reserve in an area of special significance to tangata whenua
marae	local community and its meeting places and buildings
matauranga	traditional knowledge
mauri	essential life force, the spiritual power and distinctiveness that enables each thing to exist as itself
rahui	protection of a place or resources by forbidding acess or harvest
rangatahi	Maori youth
rohe	geographical territory of an iwi or hapu
taiapure	a fisheries reserve in an area of special significance to tangata whenua (see Fisheries Act 1996)
tangata whenua	people of the land, Maori people
tapu	sacredness, spiritual power or protective force
tino rangatiratanga	independence

Acronyms

AEE	Assessment of environmental effects
BSE	Bovine spongiform encephalopathy
CBD	Convention on Biological Diversity
CFCs	chlorofluorocarbons
CJD or vCJD	Cruetzfeldt-Jacob disease or variant Cruetzfeldt-Jacob disease
CRI	Crown research institute
DDT	dichlorodiphenyltrichloroethane
DNA	deoxyribonucleic acid
DoC	Department of Conservation
EEA	European Environment Agency
ESR	Environmental Science and Research Ltd.
ERMA	Environmental Risk Management Authority
FRST	Foundation of Research, Science & Technology
GE	Genetic engineering
GM	Genetic modification
HSNO	Hazardous Substances and New Organisms Act 1996
IPCC	Inter-governmental Panel on Climate Change
MAF	Ministry of Agriculture and Forestry
MEA	Multi-lateral environmental agreement
MfE	Ministry for the Environment
Mfish	Ministry of Fisheries
MoH	Ministry of Health
MoRST	Ministry of Research, Science and Technology
NGO	Non-government organisation
NIWA	National Institute of Water and Atmospheric Research Ltd.

NZCPS	New Zealand Coastal Policy Statement
NZS	New Zealand Standard
OECD	Organisation of Economic Co-operation and Development
OST	Office of Science and Technology (UK)
PCE	Parliamentary Commissioner for the Environment
QMS	Quota management system
R&D	Research and development
RCD	Rabbit calicivirus disease
RCGM	Royal Commission on Genetic Modification
RHD	Rabbit haemorrhagic disease
RMA	Resource Management Act 1991
RNA	ribonucleic acid
RSNZ	Royal Society of New Zealand
SSC	State Services Commission
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UV	Ultra violet (radiation)
WCED	World Commission on Environment and Development
WSSD	World Summit on Sustainable Development

Endnotes

Preface

[1] Midgley, 1992, p.224

Executive Summary

[2] H.L. Mencken

Chapter 1

[1] Smith, 2001

[2] PCE, 2003a

[3] PCE, 2003b

[4] Examples include: *Long-Term Management of the Environmental Effects of Tailings Dams (1997); The Rabbit Calicivirus Disease (RCD) Saga: a biosecurity/bio-control fiasco (1998a); Setting Course for a Sustainable Future: the management of New Zealand's marine environment (1999); Caught in the Headlights: New Zealanders' reflections on possums, control options and genetic engineering (2000a); New Zealand Under Siege: a review of the management of biosecurity risks to the environment (2000b); Key Lessons from the History of Science and Technology: knowns and unknowns, breakthroughs and cautions (2001); Creating Our Future: sustainable development for New Zealand (2002).*

[5] PCE, 2002

[6] PCE, 1998b

[7] PCE, 2002

[8] MfE, 1997

[9] Department of the Environment, Sport and Territories, 1996

[10] Environment Australia, 2001

[11] Department of the Environment, Sport and Territories, 1996, p.1.4

[12] PCE, 2001

[13] Hales *et al*., 2004

[14] Gallopín *et al*., 2001

[15] Ericksen *et al*., 2003

Chapter 2

[1] EEA, 1999

[2] Ericksen *et al*., 2003, p.297

[3] Huberman, 1994 cited in EEA, 2000, pp.12-13

[4] EEA, 2001a

[5] New Zealand Government, 2003

[6] RCGM, 2001, p.349

[7] PCE, 2003a, pp. 57-58

[8] MoRST, 1998; SSC, 1999

[9] Smith, 2001

[10] MoRST, 2002

[11] http://www.ost.gov.uk/policy/sciencereview/aim.htm

[12] Professor Paul Callaghan quoted in the Royal Society of New Zealand's 'Alert' No.319, 22 April 2004

[13] OST, 2000; Industry Canada, 2000

[14] MacKenzie, 2000

[15] Van Zwanenberg and Millstone, 2003

[16] Mackenzie, 2000

[17] Jacob and Hellström, 2000

[18] PCE, 2001

[19] European Commission, 2001a

[20] Huxham and Sumner, 2000, p.33

[21] May, 2002

[22] Gibbons, 1999

[23] CAE, 2004

[24] Huxham and Sumner, 2000, p.89

[25] Cram, 2002

Chapter 3

[1] UNEP, 1995; UNEP, 2002

[2] This approach was expanded in WCED (1987).

[3] UNEP, 1999a

[4] A good example is Clark and Munn (1986).

[5] UNEP, 1995

[6] This latest project, involving 1,500 scientists, is intended to provide decision makers with authoritative information on the impacts of changes to the world's ecosystems on human livelihoods and the environment. Details and updates can be viewed at: www.millenniumassessment.org

[7] Gunderson and Holling, 2002

[8] Gunderson and Holling, 2002, p.8

[9] DPMC, 2003

[10] Kuhn, 1962

[11] Foran and Poldy, 2002

[12] Foran and Poldy, 2003

[13] Foran and Poldy, 2003, p.12

[14] Harris, 1998

[15] The Royal Society, 2001

[16] MfE, 2003

[17] See, for example, Vincent *et al*.,(1984).

[18] MfE, 2003

[19] For more information in relation to central government's response to the Rotorua Lakes issue, see http://www.mfe.govt.nz/issues/water/rotorua-lakes/index.html

[20] RCEP, 1998, p.28

[21] Holling, 1998, p.3

[22] Gallopín , *et al*., 2001

[23] UCS, 2004

[24] UCS, 2004, p.5

[25] USEPA, 2003

[26] USEPA internal memo, April 29, 2003, cited in UCS, 2004. Available online at http://www.ucsusa.org/global_environment/rsi/page.cfm?pageID=1322

[27] UCS, 2004, p.6

[28] UCS, 2004, p.6

[29] POST, 2004

[30] UCS, 2004, p.4

[31] Australian/New Zealand Standard on Risk Management (AS/NZS 4360).

[32] OSH, 1991. See also MoH (1997).

[33] PCE, 2001

[34] See http://www.mfat.govt.nz/foreign/env/atmosphere/climchangeozone.html for further information on these international agreements.

[35] EEA, 2001b

[36] Hilborn, 1987

[37] Wynne, 2001

[38] RCEP, 1998, p.56

[39] Ludwig *et al*., 1993

[40] IUCN, 2003

[41] Lack *et al*., 2003

[42] Pittock, 2002

[43] Vig and Paschen, 2000

[44] New Zealand Health Technology Assessment: http://nzhta.chmeds.ac.nz

[45] MoRST, 2003a, p.12

[46] Gibbs, 2003, p.31

[47] Office of Science and Technology and the Wellcome Trust, 2000

[48] OECD, 2001

[49] ESRC, 2003

[50] MORI, 2000

[51] Hipkins *et al*., 2002

[52] Toi te Taiao: the Bioethics Council

[53] Adapted from http://www.publicconversations.org/pcp/uploadDocs/DebateDialogue.pdf

[54] The GE Information Bulletin No. 22, May 2004, See http://www.GEinfo.org.nz

[55] Funtowicz and Ravetz, 1999

[56] Vitousek *et al*., 1997

[57] Gallopín *et al*., 2001

[58] Ludwig *et al*., 1993

[59] Ludwig *et al*., 1993

[60] Robertson and Hull, 2003

Chapter 4

[1] Thompson, M. Commentary, p. 454 in Clark and Munn (1986)

[2] Gunderson and Holling, 2002

[3] Bradshaw and Borchers, 2000

[4] Bradshaw and Borchers, 2000, p.8

[5] Matthews, 1997

[6] Ravetz, 1986

[7] Ravetz, 1986, p.429

[8] Funtowicz and Ravetz, 1992

[9] Funtowicz and Ravetz, 1999, p.4

[10] Funtowicz and Ravetz, 1999, p.5

[11] Three documents contain detailed discussions on the factors surrounding the decision and the illegal importation of RCD: PCE (1998a), Biosecurity Council (1999), and O'Hara (2003).

[12] Funtowicz and Ravetz, 1999

[13] Chapman and Howden-Chapman, 1997

[14] Allen *et al*., 2002

[15] Reid *et al*., 2003

[16] Cash *et al*., 2003

[17] See: http://www.ecan.govt.nz/air/history.html

[18] For more information see http://www.ecan.govt.nz/air/ambient-air-issues.html

[19] Coal Producers' Federation of New Zealand v Canterbury Regional Council [1999] NZRMA 257.

[20] UNEP, 1999b, p.15

[21] Cash *et al*., 2003

[22] Cash *et al*., 2003, p.8088

[23] Cash *et al*., 2003, emphasis added

[24] Canadian Centre for Management Development, 2002

[25] Winstanley, 2002

[26] See: http://www.moh.govt.nz/moh.nsf/wpg_Index/Publications-Drinking+water+in+New+Zealand+Publications

[27] MfE and MoH, 2000

[28] Cash *et al*., 2003, p.8088

[29] Harris, 1998

[30] Source: Cash, 2003

[31] Guston *et al*., 2000

[32] EEA, 2000

[33] Clark *et al*., 1999 cited in EEA, 2000; Cash, 2000

[34] See http://www.eea.eu.int/main_html for more information.

[35] Guston *et al*., 2000

[36] The mandate of the Royal Society is broader than that described here. See http://www.rsnz.org for more information.

[37] See http://www.landcare.org.nz/biodiversity/index.htm

[38] Star and Griesemer, 1989

[39] Source: Cash *et al*., 2003

[40] Holling, 1978

[41] Walters, 1986

[42] Walters, 1997, p.2

[43] Gunderson and Pritchard, 2002

[44] Parkes, *et al*., (in press)

[45] Walters, 1997

[46] Lee, 1999

[47] Lee, 1999, p.14

[48] Details are available from: http://www.otago.ac.nz/titi. Over 40 peer-reviewed papers have been published so far.

[49] Covered in a series of papers in Volume 3, Issues 1 & 2, of Conservation Ecology, 1999.

[50] Johnson, 1999

[51] Gunderson and Holling, 2002

[52] Lee, 1999

Chapter 5

[1] Jarek Czechowicz, Management Today, May 2002, p.11

[2] Smith and Halliwell, 1999, and European Commission, 2001b, referred to in appendix 6

Appendix 1

[1] OECD, 2003, p.85

[2] PCE, 2003b, pp.14-19

[3] MoRST, 2003b

[4] http://www.beehive.govt.nz/ViewDocument.cfm?DocumentID=19404

[5] http://www.beehive.govt.nz/ViewDocument.cfm?DocumentID=19860

[6] Royal Society Alert 318, 15/04/2004

Appendix 4

[1] Biosecurity Council, 2003

[2] Smith and Halliwell, 1999

Appendix 5

[1] Cram, 2002

[2] Harmsworth, 2001

Appendix 6

[1] Smith and Halliwell, 1999

[2] European Commission, 2001b

[3] Plenary address to the American Association for the Advancement of Science (AAAS), February 2004

[4] de Jongh and Captain, 1999

[5] In New Zealand, the Parliamentary Commissioner for the Environment (PCE) responds to requests from Parliamentary select committees to provide advice that is independent of Government. An example of assistance given by the PCE to a specific inquiry was the 1998 inquiry of the Transport and Environment Committee into the environmental effects of road transport (New Zealand House of Representatives, 1998).

[6] See: http://www.parliament.uk/parliamentary_offices/post.cfm

[7] European Commission, 2001b

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