Biodiversity Inventory and Monitoring:

A review of national and international systems and a proposed framework for future biodiversity monitoring by the Department of Conservation

Compiled by:
William Lee
Matt McGlone
Elaine Wright

Working Group:

Daniel Rutledge
Deb Wilson
Grant Norbury
Jake Overton
Matt McGlone
Susan Wiser
William Lee
Landcare Research

Carol West
Colin O'Donnell
Elaine Wright
Theo Stephens
Department of Conservation

Manaaki Whenua
Landcare Research

Biodiversity Inventory and Monitoring:

A review of national and international systems and a proposed framework for future biodiversity monitoring by the Department of Conservation

Compiled by:
William Lee
Matt McGlone
Elaine Wright

Working Group:
Daniel Rutledge
Deb Wilson
Grant Norbury
Jake Overton
Matt McGlone
Susan Wiser
William Lee
Landcare Research

Carol West
Colin O'Donnell
Elaine Wright
Theo Stephens
Department of Conservation

Landcare Research Contract Report: LC0405/122

PREPARED FOR:
John Ombler
General Manager Research, Development and Improvement Division
Department of Conservation
PO Box 10420
Wellington

June 2005

Reviewed by:

Rob Allen
Scientist
Landcare Research

Approved for release by:

David Choquenot
Science Manager
Biodiversity and Ecosystem Processes

Contents

Summary 1
PART I: INTERNATIONAL AND NATIONAL REVIEW 7
1. International and national context 7
1.1 New Zealand biodiversity context versus other temperate countries 7
1.2 International agreements of significance to biodiversity monitoring 8
1.3 National legislation and policy documents of significance for biodiversity monitoring 9
1.4 New Zealand national organisations and agencies with an interest in biodiversity monitoring 11
2. International review 12
2.1 International drivers and mandates for undertaking biodiversity inventory and monitoring 12
2.2 Major rationales underpinning national biodiversity inventory and monitoring approaches 13
2.3 How is monitoring and inventory organised? 13
2.4 International overview 31
3. National review 37
3.1 History of biodiversity monitoring in New Zealand 37
3.2 Policy and monitoring 43
3.3 Changing technologies and techniques 45
3.4 Monitoring and inventory by territorial local authorities 47
3.5 New Zealand Carbon Monitoring Scheme 51
3.6 New Zealand Department of Conservation: current monitoring activities 52
3.7 Conclusions: observations and lessons from the history of monitoring in New Zealand 58
PART II: REPORTING BIODIVERSITY: GOALS, DEFINITIONS, PRINCIPLES AND ISSUES 61
4. Goals and principles 61
4.1 International and national goals 61
4.2 Implications of the goal statements 62
4.3 Implementing goals: national biodiversity principles 67
5. Biodiversity inventory and monitoring 70
5.1 Inventory: how much is enough? 70
5.2 Monitoring: principles, types and issues 74
5.3 Indicators 78
5.4 Biodiversity monitoring and indicators: controversial issues 82
6. Conservation agency performance indicators 89
6.1 Trust 89
6.2 Agency efficiency 91
7. Socio-economic indicators 93
PART III: A BIODIVERSITY INVENTORY AND MONITORING FRAMEWORK FOR NEW ZEALAND 95
8. Organisation of inventory and monitoring in New Zealand 95
8.1 National level monitoring: who should do it? 95

8.2 Internal management: 'Monitoring Central' 97
8.3 How can a biodiversity inventory and monitoring system add value to the conservation management of DOC? 97
8.4 Indicators versus other approaches 97

9. Biodiversity assessment framework: outcomes and performance assessment 98
9.1 Scope – national or DOC? 99
9.2 Framework structure 99
9.3 Ecological integrity – the national outcome for conservation in New Zealand 100
9.4 Targeted national outcomes – core components of a biodiversity assessment framework 100
9.5 Outcome Objectives – actions required to maintain ecological integrity 103
9.6 Performance assessment – indicators, measures and data elements 107
9.7 Classification according to agency responsibility and current operability 108

PART IV: DESCRIPTIONS OF BIODIVERSITY INDICATORS 113

10. Objective, indicator, and measure descriptions for inventory and monitoring 113
10.1 Outcome Objective 1: Maintaining ecosystem processes 113
10.2 Outcome Objective 2: Reducing exotic spread and dominance 120
10.3 Outcome Objective 3: Environmental pollutants 122
10.4 Outcome Objective 4: Preventing declines and extinctions 123
10.5 Outcome Objective 5: Ecosystem composition 130
10.6 Outcome Objective 6: Ecosystem representation 135
10.7 Outcome Objective 7: Climate change and variability 137
10.8 Outcome Objective 8: Sustainable use 140
10.9 Outcome Objective 9: Community in conservation 144
10.10 Comparison of proposed biodiversity inventory and monitoring indicators with proposed MfE Terrestrial Biodiversity Indicators 149

11. Acknowledgements 153

12. References 154
Appendix 1 International biodiversity reporting and suggested indicators 168
Appendix 2. Assessment tables for indicators and measures 179

Summary

The Department of Conservation (DOC) is implementing a new natural heritage management system (NHMS). To support this, a national monitoring system for biodiversity is required. The monitoring system will provide a framework for monitoring biodiversity and reporting on its status and trend. It will include the development of sophisticated databases and a range of tools to assist managers in defining outcomes, planning and prioritising natural heritage work, and selecting and implementing projects.

There are three primary requirements of the monitoring system. The first is that it will be broad and inclusive so that a comprehensive, verifiable picture of New Zealand's biodiversity, the environment that sustains it, the threats it faces, and associated human interactions and interdependencies can be presented nationally and internationally. The second is for a strong management focus so that conservation management effectiveness can be independently judged on the basis of agreed biodiversity outcomes, as set out in the New Zealand Biodiversity Strategy. The third requirement is that it meets multi-level needs so that international and national reporting requirements are satisfied, the underpinning data provide essential everyday guidance to managers and fieldworkers, and the system is accessible to researchers, other organisations, and the general public.

The objectives of this report are to:

a) Review the rationale and mandate for biodiversity inventory and monitoring systems internationally, and identify the major points relevant for New Zealand.
b) Assess current and previous biodiversity inventory and monitoring in New Zealand, and determine the key factors maintaining an effective biodiversity assessment system.
c) Develop a framework for biodiversity condition measurement, and design a biodiversity inventory and monitoring programme.
d) Identify outcomes that could be measured to assess management effectiveness and progress in maintaining indigenous biodiversity.

Part I: International and national review

Context – The indigenous biota of New Zealand is highly distinctive, having high levels of endemism, numerous unusual forms, many significant missing functional groups, most notably mammals, and therefore an expansion of the role of birds and large invertebrates. Few terrestrial indigenous species are managed for economic gain and relatively extensive areas are under conservation management in public ownership. For these and other reasons it will be difficult to simply transfer biodiversity inventory and monitoring practices from elsewhere in the world. However, invasive species, climate change, and pollution are international issues highly relevant to New Zealand.

Multiple international agreements emphasise the importance of slowing biodiversity loss, facilitating sustainable use, and enhancing ecosystem functioning, and similar themes have been accepted in national policy documents.

DOC is unusual internationally because of the breadth of activities it is responsible for and the dominance it has in natural heritage management. However, increasingly other agencies are assuming biodiversity responsibilities. For example local government has the mandate under the Resource Management Act 1991 to protect significant biodiversity, and Statistics New Zealand has initiated national environmental accounts for reporting internationally on the status of our biodiversity.

International review – Internationally, a large number of countries are involved in developing national biodiversity inventory and monitoring systems to enable them to measure trends in biodiversity, and to report on condition and changes.

There are strong social, economic and ethical drivers behind the development of such systems and an obvious mandate arising from international agreements to undertake inventory and monitoring programmes.

In most countries and states, responsibility for inventory and monitoring programmes and reporting on biodiversity trends is allocated across numerous agencies, usually with a lead co-ordinating agency. In many instances biodiversity responsibilities appear uncoordinated, overlapping, and ambiguous.

Models where a lead agency is primarily responsible for national biodiversity inventory and monitoring appear to be more advanced in their development of inventory and monitoring systems. Such agencies generally develop partnerships with a network of appropriate organisations and aim for fully integrated frameworks (e.g. Australian and Canadian models).

Monitoring programmes in most countries involve multi-step, multi-scale systems. National reporting is generally based on inventory, status and trend, and surveillance monitoring, resulting in an emphasis on provision of regular, reliable, systematically recorded data produced by dedicated teams or agencies. However, such systems often fail to document total conservation effort relative to both successes and failures of the agencies responsible for biodiversity.

Most countries have adopted systems based on condition indicators associated with a subset of the biota, rather than attempting to measure all components of biodiversity.

The trend in most agency reports is to utilise a large number of individual biodiversity measures grouped according to broad themes, and to not attempt any overall integration to produce a single metric representing biodiversity condition. However, indicators selected for monitoring are often ad hoc, lacking any systematic framework or integration with one another.

The concept of 'biodiversity indicators' is widespread and a key component of all biodiversity inventory and monitoring systems. Typically, different indicators are collected by a wide range of agencies, and then passed on to a central co-ordinating agency responsible for national reporting. Nevertheless, national reporting on biodiversity condition and trends remains rudimentary in nearly all countries, although most are seeking to improve both the inventory and monitoring components, and the type of reporting undertaken.

While there are numerous science publications and policy documents at national and regional levels outlining the need for systematic inventory and monitoring, there are contrastingly few publications demonstrating how useful a contribution such monitoring has made to a national understanding of trends in biodiversity or to policy. Most countries continue to struggle to derive or link biodiversity results to policy-relevant measures.

Compared with their equivalent organisations overseas, New Zealand environmental agencies appear to be relatively poorly resourced in terms of inventory and monitoring and not so well advanced in terms of developing integrated systems.

National review – Quantitative, protocol-based monitoring was developed earliest for indigenous forests and game and sea birds by a number of government departments in control of public lands. Monitoring forest impacts of introduced herbivores and predators has been the dominant driver behind the establishment of set plots and the development of a range of assessment techniques.

The rationale for monitoring has frequently changed, with negligible alteration in monitoring intensity or methodology, the best example being the long-term forest assessment plots and techniques for measuring deer impacts in the forest understorey.

National inventory and monitoring systems have been rare, with the notable exceptions of the periodic bird census and the indigenous forest inventory. Significant intensive and long-term monitoring of selected local ecosystem elements has been undertaken by agencies and universities, but the results have rarely been used to assess conservation goals or determine biodiversity condition.

Much of the biodiversity and environmental monitoring in New Zealand has largely been detached from policy, rarely used to test assumptions relating pressure to condition, and often isolated from ongoing research. Often monitoring has been initiated and operated without clear or consistent goals, and maintained to preserve the status quo management.

Because of an emphasis on the pressure-response framework, few ongoing general inventory assessments have been undertaken, with the exception of threatened taxa. The Protected Area Programme provided additional information for a range of biota, but was limited to areas with high conservation values.

Perhaps the biggest advances have been in data acquisition and storage technology, development of remote sensing capabilities, improvement in technologies for radio-tracking animals, and molecular-based methods for identification and source testing of plants and animals.

Territorial authorities frequently inherited from catchment boards monitoring data and systems of variable quality, duration, and methodology that typically focused on soil and water values, but often included vegetation cover. Recently, under the requirements of the Resource Management Act and the Biodiversity Strategy, they have developed biodiversity goals for these areas. Although awareness is high, and many have maintained or initiated inventory and monitoring schemes, funding allocations for these activities are generally low. The role of territorial authorities in biodiversity protection remains ambiguous, but needs to be differentiated, either on the basis of land tenure or biodiversity goals, from that of DOC, if they are to progress.

There has been little monitoring in New Zealand to provide baseline trend data, the exceptions being national mapping programmes based around birds or invasive weeds and pests. Significant resources have been largely devoted to monitoring concerned with specific management issues or individual investigator interests. Monitoring has therefore provided useful information to help address specific management concerns but it has not provided a clear picture of the overall state of biodiversity.

Monitoring requires long-term commitment, adequate resources, and organisational stability. Historically, however, monitoring has often been seen as an expensive, optional extra undertaken when resources, time, and enthusiasm permit. There is a strong tendency for organisations to develop and use non-intensive, qualitative, rapid-assessment methods of low comparability and rigour, with little concern about data archiving and analysis. Funding for monitoring has been sporadic, programmes have been geographically patchy, and methods have frequently changed, weakening the ability to contrast the information over time. A significant proportion of monitoring information has never been analysed, archived, or reported on.

The role of monitoring for guiding management decisions at any level has not been well understood and needs to be linked to accountability measures. Monitoring programmes are generally not integrated in planning and management cycles to complete feedback loops or as accountability tools. Monitoring must become an integral part of the management process, following the model of adaptive management.

Part II: Reporting biodiversity: goals, definitions, principles, and issues

Species, abundance, and distribution of biota are universal components of national biodiversity inventories. However, most countries struggle to include the most numerous and small elements because they remain taxonomically and functionally unknown. The problems are compounded at the genetic level where few clear parameters have emerged that may be usefully monitored.

Larger and better-known taxa are frequently used as surrogates for smaller taxa, but the basis for this is debated. All-taxa biodiversity inventories are often a goal but are understandably rarely attempted. The advantages they provide for conservation management are not commensurate with the effort required.

The purpose of monitoring centres on measuring the status, condition, and change in biodiversity in order to inform management actions and achieve conservation outcomes, while at the same time improving our fundamental understanding of ecosystems. A classification of monitoring is presented, based on the purpose, scale, intensity, level of precision, and duration of monitoring required.

Indicators are generic biodiversity measures designed to reflect and track, with as little effort and cost as possible, the important features of the ecological system. The selection of indicators used depends on the conservation issues of interest, the most relevant hierarchical level of biodiversity, the intrinsic properties of the indicator (variability etc.), and the practicability of measuring the indicator. A checklist is provided of important factors used in selecting indicators.

The major categories of national biodiversity indicators used are: status of land tenure; extent of vegetation/landuse; indices (extent, fragmentation etc.) derived from remote sensing; abiotic factors relating to climate, soil, and pollutants; status of wetlands, estuaries, and waterways; status of vegetation canopy cover and forest growth; abundance and range of plant and animal populations; diversity indices; presence of exotic species; threatened species status.

An outline is presented of the issues associated with using species diversity, aggregated indices of biodiversity status, surrogates or proxy taxa, threatened species lists, invasive species impacts, and genetic monitoring.

National organisations generally utilise a range of biodiversity indicators but there needs to be widespread public trust and acceptance that these are adequate to describe biodiversity, reliably analysed and presented, and actually used to evaluate conservation practice. Agency self-interest must not capture the process or the information.

Sustainable use is a key component of biodiversity inventory and monitoring and must be included across a wide range of potential public uses of indigenous biodiversity. Social and cultural indicators, though often difficult to define, are increasingly seen as an integral part of general biodiversity assessment programmes.

Part III: Biodiversity inventory and monitoring framework for New Zealand

Any inventory and monitoring scheme at a national level will need to involve multiple agencies and central coordination. DOC has a key leadership role in this process, and any biodiversity assessment framework developed should consider agencies with different types of conservation responsibilities across non-public land. The advantages and disadvantages of an independent, centralised biodiversity inventory and monitoring agency are discussed.

We suggest that the primary conservation management goal is to maintain ecological integrity, defined as the full potential of indigenous biotic and abiotic factors, and natural processes, functioning in sustainable communities, habitats, and landscapes.

For biodiversity conservation, ecological integrity can be considered to be a mix of three distinct elements: long-term indigenous dominance; potential occupancy by all appropriate biota; and full environmental representation of ecosystems, which can be measured at a range of hierarchical scales (e.g. populations, species, and ecosystems).

Within this framework, nine national objectives are recognised. These are designed to measure and report on progress towards DOC's national outcomes. The national objectives are: preventing declines and extinctions; maintaining ecosystem processes; improving ecosystem composition; improving ecosystem representation; reducing the spread and impact of exotic/invasive species; responding to the impact of climate change and variability; reducing environmental pollutants; maintaining the sustainable use of indigenous ecosystems; and fulfilling community aspirations.

The nine national objectives are partitioned in relation to the three core elements of ecological integrity, and indicators developed to provide key measures of each objective. The indicators are also presented in an outline of the current DOC organisational structure to determine their utility.

Part IV: Description of biodiversity indicators

Using the national objectives identified above, 27 indicators, each with several relevant measures, are described and discussed in relation to their general importance, interpretability, policy relevance and suitability, international compatibility, conceptual basis, statistical properties (where known), robustness, reliability, compatibility, flexibility, and cost-effectiveness.

The indicators and measures outlined are compared with those proposed in the Ministry for the Environment environmental performance indicators programme. Overall, the indicators developed for DOC encompass a clearer framework and definition of biodiversity, and reflect DOC's legislative responsibilities for threatened species. However, there is considerable overlap with many indicators in both approaches.

PART I: INTERNATIONAL AND NATIONAL REVIEW

1. International and national context

1.1 New Zealand biodiversity context versus other temperate countries

New Zealand's biodiversity context differs greatly from those of other temperate countries. Physical, biotic and human factors are distinctive, as are conservation vulnerabilities. The most significant differences are:

Physical factors
- Because of its high oceanity and mid southern latitude position, few areas globally have similar bioclimatic characteristics
- Natural fire rare
- High proportion of the landscape in steep to rugged tectonically active terrain
- Most areas largely free from air pollution and significant aerial deposition of nitrogen, sulphur compounds etc.

Biotic factors
- High levels of specific endemism in most families, and relatively deep endemism in certain taxa. Endemic species make up c. 80–100% of many groups
- Absence of terrestrial mammals, long-tongued bees and moths, and termites; few ants, butterflies, dragonflies; depauperate freshwater biota, few amphibians; no snakes, turtles, or tortoises
- Dominance of unmodified terrain by slow-growing evergreen forests adapted to low nutrient-levels.

Conservation vulnerabilities
- Much of the biota highly sensitive to fire
- Exotic invasive species often novel functional types
- Extreme vulnerability to predation of larger fauna (birds, bats, large insects)
- Much of the flora highly vulnerable to mammalian browsing
- Native biota largely absent from anthropogenically transformed landscapes.

Human factors
- Sharp distinction between human-occupied and natural landscapes
- Low human population density in rural areas; population highly urbanised
- Native forests largely in public ownership, and mostly excluded from economic exploitation other than tourism
- Many exotic vertebrates (horse, deer, possum, and trout) have a triple bottom line as pests, and economic and recreational resources.

In comparing international versus local conservation practice we have to bear these differences in mind. There is no need to adopt some measures simply because they represent international best practice. In particular, the following points should be noted:

1. New Zealand taxa (genus, family level) are often poorly known on a global scale because they are predominately in southern and tropical areas. Hence, dominant international conservation practice is often centred on organisms with quite different responses to stressors.
2. Virtually none of the native terrestrial and freshwater biota (forests, game birds, freshwater fish) in New Zealand is managed for economic gain, leaving aside some fire-induced tussock grasslands and some forests managed sustainably under the Forests Act. Therefore, nearly all natural areas have to be managed on a conservation-funded basis. Many international monitoring regimes are focused on sustainable management of naturally forested areas that are also logged. Indicators are often based on forestry measures, or other economic-related activity. However, international opinion with regard to forestry will have to be taken into consideration because market access of plantation products will increasingly be influenced by the contribution of forestry to biodiversity status.
3. International practice often suggests measures suited to densely settled rural areas and indigenous subsistence farming (as in Britain and France), and is closer to micromanagement of an economic landscape. Roading and ongoing fragmentation are important issues internationally, but only minor issues in New Zealand because of the high percentage of land in public conservation ownership.
4. Many international indicators measure air pollution and aerial deposition of contaminants (ozone, nitrogen, sulphur etc.), which are currently of limited concern in New Zealand.

On the other hand, two of the factors of most concern internationally are also problems here. Invasive species are a global problem and (perhaps surprising from a New Zealand perspective) they are increasingly being viewed as a major component of global change. Climate change is a major issue and a considerable amount of research effort is now devoted internationally to detecting and predicting future changes in range and abundance of organisms.

1.2 International agreements of significance to biodiversity monitoring

Renewed international attention and effort devoted to biodiversity inventory and monitoring has three disparate drivers:

- The environmental crisis – long in the making – is focused internationally on issues surrounding loss of species and ecosystems
- Availability of sophisticated analytical, remote sensing and information technology
- Nations throughout the western world have begun to insist on quantitative accountability for expenditure on the environment and conservation.

Preventing biodiversity loss has been the subject of a number of recent major international agreements. New Zealand is committed to biodiversity and species conservation under the following international and multilateral agreements (leaving aside specific fisheries agreements):

- Convention on Biological Diversity (CBD)
- International Convention on Trade in Endangered Species (CITES)
- Convention on Wetlands of International Importance Especially as Waterfowl Habitat (the RAMSAR Convention)
- UNESCO National Protection and International Protection of the Cultural and Natural Heritage. (Includes a broad definition of ‘natural heritage’ and enjoins conservation of

natural features, formations and sites of outstanding universal values from aesthetic, science, or conservation points of view)

- Convention on the Conservation of Nature in the South Pacific (Apia Convention)
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
- The Antarctic Treaty: Protocol on Environmental Protection (offers a comprehensive framework for protecting the Antarctic environment and ecosystems)
- International Plant Protection Convention 1979 (directed at preventing spread of economic plant pests and diseases, but has clear implications for biodiversity protection).

Three non-binding, but widely supported agreements endorsed by New Zealand, with implications for biodiversity, are:

- Rio Declaration on Environment and Development (guidelines for sustainable development)
- Agenda 21 (a framework for use by governments, local authorities and the community in implementing the principles of sustainable development)
- Forest Principles (addresses the conservation and sustainable development of all types of forests)
- The Global Strategy for Plant Conservation ratified by 187 nations under the CBD.

New Zealand also cooperates with several international initiatives with implications for biodiversity, most notably:

- IUCN (International Union for Conservation of Nature and Natural Resources) threatened species: Red list
- The Montréal Process: the Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests.

The net effect of these agreements and initiatives is to place New Zealand firmly within an international framework of concepts, suggested conservation actions, extra-territorial cooperation, and compulsory, comprehensive and regular reporting. Several agreements, most importantly the CBD, have ongoing development of frameworks, criteria and proposed plans of action. The trend so far, as seen for instance in the template for National Reports to the CBD, is for more specific reporting with stringent, quantitative standards. Clearly, it will be to New Zealand's benefit if, wherever possible, it attempts to adopt accepted international concepts, language and reporting standards and protocols.

The Department of Conservation (DOC) is a major land manager and the primary conservation and environment agency in New Zealand. In developing biodiversity monitoring and inventory protocols, DOC needs to be acutely aware of its role fulfilling New Zealand's international biodiversity reporting responsibilities. Compliance and compatibility with international agreements must be built into lower-level reporting.

1.3 National legislation and policy documents of significance for biodiversity monitoring

The core legislation regarding conservation is the Conservation Act 1987, which sets out the key functions of the New Zealand Department of Conservation (discussed in the next section), and the National Parks Act 1980 and Reserves Act 1977 which set out the legislative basis for national parks and the other categories of reserves to protect outstanding scenery, ecological areas, natural features and areas with special cultural, historical or ecological features. The Wildlife Act 1953 (also administered by DOC) protects indigenous birds and some other wildlife listed in schedules to the Act, and enables the establishment of wildlife sanctuaries and wildlife reserves. The Wild Animal Control Act 1977 gives DOC oversight of the management and control of feral populations of exotic species and deer farming.

The Resource Management Act 1991 (administered by the Ministry for the Environment (MfE)) sets out how the people of New Zealand are going to use, develop or protect natural and physical resources. The section of the Act relevant to biodiversity states that all persons managing the use, development and protection of natural and physical resources shall have particular regard to the following:

a) Kaitiakitanga - The ethic of stewardship;
b) The efficient use and development of natural and physical resources;
c) The maintenance and enhancement of amenity values;
d) Intrinsic values of ecosystems;
e) Maintenance and enhancement of the quality of the environment;
f) Any finite character of natural and physical resources;
g) The protection of the habitat of trout and salmon.

Other acts that influence or include biodiversity maintenance are:

Biosecurity Act 1993 (Ministry for the Environment): prevention of potentially harmful exotic organisms arriving in the country, and their eradication or management if they do establish.

Hazardous Substances and New Organisms Act 1996 (MAF – Ministry of Agriculture and Forestry): deals with the deliberate introduction of new organisms that pose an environmental risk.

Forests Act 1949 and 1993 amendment (MAF): deals with management of the logging and export of indigenous trees.

Environment Act 1986 (MfE): established the Ministry for the Environment and the Parliamentary Commissioner for the Environment.

Native Plant Protection Act 1934 (ineffectual in practice).

Key policy documents with regard to monitoring biodiversity are:

- *The New Zealand Biodiversity Strategy (2000),* jointly sponsored by MfE and DOC, which sets out the general outline of steps to be taken to restore biodiversity;
- *The Environmental Performance Indicators: Signposts for Sustainability (1997)* in which MfE sets out its proposals for monitoring the New Zealand environment.
- *National Policy Statement for Biodiversity on Private Lands.*
- *New Zealand Coastal Policy Statement (1994)* in which DOC sets out the principles for sustainable management of the coastal environment under the Resource Management Act (1991).

1.4 New Zealand national organisations and agencies with an interest in biodiversity monitoring

The **Department of Conservation** and the **Ministry for the Environment** are the two major central government agencies in New Zealand with a core mandate regarding conservation of biodiversity.

DOC is charged with conserving the natural and historic heritage of New Zealand on behalf of and for the benefit of present and future New Zealanders. Its mission is 'to conserve New Zealand's natural and historic heritage for all to enjoy now and in the future'. DOC manages or administers on behalf of New Zealanders:

- Reserves and conservation areas
- National parks and conservation parks (formerly called forest parks)
- Protected indigenous forests
- Protected inland waters and wild and scenic rivers
- Indigenous/native wildlife
- Non-commercial freshwater fisheries
- Historic places on conservation land
- Marine reserves, marine mammals, and offshore islands set aside for conservation.

While DOC's focus is primarily on land under Crown control, its mandate to preserve biodiversity, in particular to halt extinctions, extends over the entire New Zealand landmass. It also has a major economic role through providing resources for recreation and tourism, and oversight of some relatively small land-based services and products concessions.

The MfE's core role is concerned with establishing and implementing legislation and policy regarding biodiversity. It works on national environmental standards (see Resource Management Act); national policy statements (most importantly, and in conjunction with DOC, the National Biodiversity Policy Statement); it leads and supports work to fix major national problems; and it coordinates national reporting on the environment.

Statistics New Zealand is responsible for the national environmental accounts, and has been developing a core set of Natural Resource Accounts since 2001. Accounts developed to date include fish, water, forests, energy, miners and environmental protection expenditure. Producing these accounts will, among other things, help New Zealand meet its commitments under various ratified international conventions. There are a wide variety of natural resource accounts that can be produced, including forestry, fisheries, sub-soil/energy assets, water, land and ecosystems. The presentation of natural resource accounts will vary for different resources, but they often share a common conceptual basis.

Other central government agencies with some responsibility for biodiversity include:

- **Ministry of Agriculture and Forestry** (in particular biosecurity issues on agricultural and forestry land)
- **Ministry of Foreign Affairs and Trade** (international treaty obligations)
- **Ministry of Economic Development**
- **Ministry of Research, Science and Technology** (in particular providing scientific policy advice)
- **Ministry of Transport**
- **Ministry of Fisheries**

The **Parliamentary Commissioner for the Environment** (officer of Parliament, not a government department) gives independent advice about the agencies, laws, regulations and processes used to manage and protect natural resources.

The **Environmental Risk Management Authority** makes decisions on applications to introduce new organisms to New Zealand.

Local government (territorial authorities and regional councils) has an important role in conserving biodiversity under the Resource Management Act. The Resource Management Amendment Act 2003 has specifically added ‘maintaining indigenous biological diversity’ and ‘maintenance and enhancement of ecosystems in water bodies and coastal waters’ to the functions of regional councils. There are 12 regional councils, which coordinate and set policy for resource management; 69 district and city councils with local biodiversity management responsibilities; and 4 unitary authorities, which combine the functions of regional and district councils. Besides biodiversity obligations under the Resource Management Act, the territorial authorities are responsible for control of regional plant and animal pests.

2. International review

This review is based primarily on literature from Australia, Canada, the United States, and the European Union. These nations currently lead the field of biodiversity monitoring and environmental reporting. Examination of a wide range of national reports to the Convention on Biological Diversity (CBD) suggested that little would be gained by extending the scope. We chose organisations within these countries that would provide potential models for DOC to use in developing a reporting framework for New Zealand. We also use an example of an international (United States based) organisation, The Nature Conservancy.

All the countries considered have a federal or state aspect to their structure that adds an extra layer of governance and political decision-making, and most have significant cross-border biodiversity links. The organisation of environmental monitoring and reporting is thus often more complex than is required in New Zealand.

2.1 International drivers and mandates for undertaking biodiversity inventory and monitoring

Biodiversity inventory and monitoring programmes have increased markedly worldwide over the last decade in response to concerns over extinctions and sustainability of natural ecosystems. This growing awareness of a biodiversity crisis resulted in two major international agreements, the United Nations CBD and the Montreal Process, to which most nations (with the notable exception of the United States with regard to the CBD) are signatories. While these international agreements have given a much higher profile to biodiversity inventory and monitoring, it is public concern and pressure from non-governmental conservation organisations within countries that has been the major impetus behind the growing emphasis on active biodiversity management, rather than passive legal protection of reserved areas. At the same time, new technology has increased the range of biodiversity problems that can be successfully addressed. With increasing intervention comes the accompanying responsibility for the outcomes and, therefore, the need for monitoring the results of that intervention. Monitoring itself has been transformed by the increasing range of techniques available, and the vastly improved technological capacity to store and use data.

There has also been a managerial revolution throughout the OECD countries resulting in much greater levels of accountability being demanded of those who use public money (Schick 1996). The same techniques of establishment of goals, quantification of targets and outputs, and enforceable performance agreements, once applied solely to private business, now permeate governmental and non-governmental structures alike. Quantitative monitoring of outcomes is at the core of this system.

2.2 Major rationales underpinning national biodiversity inventory and monitoring approaches

Increasingly, international concern at biodiversity loss and developing resistance to non-sustainable production has led to international agreements that attempt to formalise compliance with global standards. As well, measures documenting social, cultural and economic impacts of changing biodiversity and biodiversity management on human communities are now commonplace internationally. Finally, biodiversity management agencies are being asked to analyse and document their efficiency in achieving outcomes.

The following four components underpin the rationale for biodiversity inventory and monitoring systems in most countries (Schneider 1997):

- To inform biodiversity management and policy
- To provide audit assessments of outcome and value of interventions
- To fulfil national and international reporting responsibilities
- To obtain product compliance guarantees, such as forest certification, that confirm that biodiversity values have not been affected.

In general, while local and regional biodiversity inventory and monitoring is strong, measurement of and reporting on biodiversity at a national level in most countries is minimal. It is inadequate for reporting on obligations under the CBD, let alone providing a strong platform for measuring conservation management performance and general biodiversity condition. Specifically, countries are grappling with:

- How to define, measure and report on biodiversity condition
- How to aggregate measures across spatial scales from local to national
- How to coordinate different agencies with varying responsibilities, and often quite different missions, towards a compatible system of reporting on biodiversity conservation.

2.3 How is monitoring and inventory organised?

There are numerous approaches to national organisation of biodiversity monitoring. In the following section we describe how biodiversity monitoring and inventory is organised in Australia, Canada and the United States, and provide an overview of the European Union reporting system. Given the potentially large number of organisations and institutions that could contribute to biodiversity reporting, we have concentrated on organisations that have a counterpart in New Zealand or a mission and organisational aim and structure similar to DOC (i.e. they have to balance the competing needs of conservation and use). In particular, organisations of most relevance are those that:

- Manage land for conservation on behalf of the public

- Have a requirement to satisfy legitimate public use
- Do not in general permit extractive economic use of the land.

In general national parks fit these criteria, but limiting our focus to primarily conservation areas would have excluded large regions of public forested land in the United States and Canada that are managed for timber and, increasingly, conservation, water and general environmental values. We have therefore included examples from Canadian and United States forest parks.

It is important to note that DOC appears to be unique in its brief, combining some of the features of a national park agency with the broader mandate of a department of the environment.
Our review is focused on the following questions:

- How is inventory and monitoring structured?
- Who is primarily responsible?
- What monitoring approach (what system(s)/by whom/when-how reported)?

Australia

Although similar to New Zealand in its ratio of natural areas to agricultural land, and level of industrialisation and population pressure, Australia has the additional complexity of separate state and national governmental systems.

Reporting at national level

Environment Australia acts as the coordinating agency for both information and reporting on biodiversity, as well as other aspects of Australia's environment. It organises environmental issues around themes that cut across geographic and organisational boundaries. Environment Australia is the major agency responsible for the Environmental Protection and Biodiversity Conservation Act (1999), which requires the following:

- State of the environment report (every 5 years)
- Report on matters of national environmental significance (every 5 years)
- Annual report on operation of Act
- Annual reports from other government departments that must report on environmental matters
- Annual performance reports.

To date Australia has produced two state-of-the-environment reports (1996, 2001). The purpose of the reports is to provide accurate, timely and accessible information on the condition and prospects of the Australian environment, increase public understanding of these issues, continue the development of national environmental indicators, report on these indicators, provide an early warning of potential problems, and report on the effectiveness of policies and programmes designed to respond to environmental change, including progress toward achieving environmental standards and targets (Appendix 1: Fig. A1).

The 2001 report, following the requirements set out in the Act, discusses seven themes (biodiversity, the land, inland waters, estuaries and the sea, human settlements, the atmosphere, and natural and cultural heritage) in the context of a condition-pressure-response model. Australia investigated a set of suitable indicators for environmental reporting, and a joint Australia–New Zealand Environment and Conservation Commission (ANZECC) produced a report outlining a core set of indicators needed for state of the environment reporting. The report recommends 13 indicators for biodiversity with additional indicators for Inalnd Waters for example (Appendix 1: Tables A1 and A2).

In addition to the indicators recommended by ANZECC, a series of reports identified a larger set of indicators for each of the seven themes. Of most relevance here are the two reports focusing on biodiversity and inland waters. The first recommended a set of 63 indicators for biodiversity: 17 related to condition, 12 related to pressure, and 34 related to responses to losses or perceived threats to biodiversity (Saunders et al. 1998). The second recommended a set of 53 indicators for inland waters: 6 relating to groundwater, 3 to human health, 13 to water quality, 12 to water quantity, 7 to physical change, 8 to biotic habitat quality and 4 to effective management. In all, 18 are indicators of pressures, 19 of condition, and 16 of response. Of the 53 inland waters indicators, eight relate to biotic habitat quality: (1) AUSRIVAS survey rating, (2) FROGWATCH records of frog populations in surface waters and wetlands, (3) fish-kill records, (4) waterbird population size and breeding colonies, (5) habitat loss, (6) exotic pest number and rate of spread, (7) wetland extent, and (8) number of pest control programmes and the total amount spent on them (Fairweather & Napier 1998). The *2001 Australian State of the Environment Report* also lists reporting done independently at territorial and local levels in response to local legislative requirements.

The Natural Heritage Trust is jointly administered by the Departments of Agriculture, Fisheries and Forestry and Environment and Heritage. It runs a 4-year programme called the National Land and Water Resources Audit Australia, which assesses the condition and trend of wetlands, riparian zones, threatened species and ecosystems and the processes that threaten various elements of biodiversity. Based on a biogeographic framework of bioregions and sub-regions, it contains comprehensive mapping of biodiversity elements and quantitative and qualitative assessments by a large range of scientists and land managers. A number of products are being produced, including landscape health assessment, rangeland biodiversity, rangeland function analysis framework, and rangeland ecosystem function indices. It has developed a national vegetation information system, and an Australian-wide monitoring framework for condition and trend of rangelands and catchments, rivers and estuaries. Much of the integration is provided by the Web-based *Australian Natural Resources Atlas*, which presents Audit products from Australia-wide to regional scales. The atlas is organised by geographic region (national, state, ecological) and by topic. The latest comprehensive overview of biodiversity is provided by the *Australian Terrestrial Biodiversity Assessment 2002* (published by National Land and Water Resources Audit, Canberra).

Rangeland monitoring in Australia

The Commonwealth, State and Territory governments of Australia have established a monitoring framework for rangelands that includes biodiversity measurements. Known as the Australian Collaborative Rangelands Information System (ACRIS), it is in the early stages of development, although there is a long history of rangeland monitoring in Australia.

The information and discussion that is currently being generated is highly relevant for New Zealand. The project developers are very much aware of the difficulties of sustaining long-term biodiversity monitoring projects that maintain their relevance for land management agencies.

> Biodiversity indicators often fail as monitoring tools when too few are chosen, the purpose(s) for monitoring are loosely defined, indicators do not often link with existing indicators, or they fail to use a protocol to ensure indicators are selected with suitable rigour. Experience has shown when an inadequate balance occurs among the agreed purpose(s), sampling scheme, data collection and analytical steps, there is a high probability that no data analysis and interpretation will be performed despite the investment of substantial resources in data collection by the clients/users. (Smyth & James 2004, p. 8)

A key report by National Land & Water Resources Audit (Woinarski, et al. 2001) details purposes for monitoring, and a minimum set of 11 indicators:

Purposes for monitoring biodiversity:
1. Policy making
2. Regulation, involving performance and audit functions
3. Detecting incipient but significant change as an early warning
4. Assessing effects of management
5. Assessing niche markets for rangeland products
6. Improving public information and knowledge
7. Improving communication and education strategies.

Minimum set of indicators:
1. Progress towards a comprehensive, adequate and representative reserve system
2. Landscape function metrics

   Trends in the:
3. extent of clearing native vegetation
4. cover of native perennial grass/native perennial ground-layer
5. vegetation intensity of land use

   Trends in the distribution and abundance of:
6. exotic plant species
7. grazing-sensitive plants
8. susceptible mammals
9. susceptible birds

   Trends in the distribution, abundance and condition of:
10. fire-sensitive plant species and communities
11. listed threatened species.

Monitoring design issues are addressed in Watson & Novelly (2004). On the basis of experience with rangeland biodiversity in Western Australia, they stress that it is difficult to reconcile national with local management needs. When the monitoring system addresses state or nation-wide overarching policies, or regionally focused activities such as land-use planning or reserve networks, it is unlikely to be useful in assisting with local management decisions because of the necessarily coarse resolution.

The Western Australian Rangeland System (WARMS – 1600 monitoring sites), which has been operating since 1992 but for which planning began in the early 1970s, has provided some informative insights into setting up a biodiversity monitoring system.

> No programme could possibly deliver outputs to satisfy all purposes, especially as the reporting scale, resolution of measurements and timeframe are likely to differ

> for different purposes. A solution to this problem is to prioritize client's/users' purposes in the design phase. (Smyth & James 2004)
>
> If the design is to be cost-effective, the questions must be framed before design can begin. Over-reliance on a capacity to adapt systems in the future as the questions become clearer may be a costly strategy. Wrong decisions about the fundamentals will see much time, money and effort squandered in the evolutionary process. (Woinarski et al. 2001)
>
> Although every system will be different…approximately 25–30% of the budget should be used for data management, assessment and reporting. It was some years into the programme before this was realised, accepted and funded. (Watson & Novelly 2004)

Also, given the central importance of grazing in a rangeland system, it is somewhat sobering that Landsberg and Crowley (2004) conclude that as grazing pressure is highly variable in space and time it is not amenable to direct monitoring, and that although grazing density can and should be monitored, it can give a false impression. In respect to grazing-sensitive plants, they conclude that their use is problematic at a regional scale because:

- these plants change from region to region
- have different responses to grazing
- attempts to identify indicator response groups have met with limited success (insensitive species only available, because others have gone)
- difficult to interpret with regard to all but gross trends.

They suggest monitoring through measuring change in relation to benchmark sites.

Reporting at regional level

Each state government has its own department of the environment concerned with a wide range of issues including biodiversity. They tend to be large organisations (e.g. Victoria employs 4000 staff). They report to their government and also provide information for the national state-of-the-environment report.

Australian national parks are established and controlled by the state governments and territories, although 15 are under **Federal Parks Australia** management. The parks do not have a unified or consistent scheme for natural heritage reporting.

Australia has recognised that the current system has limitations and the Australian Commonwealth Government has a proposal to set up a stand-alone agency with the following brief:

> To ensure the information-based approach to natural resource management that Australia has implemented is effective, Australia needs to establish an information agency with assured life and independence. A legislative base would enable and facilitate processes for the coordinating of natural resource data collection, information provision, mandated assessments of progress, the review and fine tuning of major programs and the development of initiatives. (*Australia's Natural Resources: 1997–2002 and Beyond*. National Land & Water Resources Audit, a programme of the Natural Heritage Trust)

Canada

Although Canada has the same level of provincial and national complexity as Australia, the country shares borders and territorial waters with the United States, Russia, Greenland and France, which imposes an extra layer of environmental reporting through bilateral agreements.

Reporting at national level

The situation in Canada is complex because many organisations have mandates that involve the monitoring of environmental variables and include cross-border relationships. Municipal, provincial, territorial and national government departments and organisations have developed environmental indicators related to their mandates (e.g. Agriculture and Agri-food Canada's Agri-Environmental Indicators; Canadian Council of Forest Ministers Criteria and Indicators of Sustainable Forest Management). Coupled with this are various universities, environmental non-governmental organisations (ENGOs), and citizen science groups that conduct long-term monitoring. Collectively these groups invest much time and effort in monitoring large areas of Canada. However, due to different priorities and monitoring protocols, the aggregation of such data to detect ecosystem-level or national trends is difficult.

The key national agency is **Environment Canada**, which focuses on three broad lines of business (Clean Environment; Nature; Weather and Environmental Predictions). It also includes the Canadian Wildlife Service, which has national responsibility for wild animal populations, including cross-border agreements. Environment Canada (National Indicators and Reporting Office) produced a national set of environmental indicators in 1993 and subsequently reported on these in 2003. Canada is still working on producing a single national set of 'core' environmental indicators. Regional offices of Environment Canada have developed programmes to report on regional ecosystem issues.

The central national agency for inventory and monitoring is **Ecological Monitoring and Assessment Network (EMAN)**.

We will discuss the role of EMAN in some detail, because it is one of the strongest models for a national monitoring system anywhere in the world.

The EMAN network (hosted within Environment Canada's 'Nature business') is a cooperative partnership of federal, provincial and municipal governments, academic institutions, aboriginal communities and organisations, industry, environmental non-government organisations, volunteer community groups, elementary and secondary schools and other groups and individuals involved in ecological monitoring. Partners within the network can be involved in ecological monitoring in many different ways. Most partners consist of institutional scientists and researchers who maintain integrated monitoring sites to detect long-term ecosystem trends using a variety of ecosystem monitoring variables.

When it was established in 1994, EMAN was mandated to coordinate integrated ecosystem monitoring and research to provide an understanding and explanation of observed changes in ecosystems, without directly funding monitoring sites or duplicating initiatives already underway. The four basic objectives were to:

- Provide a national perspective on how Canadian ecosystems are being affected by the multitude of stresses on the environment

- Provide scientifically defensible rationales for pollution control and resource management policies
- Evaluate and report to Canadians on the effectiveness of resource management policies
- Identify new environmental issues at the earliest possible stage.

EMAN aims to establish a reliable and compatible set of environmental indicators at all levels, and is coordinated by Environment Canada's **Ecological Monitoring and Assessment Network Coordinating Office (EMAN CO)**. EMAN CO is accountable to the federal Minister of the Environment, and also to EMAN partners.

EMAN CO contributes to partnerships by coordinating the development, modification and/or recommendation of standardised protocols for ecological monitoring. Protocols are developed through wide consultation with scientists, researchers and experts related to the variable or indicator under study. EMAN CO offers three different protocol areas to meet the various goals and objectives of different monitoring activities:

- Biodiversity monitoring protocols have been prepared and/or reviewed for EMAN by or through the Biodiversity Science Board's (BSB) expert teams. Subject to a peer-review process, these protocols are recommended for intensive research-based projects.
- EMAN standardised ecosystem monitoring protocols (EMPs) complement plot-based monitoring programmes and can be used for more specific investigation purposes. EMPs in combination detect and track ecosystem changes over time, particularly in protected areas and working landscapes. Based on environmental indicators responsive to significant changes in ecosystems, the suite selected was developed through wide consultation with specialists.
- Community-based monitoring protocols are EMPs that have been rewritten to make them relevant and accessible to schools, community groups, individuals, naturalists, backyard enthusiasts, or scouts and guides, who are engaging in the monitoring of different aspects of environmental quality.

EMAN CO is working with its partners to build a common system for managing distributed data quality. Focusing on internationally used and developing metadata and environmental data management standards, EMAN CO trains, presents information sessions, and hosts data systems. EMAN CO also works with Environment Canada as it builds its own library system for distributed data. EMAN CO's goal alongside the EMAN partners is to build a window where metadata and environmental data are accessible through online interfaces. These include interactive maps, a solid search engine, and online trends. Early-warning reporting is a central task of EMAN CO, through providing widely circulated documents on ecological change based on risk probability and expert opinion, and the scientific and general public are encouraged to provide feedback. A national science meeting is held each year when EMAN CO reports to the network the results of the past year and facilitates the discussion for coming-year strategies. Partners have the opportunity to present and release their findings and some meetings have seen the launch of major environmental programmes, such as the NatureWatch in 2002.

EMAN plans to develop relationships with the International Long Term Ecological Research (ILTER) network, the US LTER network, and the United Kingdom's Environmental Change Network (ECN). EMAN is already an active partner in the North American Biodiversity Information Network and currently maintains both an environmental metadata clearinghouse and a Species Analyst observation data node.

EMAN is also fostering links with the broader community. The **Canadian Community Monitoring Network (CCMN)** is a partnership between the Canadian Nature Federation (CNF), EMAN CO and a network of communities, organisations, individuals and government agencies. It is a new initiative to enable communities to define and manage local sustainability through effective, scientific, standardised, and generally inexpensive monitoring practices compatible with environmental values of the community. The CCMN pilot project has been launched in more than 30 communities across Canada. EMAN CO, the Canadian Nature Federation (CNF) and the University of Guelph have established a series of NatureWatch programmes designed to collect reliable information to contribute to local, regional and national monitoring programmes. The focus is to encourage the cooperation of community partners to expand geographic coverage and augment the frequency of observations, while communities gain firm information on local changes to aid local decision-making.

Parks Canada - The Federal Canadian Government has established 38 national parks totalling 269 250 sq. km (roughly equivalent to the area of New Zealand). Parks Canada has an ambitious environmental reporting scheme under development, following a review of overall monitoring and management practices.

Parks Canada has settled on 'ecological integrity' (EI) as the key element in its monitoring and inventory programme. As defined in legislation (Canada National Parks Act) ecological integrity is: 'a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes.'

Each park is currently adjusting its present EI monitoring programmes to report on both specific management issues and on the whole park ecosystem, as set out in the national EI framework (Table 1). In 2003 a national park survey was underway to summarise all the ongoing monitoring.

Table 1. Canadian national Ecological Integrity monitoring framework.

Assessing ecological integrity		
Biodiversity (characteristic of region)	**Ecosystem function** (resilient, evolutionary potential)	**Stressors** (unimpaired systems)
Species richness - change in species richness - numbers and extent of exotics	**Succession/retrogression** - disturbance frequencies and size (fire, insects, flooding). - vegetation age class distributions	**Human–land-use patterns** - land-use maps, road densities, population densities
Population dynamics - mortality/natality rates of indicator species - immigration/emigration of indicator species - population viability of indicator species	**Productivity** - remote or by site	**Habitat fragmentation** - patch size, inter-patch distance, forest interior
Trophic structure - size class distribution of all taxa - predation levels	**Decomposition** - by site	**Pollutants** - sewage, petrochemicals etc. - long-range transport of toxics
	Nutrient retention - Ca, N by site	**Climate** - weather data - frequency of extreme events
		Other - park-specific issues

The summary conclusions from *Conserving Ecological Integrity with Canada's National Parks* (Panel on Ecological Integrity of Canada's National Parks 2000) made the following comments on traditional monitoring in the parks:

- Monitoring requires long-term commitment, adequate resources and stability. Historically, however, monitoring has been seen as an extra, expensive programme.
- The important relationship between monitoring and management is not clear. Monitoring must become an integral part of the management process, following the model of adaptive management.
- Parks Canada has devoted significant resources to monitoring activities but monitoring programmes have been driven largely by specific management issues such as human–bear conflicts, or by the individual interests of park staff or university researchers. Monitoring has provided some useful information to help address specific management concerns but generally it has not provided a clear picture of the overall state of ecological integrity.
- Funding for monitoring has been sporadic and methods have changed frequently, weakening the ability to use the information over time. Close to 50% of all studies done in national parks have been lost because of poor data management.
- Monitoring has been patchy throughout the national parks, with some parks having comprehensive programmes and others very little.

An interesting point, given the coordinating role of Environment Canada and EMAN, is that little, if anything, is mentioned in primary Parks Canada documentation about the role of EMAN. The strong impression given is that Parks Canada is focused almost entirely on documenting EI on its land, with little reference to the national EMAN overview.

Canadian forests - Canadian forests cover 42% of its landmass, of which 94% are under public ownership. The provinces or territories manage productive timberland and each produces its own state of the forest report (e.g. *State of the Forest Report 2001*, Ontario Ministry of Natural Resources). Ontario, for example, reports on the basis of seven criteria (4 ecological; 2 socio-economic; 1 policy). The ecological criteria are: (1) Conserving biological diversity, (2) Maintaining and enhancing forest ecosystem condition and productivity, (3) Protecting and conserving forest soil and water resources, and (4) Monitoring forest contributions to global ecological cycles. Each criterion is broken down further into elements, and these are measured by 31 indicators.

The provinces and territories combine in this common forest framework to report on the nation as a whole (Canadian Council of Forest Ministers 2000: *National status 2000, Criteria and indicators of sustainable forest management in Canada*). The council has developed a complex eco-region classification for Canadian forests, and harmonised their criteria and indicators. While clearly tilted towards growth measures, it is of interest to see how many measures are regarded as necessary to capture the forest system processes. The current system of criteria and indicators for ecologically relevant issues is outlined in Appendix 1, Table A2. As with Parks Canada, the reports available to us showed no clear links to Environment Canada programmes. These links may exist, but they are certainly not highlighted in Canadian Council of Forest Ministers' reports.

United States

A large population, strong tradition of state and individual rights, and a proliferation of governmental and non-governmental organisations have produced in the United States an extremely complex environmental management matrix, with no legal requirement for reporting on the state of biodiversity for the entire country, or internationally since it is not a party to the CBD. Nationally, biodiversity reporting is scattered among land-owning or managing federal agencies (Table 2).

On the ground, monitoring tends to be done by those organisations that have statutory responsibility for land management or have a wider policy brief for some aspects of the environment but no direct management responsibility. An example of this split is where the USDA Forest Service has management and environmental responsibility over public forests but the Environmental Protection Agency has jurisdiction over resource issues related to quality of land and water, including ecological condition (Table 2).

The governmental organisations we have found most instructive are the USDA Forest Service, the Environmental Protection Agency and the National Park Service.

Table 2. National environmental reporting agencies in the United States.

Agency	Mission & goals	Jurisdiction	Reporting
Bureau of Land Management	Sustains the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations	Forest & rangeland, mostly in the western United States	National Assessment Prototype (2002)
Fish and Wildlife Service	Working with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people	National wildlife refuges throughout the United States	Annual performance reports
USDA Forest Service	Sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations	National forests throughout the United States	Annual report
National Park Service	Preserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations	National parks throughout the United States	Annual report
Environmental Protection Agency	Protect human health and safeguard the natural environment – air, water, and land – on which it depends	Various air, land, and water resources	None yet

USDA Forest Service - Responsible for federally owned forested land, the USDA Forest Service aims to sustain the health, diversity, and productivity of forests and grasslands throughout the United States. Of the forested land, 35% is available for regularly scheduled timber harvest and about 0.5% of those trees are harvested annually. The remaining 65% is designated for non-timber uses, such as wilderness and recreation, or cannot be harvested due to environmental conditions, such as steep slopes and fragile soils. The Forest Service conducts considerable research aimed at finding more effective ways of managing forests in an ecologically sound manner. Its mandate is therefore similar to that of the New Zealand Forest Service until 1987.

Currently, the USDA Forest Service is undertaking a review of its renewable resources, as required every decade by the Forest and Rangeland Renewable Resources Planning Act 1974. The legislation requires the agency to:

- Report on present and anticipated uses, demand for, and supply of renewable resources, with consideration of the international resource situation, and an emphasis on pertinent supply and demand and price relationship
- Provide an inventory of present and potential renewable resources, and an evaluation of opportunities for improving their yield of tangible and intangible services
- Discuss policy considerations, laws, regulations, and other factors expected to influence and affect significantly the use, ownership, and management of forest, range, and other associated lands
- Analyse the potential effects of global climate change on the condition of renewable resources
- Analyse rural and urban forestry opportunities to mitigate the build-up of atmospheric carbon dioxide and reduce the risk of global climate change.

The *2000 Resource Assessment* is organised around six criteria established by the signing of the Santiago Declaration in 1995, which committed the United States to develop and evaluate national indicators for sustainable forest management. The six criteria are:

- Conservation of biological diversity
- Maintenance of productive capacity of forest and range ecosystems
- Maintenance of forest ecosystem health and vitality
- Maintenance of forest contribution to global carbon cycles
- Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies
- Legal, institutional, and economic framework for forest conservation and sustainable management.

Indicators are used to characterise relevant trends, and for criterion 1 (conservation of biological diversity) the following indicators are enumerated:

Ecosystem diversity

- Historical trends in land cover
- Area of forest land by forest type
- Extent of timber land by forest type and age class or successional stage
- Extent of areas by forest type in protected area categories as defined by IUCN
- Fragmentation of forest types

Species diversity

- Number of forest-dependent species
- Status of threatened and endangered species

Genetic diversity

- Number of forest-dependent species that occupy a small portion of their former range
- Population trends in wildlife species.

The USDA Forest Service has periodically inventoried the status of the nation's forests through the Forest Health Monitoring Programme (FHMP), which replaces the older Forest Inventory and Analysis Programme (FIA). The FHMP inventory is based on a nationwide 27-km-grid network, with subplots sampling a variety of attributes at grid points. The subplots scale to the nature of the attributes and range from 2 m^2 to 1 ha. The plots are sampled every 4 years for a wide variety of ecological attributes extending far beyond traditional timber and site measures.

The USDA Forest Service has also initiated the LUCID project, a wide-ranging and inclusive attempt to establish monitoring protocols and develop operational indicators for national forests and grasslands. LUCID has suggested a hierarchy of elements for a reporting plan (Wright et al. 2002). It is compatible with the widely used Criteria and Indicator framework for international agreements such as the Montreal Process.

The conceptual framework for the indicators is of interest as a model for a possible New Zealand system. It is as follows:

Principle: A fundamental law or rule serving as a basis for reasoning and action. An explicit goal.

Criterion: A component of the structure or function of the ecological, social or economic systems, which should be in place as a result of adherence to a principle. Criteria form the conceptual architecture of the systems under investigation.

Indicator: A quantitative or qualitative parameter that can be assessed in relation to a criterion. Note that indicators have no implied direction, measurement method, spatial or temporal scale, or reference value.

Measure: The methodology and source of information for the indicator. The form, scale, timing and units of data that are gathered are specified.

Data element: The elemental data that support a measure. Some measures are specific enough that the level of data element is not needed.

Reference value: The benchmark, standard, or norm against which the data are assessed. Reference values specify the range or threshold expressing the desired future systems condition over a given period.

An example sets out how this structure is applied in practice:

Principle: Ecological integrity is maintained

Criterion: Landscape structure/composition

Indicator: Landscape patterns

Measure: Density and distribution of human-developed features by use class (e.g. road density, number of road crossings, and distance to human-developed features)

Data element: Road density by 4th field watershed

Reference value: Open-road density in 4^{th} field watershed 0.7–1.7 road miles per square mile.

It is not clear whether LUCID will be made operational by the USDA Forest Service, and some we spoke to suggested a major reason is that it does not address all the needs of the Forest Service. Given the major investment into the project this uncertain outcome underlines the need for any system to obtain comprehensive approval before moving onto detailed design work.

Environmental Protection Agency - The EPA, which does not manage any land, has jurisdiction over a number of resource issues related to quality of land and water. To that end, the EPA began an initiative to develop and report on ecological indicators at the national level. That programme, however, is still being developed, and to date, the EPA has only produced an outline for a state of the environment report, which is expected to cover five themes: human health, ecological condition, clean air, pure water, and better protected land. They have also produced a draft list of indicators on which to report (Appendix 1: Table A4).

In addition to the indicators programme, the EPA has an Ecological Monitoring and Assessment Programme (EMAP) that is designed to monitor and report on ecosystem condition throughout the United States. Within EMAP, the Ecosystems Indicator Working Group is studying the characteristics that make indicators useful, to improve the quality and utility of existing indicators and identify the need for new indicators of ecological condition. EMAP is also a partner in the Multi-Resolution Land Characteristic Consortium, a group of six federal agencies pooling resources to obtain remote-sensed information to develop comprehensive land characteristics information for the United States.

National Park Service - Of all the agencies in the United States, the National Park Service (NPS) has the closest organisational mission and set of goals to those of DOC. National Park Service policy and recent legislation (National Parks Omnibus Management Act 1998) requires that park managers know the condition of natural resources under their stewardship and monitor long-term trends to fulfil the NPS mission of conserving parks unimpaired. However, the need for coordinated, agency-wide inventory and monitoring was recognised nearly 10 years earlier. In 1987 a task force designed an inventory and monitoring system, and a second task force in 1991 highlighted the need for a programmatic and systematic approach. In 1992, prototype monitoring began in four national parks. In 1997, three more parks (or ‘units’ in the NPS lexicon) joined the prototype inventory-and-monitoring programme. By 2000, the NPS had identified 11 parks for prototype inventory and monitoring, but only seven had active programmes due to budget constraints, out of approximately 270 units within the system. The inventory and monitoring programme received $18.4 million in 2001, but much less than the funding estimated ($100 million) to implement full inventory and monitoring in all parks. To date, approximately 930 inventories have occurred over 95 parks. Currently, programme staff consist of a manager and six support staff. A national advisory committee, consisting of two permanent members and 13 rotational members such as park superintendents, natural resource management specialists, programme managers, and Biological Resources Division scientists, develops strategic policies and makes programmatic, technical, and budgetary recommendations. Ad hoc working groups of technical experts address specific policies and technical issues, and personnel in support offices coordinate activities between the parks and the national programme office.

The Biological Resources Division of the U.S. Geological Survey also provides indirect support by funding research efforts aimed at NPS inventory and monitoring efforts through support for vegetation mapping and research and development of prototype monitoring systems.

Since 1996, the national programme office has produced annual reports. The NPS identifies '12 natural resource data elements' that it considers are essential for proper park management, planning, and natural resource protection . Those elements are:

- Air quality & related values
- Base cartographic data
- Geology map
- Location of air quality monitoring stations
- Natural resource bibliography
- Precipitation and meteorological data
- Soils maps
- Species distributions and status of vertebrates and vascular plants
- Species list of vertebrates and vascular plants
- Vegetation map
- Water body location and classification
- Water quality data.

The annual reports only present a selected sample of the full inventory and monitoring programme. Within the section on 'Monitoring and Status of Natural Resources,' topics are organised around the following themes: air quality, water quality, weather, aquatic communities, terrestrial communities, terrestrial vegetation, forest pests, fishes, birds, and mammals. Within each theme, the report discusses conditions of various resources at some or all the prototype monitoring sites. With respect to water quality, for example, the latest annual report discusses stream-channel reference sites in Denali National Park and Preserve, water quality in Great Smoky Mountains National Park, and water and watersheds in Shenandoah National Park.

In general, the annual reports provide detailed information on the condition of selected features within selected national parks. They go beyond the traditional outputs typically found in most reports and describe in detail the rationale for selected inventory and monitoring, the methods used, and the results obtained. In particular, they provide excellent contextual background in the form of natural history information that sheds light on both the historical and current conditions, pressures, and known or suspected sources of pressure. In cases where pressure is known, the reports also describe actions taken to mitigate those pressures and the results.

However, variation of topics between years and the limited number of parks (7 of 270) that are regularly reported on make it difficult to obtain a consistent national picture as to the overall effectiveness of NPS activities. Also, the reports are technical, and the information is not readily accessible to non-scientists. Nevertheless, the in-depth detail provided by the NPS reports represents a refreshing change from the mostly uninformative output-style reporting that many other agencies, including DOC, have typically conducted in the past.

Finally, the NPS maintains a website dedicated to natural resource planning that allows people to track the status of various planning documents relative to individual national parks or other topics, including general management, implementation, special resource studies, commercial services, resource management, sites, and wilderness areas.

The Nature Conservancy - The Nature Conservancy (TNC) is a large non-governmental conservation organisation based in the United States, but with considerable overseas involvement. Its mission is 'to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive.' TNC works to achieve these goals through a variety of means, including acquiring land and building partnerships with other conservation organisations or industry to promote broad-scale conservation goals. To date, the Conservancy has protected nearly 58 million hectares worldwide, and in 2002 raised US$0.9 billion for conservation.

The Nature Conservancy has adopted a multi-step, multi-scale conservation strategy called 'Conservation by design' (TNC 2002). The strategy consists of four steps: setting priorities, developing strategies, taking action, and measuring success. The first step, setting priorities, involves developing broad-scale conservation portfolios that extend across large geographic areas. These contain the full complement of biodiversity assets within a given area.

For each portfolio TNC develops a conservation strategy that considers both multiple and individual sites. At the lowest level, they have single sites consisting of individual preserves to which they apply the '5-S Strategy.' This strategy consists of identifying at each of those sites: systems, stresses, sources of stress, strategies, and success measures. At broader scales, the Conservancy has a multi-area strategy that links multiple conservation areas. This process consists of four steps:

1. Identifies common stresses and sources of stresses to those multiple conservation areas.
2. Identifies the institutions capable of achieving desired conservation outcomes.
3. Designs strategies to reduce stresses across multiple conservation areas.
4. Holds itself accountable for measuring success across those areas.

Based on the conservation strategy, TNC implements the necessary actions to reduce stresses to the system, including purchase of property, arranging agreements with other institutions to promote land-use practices that are compatible with conservation goals, engaging community groups to perform conservation actions, and educating the public on conservation issues and goals.

In the final step, 'measuring success,' TNC regularly measures both the level of threat and the biodiversity health at areas identified for Conservancy action in ecoregional portfolios. Biodiversity health is a measure of size, condition, and landscape context. Each area receives a categorical rating of very good, good, fair, or poor. Threats (note this term differs from stresses used earlier, but likely means the same thing) to biodiversity are also measured categorically as very high, high, medium, or low. Assessments for both health and threats occur every 3–5 years. Ironically, the Conservancy states that they use these measures to 'quantify our conservation impact' (TNC 2002, p. 9).

Surprisingly, comprehensive reports are not readily available. The annual report consists of several individual stories and short descriptions of specific projects that TNC pursued during the previous year, but does not contain any quantitative or even categorical assessments of the biodiversity health or stress/threats.

NatureServe - A sister organisation to TNC, NatureServe has a more scientific focus. It runs natural heritage programmes in each state and works closely with state natural resource agencies to assess the status of natural heritage. The natural heritage programmes track occurrences of endangered and threatened species at the state and federal level and locations of rare ecosystems, communities, or natural features. Data from the different programmes can be combined to provide information at regional or national scales. They have also developed a set of data standards and protocols for their nature heritage programmes, as well as an extremely detailed biodiversity data model (Biotics 4) for the storage and retrieval of natural heritage data.

NatureServe recently published a report entitled *States of the Union: Ranking America's Biodiversity* (NatureServe 2002) that presents information on the status and rank of each state for species-based measures of diversity, risk, endemism, and extinctions. The indicators are usually the number and percentage of species involved. NatureServe also maintains an online data server (www.natureserve.org/explorer) that allows Internet-based searches for data on the conservation status of plants, animals, and ecological communities. Each record returns a summary providing ecological context for the element, a distribution map showing the state or states of occurrence, and conservation status relative to its global heritage status rank.

European Union

Policies and agreements - A large number of agencies interact in complex ways to establish standards, collect results, and report on biodiversity inventory and monitoring in the European Union (EU) (Appendix 1: Fig. A2). Nature protection and biodiversity conservation are driven by four major policies: Conservation of Wild Birds (Birds Directive – 1979); Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention – 1982); Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive – 1992); Pan-European Biodiversity and Landscape Diversity Strategy (PEBLDS – 1995).

The first two policies are species-focused. The Birds Directive requires countries to maintain native bird species 'at a level which corresponds in particular to ecological, scientific and cultural requirements, while taking account of economic and recreational requirements, or to adapt the population of these species to that level.' The Bern Convention has three objectives: (1) to conserve wild flora and fauna and their natural habitats, (2) to promote cooperation between states, and (3) to give particular emphasis to endangered and vulnerable species, including endangered and vulnerable migratory species. It arose from agreements at the Council of Europe, a trans-national agency similar to the United Nations but with a European scope. Associated with the Bern Convention is the Emerald Network, a series of sites protected for individual specific species or habitats.

The Habitats Directive and PEBLDS are more recent and are ecosystem focused. The Habitats Directive originated through the European Commission, whereas PEBLDS arose from further meetings of the Council of Europe. The aim of the Habitat Directive is to ensure biodiversity through conservation of habitat and flora and fauna, taking into account economic, social, and cultural requirements, and regional and local characteristics. PEBLDS takes a holistic approach focusing on conservation at broader spatial scales for both biodiversity-conservation and sustainable-use purposes. Similar to the Bern Convention, both the Habitat Directive and PEBLDS have associated networks to achieve their goals, called

Natura 2000 and the Pan-European Ecological Network (PEEN), respectively. Natura 2000 consists of areas designated as significant under the directive and covers almost 60 million hectares of current and proposed sites (18% of EU territory). The ultimate aim of PEEN is to set up a series of core areas with sufficient associated buffer areas and corridors to preserve the structure and functions of entire landscapes and ecosystems, including the species that comprise them. The relationship between Natura 2000 and PEEN is unclear.

The European Environment Agency - The EEA (www.eea.eu.int) coordinates the collection, dissemination, and reporting of biodiversity on behalf of the European Union, and has an annual budget of approximately €25 million and 100 staff. EEA is charged with producing four series of reports:

1. Broad integrated assessments (Five-year state & trends reports, e.g. Turn of the Century, Kiev).
2. Indicator-based reports (yearly Signals report, TERM report).
3. Specific issue reports (e.g. greenhouse gases, GMOs, hazardous waste).
4. Best practices (e.g. wastewater treatment report, env. taxes reports, EnviroWindows).

To support its efforts, the EEA has established the EU Biodiversity Clearinghouse and EIONET (European Environment Information and Observation Network). The Clearinghouse is a web-based database designed to capture a broad array of biodiversity information found across multiple organisations and institutions. The EU Clearinghouse has been designed following CBD guidelines so that it can interact with the CDB clearinghouse. EIONET links information from institutions across Europe with the intent of helping people make better decisions regarding the environment. It is a distributed network consisting of 33 servers spread throughout various government agencies linked via the Internet.

Supporting the EEA are two organisations: the **European Topic Centre for Nature Protection and Biodiversity (ETC-NPB)** and the **European Centre for Nature Conservation (ECNC)**. The ETC-NPB acts as the science and research arm of EEA. It is responsible for development of the biodiversity indicators that the EEA will use in its overall reporting effort. The ECNC works to promote cooperation and exchange of ideas among many institutions throughout Europe. It has a large network of partner organisations, totalling 42 members in 22 countries covering a broad range of expertise including training, education, information management, policy, economics, legal affairs, and remote sensing.

Within the European Commission resides the **Directorate-General of the Environment (DG-Environment)**, one of 36 directorates-general (DGs) that make up the European Commission. Its main role is to initiate and define new environmental legislation and to ensure that measures, which have been agreed, are actually put into practice in the Member States. DG-Environment is based largely in Brussels and has around 550 staff.

The DG-Environment has responsibility for implementation of the Birds and Habitats Directive, and has released a biodiversity action plan designed to ‘integrate the protection of biodiversity into EU agricultural, fishery, environment and development and cooperation policies’ and aims ‘to stop losses in wildlife, ecosystems, varieties of crops, domestic animals and fish.’ Part of the action plan includes developing indicators for species found mainly in agricultural areas and for selected marine and aquatic species.

To date, the EU has produced three environmental assessments. The first, the Dobris Assessment in 1995, included an extensive chapter on nature and wildlife. The approach taken was to sample sites that represented seven major ecosystem types: forests; scrub and grasslands; inland waters; bogs, fens, and marshes; coastal and marine ecosystems; mountains, rocks, screes, inland dunes, caves; and deserts and tundras, which are divided into seven broad geographic regions: boreal, Baltic, central, Atlantic, east, Alpine, and Mediterranean. Sites were chosen according to five criteria: representativeness: habitats that are typical for a region, but have become rare or have degraded; naturalness: non-altered, species relatively identical with natural potential vegetation; diversity: number of habitat types and species within one area; threat: types of habitats that are suffering severely under environmental stresses; and size: those covering the largest areas fulfilling these criteria.

Each section on ecosystem type contains an introduction discussing the former state of the ecosystem in terms of areal extent and dominant plant species, analysis of functions and values, perceived habitat threats, description and analysis of the representative sites, and a conclusion outlining the state of knowledge, potential threats, and potential next steps.

The second assessment, prepared in 2001, mostly provided general statements on biodiversity declines, such as saying that half of all vertebrate species are ‘under threat’. The Third European assessment (EEA 2003) provided more information on biodiversity, on broad trends, such as loss or gain in forest cover, wetlands, or total protected area. However, it does include detailed information where available, such as population trends for some large mammals and bird species. Curiously, the ‘Country Table of Key Statistics’ at the end of the report does not include any measures of biodiversity.

The EEA is current working on developing a set of biodiversity indicators for use in reporting, based on three groups: (1) State and trends in Europe’s biodiversity, (2) Conservation and restoration of Europe’s biodiversity, and (3) Integration of biodiversity issues into sectorial policies. The list of potential indicators is available online (http://ims.eionet.eu.int/Topics/BDIV/indicators). Each link leads to a table that provides a summary of the indicator, with further links that lead to a full description including metadata. In addition, the EEA provides a clearinghouse website (http://countries.eea.eu.int/SERIS) with links to national-level reporting for many countries both in and associated with the EU.

Finally, since 2000 the EEA has also produced a series of reports entitled ‘Environmental Signals,’ targeted towards the high-level policy makers of the EU member states. They focus on human concerns, such as air pollution, water pollution, and ozone depletion. Some of the topics deal indirectly with biodiversity or directly with particular aspects of biodiversity. As mentioned above the Third European assessment (EEA 2003) provided more information on broad trends in biodiversity, based largely on changes in extent. Biodiversity-relevant sections are included in accounts of climate change and on dry grasslands. Although it did not include a specific section on biodiversity, it did mention what a biodiversity indicator would entail: ‘an overview indicator on the status of biodiversity in Europe would require a complete coverage of changes in the natural status of each piece of land (and sea), which is not currently available’ (EEA 2001, p. 60).

The most recent report (EEA 2002a), entitled ‘Environmental Signals 2002 – Benchmarking the Millennium’, states that biodiversity indicators are under development and highlights trends in forests as examples of biodiversity measures.

2.4 International overview

What organisations take responsibility for monitoring and reporting on biodiversity?

All countries examined had a diverse range of agencies involved at some level in reporting on biodiversity, whether or not they had a specific governmental mandate to provide such information. These fall into a number of categories listed below, with international examples, including New Zealand equivalents where possible:

1. Purpose-designed government agencies for biodiversity/environmental monitoring and reporting at a national level: *National Land & Water Resources Audit, Australia; New Zealand Parliamentary Commissioner for the Environment.*
2. Government agencies for which biodiversity/environmental reporting and or monitoring is a major or legislatively required part of their brief, but management is not: *US Environmental Protection Agency; Environment Canada; New Zealand Ministry for the Environment; Statistics New Zealand.*
3. Government (at all levels) agencies that are responsible for managing components of biodiversity (regional governments, national parks, national forests, fisheries, agriculture) and need to report on it in relation to their brief: *National park agencies in all countries, Departments of agriculture and fisheries; New Zealand regional councils.*
4. Organisations with an environmental or biodiversity brief, partly or wholly funded by governments but not actually government agencies: *The National Round Table on the Environment and the Economy, Canada.*
5. Organisations, or programmes, not funded (or not substantially funded by governments) but that regard themselves as having a biodiversity/monitoring or reporting role: *Heinz Center for Science, Economics and the Environment (United States); The Nature Conservancy (United States); British Trust for Ornithology; QEII New Zealand; indigenous people organisations.*
6. Non-governmental environmental advocacy groups: *Greenpeace; New Zealand Forest and Bird Protection Society.*
7. Universities and other non-government agency research units: *Swedish Species Information Centre.*
8. International organisations that, by agreement, have some jurisdiction over local biodiversity and environmental monitoring: *Forest Stewardship Council.*
9. International organisations that have some responsibility for archiving, or reporting on local biodiversity: *European Environment Agency; European Centre for Nature Conservation; Man and the Biosphere.*

In all nations we looked at in detail, biodiversity measurement and reporting has historically been spread across multiple agencies and organisations that only report on biodiversity condition within areas under their jurisdiction. Our impression was that these agencies are narrowly focused, and apparently unaware of synergies that could be gained through cooperation and integration of efforts across agencies, even when they are government departments that share a common goal and report to the same central authority.

The proliferation of international- and national-level organisations and duplication of programmes of all types seems set to continue unabated. As is apparent from our list, New Zealand shares in this organisational prolixity. While it appears inefficient to have several different monitoring and inventory reporting schemes covering the same region, it is difficult to know exactly how much overlap there actually is. More to the point, it is unclear how great the gains made through cooperative ventures would be in relation to the increased costs following from the inevitable increase in organisational complexity. Many organisations have to collect biodiversity information for their own purposes and in ways that meet their specific requirements. Unless carefully designed, a monitoring system organised at a national level is unlikely to provide the detailed information and timeliness such organisations need. In many countries non-governmental organisations have taken on the responsibility for certain sorts of monitoring (e.g. amateur bird groups). This results in savings in conservation funding and, importantly, mobilises the public behind conservation goals. It is possible as well that a variety of approaches and goals may lead to a better overall picture of biodiversity than a single approach, however well-thought out and organised. Finally, integrity of the system may be better guaranteed by dispersal among several agencies than by concentration within one.

However, because of the requirements of the CBD, and growing awareness of many governments that they have been spending considerable public money with little objective documentation of overall achievement, most countries have delegated a single government agency to report at a national level. The United States is somewhat different in that national-level reporting is split among a number of governmental agencies and the only coherent national attempt at indicators and reporting for the whole of the environment has been carried out by the *Heinz Center for Science, Economics and the Environment*.

Those that have formal reporting requirements to the CBD have a nominated lead agency that coordinates and writes those reports. For example, in Canada it is Environment Canada (Biodiversity Convention Office); in Britain, the Department of Environment, Transport and the Regions; and in Australia; Environment Australia (Department of Environment and Heritage). Mostly these are not land-holding organisations, and therefore do not directly undertake the bulk of the monitoring. Instead, they have accepted responsibility for setting standards, promulgating protocols, compiling national-level monitoring strategies, and preparing national-level reports. There is also a widely recognised need for biodiversity data to be collected and stored in a way that facilitates its use for multiple purposes, and this requires a nationally coordinated approach.

Summary of biodiversity and environmental indicator types used in national-level programmes

Here we summarise and discuss the types of indicators commonly in use in other countries. Indicators mainly fall into the following categories:

Group 1. Protection status – This information is relatively easy to collect, and highly accurate. It is required under international CBD reporting protocols and is reported on by all countries. It is of most relevance in countries and areas where concern over degradation of biodiversity through exploitation is an issue. By itself, this category of indicator does not address biodiversity status, although in the long term it is clearly highly significant. In Canada, it has been used in state of the environment reporting as a major indicator of biodiversity status.

Group 2. Extent of landcover types – The advent of aerial and satellite-based remote sensing has made it possible to accurately measure the extent of distinctive landscape elements such as forests, grasslands, and wetlands. At a basic level, it is essential information because most other indicators relate to them directly or indirectly. Most of the Earth's surface is covered by Landsat TM (Thematic Mapper) and AVHRR (Advanced Very High Resolution Radiometer) at 30-m and 1-km resolution respectively, and record intensity of radiation reflected from the surface in 5–7 spectral bands that can be used to report on a wide variety of ecosystem attributes.

Group 3. Remote sensing of biodiversity-related indices – There is a trend to use indices of ecosystem integrity derived from remote sensing for reporting purposes, in particular those related to patchiness, edge, connectivity and extent. These indices combine the ability of remote sensing to map different cover types and simple ecological theory. For example, connectivity has been suggested as a key landscape feature in maintaining species diversity as interchange between similar habitats can influence population densities and survivorship.

More investigation will be needed before these indices can be confidently used to characterise biodiversity status and trend. As an example of the problems that can arise: a connectivity index has been mapped for Ontario and reported as a biodiversity indicator (Ontario Ministry of Natural Resources 2002). It showed lower degrees of connectivity in the more natural forests of the northern region. However, this clearly didn't make sense in the context of overall biodiversity. The index failed to distinguish between natural patchiness and human-induced patchiness, nor was it related to the component of biodiversity putatively affected by patchiness. Indices derived from satellites or other map-based measures often appear to be used because they are easy to produce and visually impressive, rather than for any compelling biological reason.

Group 4. Abiotic factors (climate, air pollution, nutrient runoff, water status, soils) – These data require intensive collection and field effort. However, they have a very long history, well-established protocols, and can be relatively simply aggregated up to national levels. As far as biological diversity is concerned, they are essential background for conservation effort and monitoring, but of themselves they are not the responsibility of conservation agencies, except at a local level for specific purposes. Mainly they are collected and archived by specialist agencies or units.

Group 5. Status of wetlands, lakes, estuaries, and rivers – Freshwater systems have been a focus of resource conservation interest for many years because of the prime importance of water yield, quality and fisheries. Effective methodologies and protocols have therefore been developed for measuring and reporting on both physical and biotic aspects. Unlike terrestrial ecosystems, freshwater systems tend to have sharply defined boundaries and lend themselves to categorisation and assignment to various classes on the basis of well-understood measures. Indicators and measures for freshwater systems therefore form a significant part of all national biodiversity and environmental reporting. Difficulties in reporting tend to centre around marshes and peaty wetlands, which face many of the same problems of definition and suitable measures that are found in terrestrial ecosystems.

Group 6. Status of vegetation cover and forest growth – Developed nations tend to have extensive plot-based programmes across a range of ecosystems measuring a large variety of plant-based indicators. Trees are always included, shrubs very often, total vascular plants often, non-vascular green plants occasionally, and fungi very occasionally. Establishment of many thousands of plots with more or less standardised protocols worldwide has provided most nations with a forest survey system that can be used for measuring and reporting on some aspects of forest biodiversity, such as vascular species numbers, tree abundances, presence of exotics and a limited amount of information about other biotic elements. Forest growth measurements (e.g. basal area increase, canopy height) have been routinely undertaken and augmented with other biodiversity attributes as forestry accepts broader environmental responsibilities over many years. For instance, 57 separate environmental variables are collected by US national forest plot networks, alongside 22 control and location variables (Lund et al. 1998).

Satellite imagery has led to the use of models that will calculate basic ecological parameters such as canopy height, leaf area and net primary production, and to classify vegetation cover. Increasingly biochemical composition can be measured, e.g. nitrogen and lignin concentrations (Martin & Aber 1997). Remote sensing imagery must be supplemented by on-ground measurements and verified using extensive ground-truthing if it is to provide acceptable information.

In many countries (mainly Europe and North America) there is a widespread apprehension that pollutants will damage the canopies of forests, and canopy condition indices derived from (often qualitative) plot field measurements are regularly used. The United States National Academy of Sciences (2000) recommends the following indicators: land cover; production capacity of ecosystems (total chlorophyll per unit area); net primary production; carbon storage; stream oxygen; and trophic status of lakes. Careful consideration has to be given to each indicator as to why a conservation agency would want to report on it. Here, a careful separation between a more generalised environmental reporting function – perhaps best carried out by an environmental ministry – and a conservation-specific reporting function should be made.

Group 7. Abundance and range of plant and animal populations – Abundance of plant populations has been measured in many countries over a very long time at differing degrees of intensity and specificity. Usually it has been done according to more-or-less standard plot-based procedures and by professionally trained teams and the data gathered by Group 6 indicators has provided a core data source. Large mammals and game birds have also been monitored by professionals over long periods because of the interest of game agencies. This type of monitoring has been mainly done in areas of specific interest for control or exploitation purposes. Larger-scale surveys rely extensively on amateur organisations or networks. For example, many state agencies in the United States utilise rural mail carriers to monitor trends in game birds, and small game mammals (Williams et al. 2003). The behavioural and size differences of the animals have led to the development of a wide variety of animal-specific techniques. Butterflies, dragonflies, large beetles, birds, amphibians and reptiles have also been monitored for research purposes for varying periods but nearly always on limited scales. Aside from the exceptions mentioned above, the vast majority of arthropods have been ignored unless of pest status or the subject of short-lived research projects.

Group 8. Diversity indices – Species diversity indices are much discussed (see United States National Academy of Sciences 2000) but rarely used.

Group 9. Presence of exotic species – How many, how dominant and how widespread exotic species are is now a major concern for conservation agencies. Indicators (mostly presence/absence) of most threatening species are regularly used for conservation reporting.

Group 10. Threatened biota status – The status of threatened species is possibly the most widely used conservation index. Threatened species lists are available in most countries at a national scale. However, they must be used judiciously. This issue is discussed below.

What monitoring systems are used?

As shown above, national reporting in all countries is based on inventory, status and trend, and surveillance monitoring. Our observations suggest that in most countries the core of national-scale long-term monitoring was developed out of broad-scale water and air quality, forestry and game animal applications. There is, therefore, a heavy reliance on remote sensing, forest plots and freshwater stream and lake sampling, and pollution frameworks. Techniques are largely based on standard forest plot methodology, protocols for observation of large vertebrates, and specialised waterway assessments. Large components of biodiversity are poorly covered by such approaches, if at all. More comprehensive national-scale biodiversity monitoring is at the early stages of development in most countries.

Reporting at national level, therefore, is usually based on ad hoc compilation of data from different organisations, and not collected in any rigorous, standardised or systematic way. In nearly all countries biodiversity assessment is nested within a more inclusive environmental theme that includes socio-economic indicators from natural resource areas such as agriculture and forestry. This results in an emphasis on provision of regular, reliable, systematically recorded data produced by dedicated teams or agencies. It also manages, however incompletely, to document the changing biodiversity landscape. On the other hand, it fails for the most part to document the total conservation effort relative to both successes and failures of the agencies responsible for biodiversity.

Reporting achievement

National-level reporting is still in its infancy. It is only really functional where forest and waterways, and pollution reporting is concerned. This is because of a long history of systematic collection of data and national networks because of the economic importance of these assets, and the controversy over sources and effects of pollutants. The countries we have reviewed have and are further developing frameworks for reporting a wider range of biodiversity elements, but they still struggle to produce convincing, policy-relevant measures. Mostly, what are reported are the nationally collated summaries of inventories and surveys of varying ages, and national statistics (e.g. natural forest cover, number of plants and animals in the country, number of rare and endangered species). When an attempt is made to report indices, to provide a more meaningful policy guide, the result is often confusing.

For example, Environment Canada (2003) has adopted the single-index approach in an extreme form. For each indicator, for instance 'Biodiversity and protected areas', a number of components are measured – in this case *Percentage of total and strictly protected area in Canada* and *Change in status of reassessed species at risk*. A trend for the two components is presented for the last decade (70% increase in totally protected areas since 1992; a worsening in status of 33% of 402 assessed wildlife species, and an amelioration for 16% in the period 1985–2002). An indicator meter is calculated for the key component ranging from –100 to + 100. The meter for this indicator was set at 70% improvement on the basis of the land status improvement. The problem with this approach can be seen immediately: it is hard to reconcile a 70% increase in legally protected land area with the fact that the status for most species declined or did not change. The wildlife decline was not included in calculating the meter in this case, neither was it mentioned in the report highlights.

Because of these problems with indices, the trend in most agency reports is to include a large number of individual biodiversity measures grouped according to broad themes, and not to attempt to relate them to each other, nor come up with a final score card. The Heinz Center (2003) exemplifies this approach with its 103 indicators to track change in the continental United States. Internationally an assessment of the state of biodiversity will remain, for the foreseeable future, a subjective judgment informed by a mass of individual indices and measures.

Evidence for policy interactions

A great amount of literature on conservation science and policy is concerned with establishing the need for inventory and monitoring systems, the principles underlying them, and their development. However, there is a dearth of publications demonstrating how useful such monitoring has been at contributing to national understanding of trends in biodiversity and in influencing policy changes. In part this is because comprehensive biodiversity assessment seems not to have begun in most countries until after the Rio Earth Summit Declaration in 1992. In the decade since then there have been concerted efforts to get national biodiversity assessment systems functioning, but few are fully operational and most have significant gaps, as assessed by National Reports to the CBD in 2002. However, even for a well-researched and critical area such as invasive organism biology, a leading authority on invasive plants informed us that critical accounts of policy, management and monitoring interactions are rarely written up and comment is usually buried in annual reports (Dr Richard Mack, University of Washington, Spokane; pers. comm. 2003). As a result, there is little evidence of feedback from biodiversity assessment to policy formulation. Instead, there are numerous publications deploring the lack of action and real achievement at an international level in the decade since the Declaration (e.g. Herkenrath 2002; Wynberg 2002). In essence, the complaints are that biodiversity assessment is not adequately incorporated into land-use plans; and there are no clear, unambiguous criteria and principles for quantifying biodiversity loss in relation to socio-economic gains.

While the documentation and analysis of policy/monitoring and inventory links maybe scarce, is it clear in New Zealand that it has had some influence. There is interaction between policy managers and staff carrying out and reporting on monitoring/inventory exercises although the links are almost certainly not as intensive and effective as they should be. For instance, inventory and surveys formed the basis for priority setting for conservation of endangered birds and Kaingaroa Forest was planted in response to the first National Forest Survey that highlighted the rapidity with which the native forest resource was being depleted (Roche 1990).

Internationally there are some examples of analysis of policy effects of monitoring. The National Resource Survey (NRI – United States) provided information on changes in extent (−1.1%) of wetlands over the period 1982–1987, and yielded accurate spatial information on when, where and why the decline took place (Brady & Flather 1994). This is a good example of policy-relevant information, as the trend was unmistakable but subtle, and measures specific and linked to causal agents. The impact of the Common Agricultural Policy (CAP) for set-aside in England, where 11% of arable farmland has been set aside, beginning in the 1990s, has been extensively monitored for its impact on birds (Omerod & Watkinson 2000), and policy implications have been made (Firbank et al. 2003). However, it is clear that such wide-ranging policy instruments as the CAP are influenced strongly by other factors, because policy aims were not explicit and environmental arguments remained peripheral (Winter 2000). Even so, the policy was unlikely to have gained traction without the strong long-term data on significant declines in 'common' bird species collected by the British Trust for Ornithology. Because birds are globally the best-monitored biotic group, policy implications of international agreements and local actions are already clear (Herkenrath 2002).

Implications for a New Zealand system – a summary

- The basic monitoring and inventory data are produced by a wide range of agencies
- A national coordinating office for biodiversity and environmental reporting is the international norm
- A diverse range of concrete indicators are used in most reporting systems
- The most comprehensive systems are firmly based on long-term pre-existing forestry, wildlife, freshwater and pollution monitoring networks
- Interaction with policy seems poor or ad hoc in most jurisdictions.

3. National review

This review briefly covers the history of monitoring in New Zealand in order to provide a context for the overviews that follow of current DOC monitoring, and that carried out by local and regional authorities.

3.1 History of biodiversity monitoring in New Zealand

Concerns about loss of natural environment values, initiated by disquiet over destruction of visually magnificent forest tracts for agriculture and timber, and clear declines in native birds, were expressed early in the 19th century (Star & Lochhead 2002). Repeated attempts were made to establish sanctuaries for wildlife and to preserve scenic values. However, these conservation views had little effect on environmental policy, which, until recently, was subservient to economic development. However, at around the turn of the 19th century, profligate use of indigenous forest resources had raised questions about the size of the economic resource, the sustainability of the timber take, adequacy of regeneration to support repeated logging, and the environmental effects of deforestation on steep country (Wynn 2002). The impact of exotic herbivores (rabbits, hares, possums, goats, deer) on cultivations, rangeland and forest alike, was viewed as a threat to sustainable production. The impact of deer, goats and possums in indigenous forest raised the spectre of forest and scrub collapse and uncontrollable erosion from the steep country onto fertile productive lowlands (McKelvey 1995). Concern over weed impacts, burning, overgrazing and soil loss on pastoral production were all recognised early. However, attempts to quantify impacts relied on broad, non-quantitative surveys and anecdotal reports of damage until well into the 20th century.

The origins of systematic, quantitative, purpose-driven monitoring date only to the 1920s. By then, the socio-economic impacts of various land-use decisions and animal introductions had become all too evident. Governmental and other organisations awoke to the need to have reliable trend information on the environmental changes and accompanying ecological and productive impacts. Monitoring was selectively introduced, and natural environmental values were very secondary to assessing potential economic impact. At first, monitoring was largely based on visual surveillance – on-the-spot assessments by forest rangers and agricultural officers (McKelvey 1995) – and focused on establishing the reality of anecdotal reports of damage.

Introduction of quantitative, protocol-based techniques and the subsequent professionalisation of monitoring developed slowly in New Zealand, in pace with the growth of central government departments. The New Zealand State Forest Service was established in 1920, and the National Forest Inventory followed (1920–1923). After 1945, all the central government departments concerned with natural resources and environmental values (Department of Agriculture; New Zealand Forest Service; Internal Affairs Wildlife Service; Department of Lands and Survey; Department of Works) and quasi-governmental organisations (catchment boards; rabbit destruction boards; noxious-weed control boards) established some type of systematic, quantitative monitoring, however rudimentary. Two parallel administrations – the Department of Lands and Survey (national parks and Crown scenic and scientific reserves) and the New Zealand Forest Service (state forests, production forestry, protection forestry) – were set up to manage public lands. These departments coexisted, albeit in the context of a somewhat competitive relationship, until both were abolished in 1987. The Wildlife Service of the Department of Internal Affairs was primarily concerned with the management of native animals (most emphasis given to birds), introduced game birds, and freshwater fisheries of Rotorua/Taupo and the Southern Lakes District. It was responsible for the Fisheries Act and Wildlife Act (as regards game birds and protected species). The legacies of these three departments can still be seen in the patchwork of protected land systems.

In the late 1960s and early 1970s, a new emphasis was given to ecosystem values above and beyond those closely connected to economic return and gross environmental degradation. Public attitudes had been slowly changing in favour of preservation of natural ecosystems from at least the turn of the 19th century. However, eco-centric attitudes became significantly more politically influential in the 1960s to 1980s as anxiety increased about environmental degradation, and the loss of the natural world. The economic justification (wood production, agricultural production, prevention of erosion, disease, water quality, maintenance of game birds and fishes) for land use was now being considered against competing claims for environmental quality, especially loss of habitats, species and scenic and recreational values. All key central government departments that managed natural ecosystems were required to respond, however unwillingly. For instance, the Biological Resources Centre (DSIR) and the Protected Natural Area (PNA) surveys were initiated in the 1980s to cope with this increasing demand for action. Monitoring systems set up to deal with economic consequences of environmental change were now pressed into service for ecological purposes, and fresh approaches devised to deal with issues such as mammalian predators that had been hitherto neglected.

This era of rapidly developing environmental consciousness resulted in the establishment of the Ministry for the Environment and the Department of Conservation in the late 1980s – government agencies with clear responsibilities for the well-being of the natural environment. At the same time, global awareness of the issue of environmental decline accelerated, culminating with the Rio Agreement of 1992 and New Zealand's signing of the CBD, which initiated the need to report at a country-wide level. Focus on primary natural values and prevention of species loss radically changed the sort of monitoring undertaken. Monitoring became more intensive, smaller scale, and management orientated.

Expansion of the scientific workforce and better ecological training in the 1970s and 1980s resulted in widespread questioning of the dogmas that had previously underpinned the rationale for monitoring. Notable examples of debates include the following: Was erosion a consequence of burning, pastoral overgrazing, and eruption of wild-browsing-animal populations or was rainfall more important? Was control of deer by ground hunting useful, or did it merely maintain deer at levels where habitat degradation continued? Did possums alone cause accelerated decline of susceptible tree species, or were more complex factors involved? Were introduced freshwater fishes and birds benign influences? How important were habitat loss and climate changes on bird declines versus predation?

Vegetation, birds, and mammalian pests provide the longest and clearest examples of monitoring effort in New Zealand, and are discussed below. They also illustrate the way monitoring informs policy and vice versa, and the major drivers of sustained monitoring effort.

Vegetation monitoring

Scientific appraisal of New Zealand ecosystems began in the 1860s, but the first monitoring did not take place until just before the turn of the 20th century with Leonard Cockayne’s systematic vegetation investigations (e.g. Cockayne 1899, 1928). Later, he extended these descriptions to include changes in plant communities over time, based on observations from permanently marked sites. He established belt transects in beech forest, subalpine scrub and red tussock grassland at Arthur’s Pass after fire (Cockayne 1898; Cockayne & Calder 1932), which have been remeasured three times since, and regrassing trials in Central Otago in 1920 (Cockayne 1922). Formal national surveys of New Zealand’s vegetation began in 1923 with the National Forest Inventory, a standardised inventory of the country’s forests to assess their potential timber yield. The second standardised survey was the National Forest Survey of 1946–55, which was primarily a timber inventory but ecological data were also collected (Thomson 1946; Masters et al. 1957). It mainly covered lowland and mid-altitude forests from which timber could be extracted, with limited coverage of upland forests. Comprehensive collection of volumetric and ecological data was a feature of this survey, which routinely recorded birds and browsing indications.

The increasing focus on the role of natural forest and grassland ecosystems in protecting catchments and the vulnerability of these to the effects of browsing mammals ushered in an era of vegetation monitoring. Government departments, in particular the New Zealand Forest Service, and catchment authorities in the South Island began to monitor condition and trend of vegetation in the 1950s (Stewart et al. 1989). Survey of protection forests started in 1956 and continued through to the later 1970s. In 1956/57 the coverage was extended by the North Island Forest Ecological Survey (North Island Ecosurvey), which provided comprehensive ecological information on forests not surveyed in the National Forest Survey (McKelvey 1995). The National Forest Survey and Ecosurvey provided the foundation for a community classification of New Zealand forests (e.g. Nicholls 1976; McKelvey 1984). Standardised methods were developed, and later refined, for forests, grasslands and other non-woody ecosystems (Holloway & Wendelken 1957; McKelvey & Cameron 1958; Wraight 1962; Scott 1965; Atkinson 1975; Wardle & Guest 1977; Batcheler & Craib 1985; Dickinson et al. 1992; Allen 1993; Wiser & Rose 1997).

In 1955, deer control was transferred from the Department of Internal Affairs to the New Zealand Forest Service (NZFS). The NZFS was now mainly concerned with watershed implications of the impact of deer, goats and possums on upland forests, in addition to their standard inventory to establish commercial log volumes. Later, increasing controversy about extensive plans for utilisation of indigenous forest, such as the West Coast Beech scheme of the 1970s, resulted in more large-scale surveys and establishment of monitoring plots. Between 1947 and 1985 the NZFS undertook over 300 vegetation surveys, and established more than 16 000 re-locatable plots and c. 300 deer exclosures (Stewart et al. 1989).

From the 1940s to the 1980s catchment boards initiated permanent monitoring plots and exclosures in grassland areas of North and South Canterbury and Otago, in order to establish the effects of burning, grazing, oversowing and top-dressing on vegetation cover and erosion of pastoral leasehold land (Wiser & Rose 1997). The regional councils now subsume the functions of the catchment boards, and some continue to monitor permanent plots. However, most permanent grassland plots (over 3000 of them) were established by the NZFS from 1955 to 1978. As with forest plots the main impetus was to understand the impact of introduced animals on erosion, and more recently, on vegetation composition.

Besides these large-scale governmental monitoring efforts, numerous smaller-scale, shorter-duration monitoring studies devoted towards specific issues or problems have been carried out, usually initiated by individuals or small groups associated with universities, divisions of the now disestablished DSIR, Ministry of Agriculture and Fisheries, Ministry of Works, and the National Water and Soil Conservation Organisation (Meurk & Buxton 1991). In the early 1970s the Department of Lands and Survey began a vegetation monitoring programme for Crown land management areas, including South Island high-country pastoral lease land, that has since been continued by other organisations, most recently DTZ (was Knight-Frank New Zealand) as part of a contract to administer Crown pastoral leases. Over 1100 permanent plots were established in a wide range of vegetation types, the primary goal being to record vegetation response to various management regimes including retirement from grazing.

During the late 1980s and early 1990s, vegetation survey and monitoring was a relatively low priority (Bellingham 1996), although some national initiatives continued, notably the reconnaissance surveys of the Protected Natural Areas (PNA) Programme. Based on methods in widespread use internationally, standard methods using reconnaissance descriptions were modified to New Zealand ecosystems and adopted for general surveys and for data collection (e.g. Myers et al. 1987; Allen 1992). Vegetation communities were described in many parts of New Zealand where standardised survey data were scant (e.g. Kelly 1972). In the agricultural context, a systematic national distributional sampling programme, mainly on farmland, was undertaken for selected scrub weeds (Bascand & Jowett 1981, 1982), including several native species (matagouri, bracken, kanuka/manuka, tutu).

In 1987, the Department of Conservation was established during a time of major restructuring in the New Zealand civil service (Kelsey 1997). Staff turnover was high, resulting in the loss of specialist skills associated with vegetation surveys, and institutional memory about the value (and location) of major data sets (Bellingham 1996). Parallel events also occurred in some research institutes and other government agencies.

In the 1990s, a downturn in the amount of monitoring information is apparent, but standardised data collection continued in a piecemeal fashion by individuals in government agencies, universities, private consultancies and research institutions (Wiser et al. 2001). A new development was the upsurge in interest among farmers, landowners and community groups in restoring native vegetation cover or improving the ecological integrity of existing cover. While systematic monitoring was only rarely undertaken in conjunction with these initiatives, it did lead to some developments such as REDIS, the community-based tussock grassland monitoring scheme (Hunter et al. 2003).

Starting in 1997, new management procedures within DOC led to a revival of vegetation survey and monitoring, and the Department began to rebuild the requisite skill base. Standard methods are now being used increasingly within DOC to ensure comparability of results. Regional and local authorities are also placing more emphasis on vegetation survey and monitoring, especially for pest plants (Partridge et al. 2002), and several have also utilised recent remote sensing products depicting vegetation and habitats (e.g. Dymond & Shepherd 2004) .

Despite the ever-changing aims and institutional home for vegetation monitoring, it has resulted in a vast amount of usable and potentially valuable data (Wiser et al. 2001). The National Vegetation Survey Databank (NVS) stores, manages and provides access to a large portion of the data on vegetation structure and composition collected over the last 50 years. Other vegetation databases include the South Island data held by DTZ and Timberlands West Coast (both now incorporated in NVS), and a large number of small data sets held by universities, private consultancies, national and local government, and Crown research institutes.

Bird monitoring

Monitoring activity (and study in general) of indigenous birds has been hindered by a combination of factors. Many bird species are scarce, located in areas of difficult terrain, and have nocturnal habits that make them difficult to observe. Population sizes are often small and frequently inadequate for statistically robust sampling approaches. Moreover keeping birds in captivity under semi-natural conditions has proved difficult for many species (Williams 1973). There has also been a general neglect of introduced birds (aside from game birds), in part because they were considered to be well known in their lands of origin. As a result, comprehensive studies focused for many years on abundant, colonially nesting seabirds (gulls, petrels, gannets and penguins) because of ease of study rather than any pressing conservation need (Williams 1973).

Despite these limitations, the avian dominance of the terrestrial vertebrate biota, and the preponderance of European settlers from the UK with a strong tradition of bird societies and game-bird management, resulted in birds being given a high profile in conservation, monitoring, and research. One of the longest-duration monitoring studies (since the late 1800s with aerial surveys since 1945) of any sea bird anywhere is that of the Australasian gannet (*Morus serrator*) at Cape Kidnappers (Darby 1989). The Ornithological Society of New Zealand was established in 1939, and its journal *Bird Notes* (later renamed *Notornis*) appeared. The Wildlife Service of the Internal Affairs Department (est. 1945) focused in the early years on game birds and waterfowl, while the forerunner to the Ecology Division DSIR (est. 1948) studied birds of agricultural importance (Williams 1973). A key event for avian monitoring and threatened species research in New Zealand was the rediscovery of takahe in 1948, which caused a major shift in allocation of resources from birds of recreational and agricultural importance to indigenous species.

Bird banding came into general use in 1936, and shortly after the banding scheme of the New Zealand Ornithological Society was initiated. In 1948, the Wildlife Service banding scheme focused on waterfowl and game birds. In 1967, the Wildlife Service administered an amalgamation of the two schemes, which were transferred to DOC in 1987. By the end of the century 1 250 000 birds had been banded, with 400 000 to 500 000 recoveries (Froude 1999). Bird banding has underpinned many monitoring studies.

In the 1970s, the Ornithological Society, Ecology Division DSIR, and the Wildlife Service initiated the New Zealand Bird Distribution Mapping Scheme to map the distribution of all bird species in 10 000-yard grid squares throughout the country. This culminated in the *Atlas of Bird Distribution in New Zealand* (Bull et al. 1985; Hay et al. 1989). The survey is repeated. The proposals to ultilise native forests in the 1970s led to the Wildlife Service and Ecology Division DSIR initiating a large number of bird survey schemes, the forerunners of the detailed population work which continues in DOC at present, based mainly on 5-minute bird counts at points along a sampling transect.

Mammalian pest monitoring

Numerous mammal introductions began with the first European explorers leaving pigs, goats and rats behind them and deliberate introductions only halted around 1910 (King 1990). The first half of the 20th century saw rapidly growing concern about the increasing impacts being documented. Initial anxiety about animal pests was based on potential agricultural impacts. Goats interfered with pastures, and runholders around the central South Island lakes paid for their destruction from about 1916. Episodic local control of large mammals continued until the Internal Affairs Department took charge (Wodzicki 1950). In the early years, rabbits were recognised as a potential problem for pasture growth, resulting in the Rabbit Nuisance Act of 1876. Much of the early monitoring work of the Wildlife Service and Ecology Division DSIR concerned rabbits, and a long-term ecological site to study population fluctuations in relation to predators in the Wairarapa was undertaken over 10 years in the late 1950s and 1960s (Gibb et al. 1995). Similar concerns about the economic and natural-value impacts of possums on lowland forest resulted in the establishment of the ongoing long-term Orongorongo ecological site near Wellington, which has been running in one form or another since 1946 and has monitored for varying lengths of time a number of introduced mammals, birds, invertebrates and plants (Brockie 1992).

Despite the level of concern about wild and feral mammals, national assessments have been patchy (King 1990). For instance, the last national-scale survey of stoats was published in 1963 (Marshall 1963), and even for large mammals, mapped distributions have been inconsistent in scale and level of detail.

Deer were recognised as a national problem in the 1930s, and understanding their impacts on erosion and water quality shaped subsequent monitoring, especially in protection forest areas in the 1960s to 1980s, based on measurements of changes in forest structure. Hunting returns and faecal-pellet-line surveys have been used to provide indices of deer abundance, and browsing studies have been undertaken to document impact on vegetation (e.g. Fraser & Burrows 2000). However, the methodologies used are highly sensitive to local conditions, and other than mapping, there appears to have been no attempt to quantitatively summarise the pressure or effects of deer at anything but a local level.

To take another example, possums are the most intensively managed and studied feral mammal in New Zealand. Operational monitoring has been routinely carried out since the 1950s, but outcome monitoring was initiated only in the 1990s (Warburton 2000). While monitoring has extended over 50 years, quantification of impact only began in the mid-1970s. An array of techniques has been used to link possum density and vegetation impacts (Payton 2000), but assessments at a national level are not available. Considerable effort has been put into increasing precision of both possum abundance estimates and damage caused at a local level, but at a national scale variation in possum density is still poorly understood and the question as to whether or not we presently have 70 million animals remains unanswered (Efford 2000).

Nevertheless, intensive local monitoring has yielded useful research results, especially as regards interactions in multi-species systems. As an example, local, intensive monitoring of plants and introduced animals has documented the link between food availability and mammalian population changes that are proving important for avian conservation management. Mouse (*Mus musculus*) populations increase in New Zealand beech forests (Riney et al. 1959; King 1983; Choquenot & Ruscoe 2000) following mast years. Mice (along with rats, which are themselves also primary bird predators) are a main prey item for stoats and a key control on stoat numbers. As stoats are highly efficient bird predators, understanding and monitoring the seed–mice link has become a crucial element in indigenous bird protection programmes (Ruscoe et al. 2001). Similar-scale monitoring during selective mammal control operations has also highlighted the importance of predator–prey interactions amongst co-existing mammals, and the general need for multi-species control for effective conservation gains.

3.2 Policy and monitoring

New Zealand environmental policy, as we have seen, has tended to be driven by a complex mix of agency, public and sectoral perceptions that may or may not have a sound basis in scientific fact. Underpinning policy has been a conceptual pressure-state-response framework where the nature of the pressure was thought to be well understood. The role of monitoring, therefore, has largely been to quantify the changes believed to be occurring as a result of environmental pressures, not to establish whether those pressures are actually having the effect posited. Here is a recent example in regard to an agricultural pest:

‘The amount of damage Canada geese cause to pasture is a major point of contention for goose management in New Zealand, with increasing debate between farmers and hunters as to whether the problem is a significant one or not. Surprisingly, the South Island Canada Goose Management Plan (SICGMP) was developed without any reference to the amount of damage Canada geese cause. Currently, much of Fish and Game’s management seems based on human perceptions rather than on scientific research…it focuses on reducing goose numbers, without requiring management to investigate whether these reductions are indeed reducing goose damage on farmland.’ (Win & Hickling 2001).

As has been seen repeatedly in New Zealand monitoring, an assumption of pressure is made, and then that applied with no attempt to get the all important figures that would match the return (in terms of asset protected) versus the investment (in this case, denial of hunting opportunities by reduction of geese).

Moreover, there has been a tendency for the monitoring operations to become detached from policy, and to lose connection with ongoing research efforts. Under these circumstances, monitoring tends to become ossified, continuing on long past the policy or science need that gave rise to it. Official management policy can thus change dramatically with little effect on the monitoring effort. The classic New Zealand case for this is control of browsing animals.

Caughley (1988) used the example of deer control in New Zealand to underscore his point about the shifting politics of control. Deer control began in the 1920s and monitoring of vegetation condition shortly thereafter. Improving vegetation condition was seen as a key reason for deer control from the beginning, both for direct (habitat quality) and indirect (erosion control) reasons. Deer control continued under different policy regimes with radically different rationales, but few changes in either control or monitoring were made as a consequence. According to Caughley, the ever-changing official reasons for deer control were:

- Increase in antler size (1920–29)
- Reduced competition with sheep (1930–31)
- Prevention of accelerated erosion generally (1932–66)
- Prevention of erosion in headwaters of rivers that may flood cities (1967–80).

From 1980 onwards, Caughley suggested there has been no verifiable reason for deer control (except in very specific cases – e.g. restoration of takahe habitat in Murchison Mts). As evidence accumulated in the 1970s that by and large did not support the more extreme contentions of the erosion–browsing-animal link (McKelvey 1995), the basis for deer control changed, although the necessity for control was unchallenged. In 1972 the indigenous forest values most jeopardised by animals were almost exclusively regarded as those of stable catchments, water quality and flow regulation, although 'side' values of indigenous flora were recognised (Bathgate 1973). By 1985 the Forest Service Policy statement stated: 'The major role of existing mountain forests and the emerging objective of mountain land revegetation is to maintain or improve the soil resource and on-site production, as opposed to the protection of off-site values, which has previously been accorded greater emphasis' (New Zealand Forest Service, Progress Report 1980–84, p. 12). By 2000, these main factors do not play any substantial role in forming conservation policies of successor agencies, and the 'side-value', now termed biodiversity, is the dominant focus at present.

With hindsight, it is clear that monitoring and reporting vegetation condition per se was an important task during the lifespan of the NZFS. However, if this had been recognised as a national need, independent of the particular issues of the day, better value for the large monitoring investment may have been achieved. In large part, the pressure-state-response monitoring framework sidelined any possibility of a comprehensive monitoring system designed to detect change in status of New Zealand ecosystems as a whole. In any case, initially there was no one agency charged with such a responsibility. When the Environmental Council was established in the 1970s, it found that its resources fell short of carrying out such a task. 'Reporting on trends in the state of the New Zealand environment was for many years one of the responsibilities of the Environmental Council; a responsibility the Council could never discharge because the information was not available' (David Thom, Chairman National Parks and Reserves Authority 1988; quoted in Caughley (1988)).

Monitoring is sometimes initiated because difficult or controversial policy choices have to be made. For instance, tenure review and the change in high-country land administration initiated a programme of indigenous grassland monitoring to provide a basis for decisions to follow. However, often the monitoring results fail to help settle issues. When there is no common ground and no a priori agreement to abide by results, far from resolving a problem, monitoring will often exacerbate it. The Kaweka deer-browsing controversy is a good example (Rob Allen, pers. comm. 2003).

In the mid-1970s regional staff in the Napier office of the former NZFS considered, from observations, that there was a paucity of mountain beech regeneration in high-elevation forests in the Kaweka Range attributable to browsing by sika deer. Forest Research Institute (FRI) staff considered that (taking account of forest dynamics) paucity of regeneration was limited to dieback stands and this was the consequence of sika deer browse. FRI recommended monitoring, including deer exclosures, and deer control, which was opposed by local hunters. In about 1980 regional NZFS staff established deer exclosures and plots. By the mid-1990s local DOC staff became concerned about the lack of regeneration of mountain beech, and wanted further deer control. The NZ Deer Stalkers Association asked for evidence of vegetation impacts by deer, and the plots and exclosures were remeasured, showing slower growth and lower density of seedlings in the presence of sika deer. However, hunters argued that the plots and exclosures were an insufficient sample, and pointed to areas with beech regeneration in the presence of sika deer. This led in the late 1990s to the establishment of more plots and exclosures, primarily in canopy gap areas. Deer control was imposed in one area as a treatment for plots. In 2000, plots were remeasured showing slower growth by mountain beech in canopy gap areas without deer control. Results, parameters measured, and sampling design were debated and discussions continue as to the way ahead.

This example shows that monitoring can provide clear results within the limitations of the sampling programme. However, the more important lesson is that any monitoring system will have weaknesses that will be exploited in adversarial circumstances. Monitoring alone is of limited help with problems that essentially need a political solution.

At the level of management policy, our impression in the course of this review is that the facts and figures produced by monitoring are dramatically underutilised in decision making and policy setting whether through ignorance of their existence, unsuitability of the measures, or intrusion of other factors. It is difficult to get any concrete information on this, for there are virtually no measures, anywhere in the system, of rate of uptake and usefulness of monitoring information. One is left only with the perhaps naively optimistic assumption that so much of it would not be done if it had no practical utility.

3.3 Changing technologies and techniques

Until the late 1930s, the survey and monitoring techniques available were, aside from some pioneering efforts, largely based on visual observations and notes written in the field, with little quantification. Statistical techniques had yet to make an impact, and placement of survey plots (when used) was usually based on a subjective idea of what was ‘typical’ for an area. Because of the problems with mapping of densely forested terrain, systematic surveys were difficult.

By 1945, aerial photography, increases in the quality of mapping, better road access, and faster means of transport made systematic surveys on a national scale feasible for the first time. Statistical awareness of the biases inherent in non-random placement of plots or survey lines was widespread, and there was much experimentation as to the ‘best’ shape of plot and sampling interval. Monitoring techniques for all types of organisms were under development at this time, together with various trapping and tracking devices. Standard techniques rapidly replaced previously more loosely organised observations. However, individual experiments in differing techniques occasionally meant loss of inter-comparability. Within the NZFS differing approaches to monitoring in various conservancies led to loss of millions of dollars of monitoring investment (Rob Allen pers. comm. 2003).

The transport and mapping problems of the first half of the 20th century were superseded in the second half by a lack of analytical power to interpret and synthesise the results. Report writing, analysis and databasing lagged far behind data collection (McKelvey 1995). The phenomenon of the vast paper-record stack in backroom cupboards became endemic. By the 1970s, increased computing power and access to new statistical techniques eased the problems of analysis, but highlighted the challenge of transferring data from paper records to electronic databases. Even when achieved, the rapid obsolescence of data formats and storage devices led to the phenomenon of successive heaps of dusty computer cards, magnetic tapes and then floppy discs in unreadable formats.

Remote sensing can be considered to have begun with aerial photography but in the 1970s availability of multi-spectral images from satellites transformed the field. The approach has numerous advantages including being multiple-scale, quantitative, repeatable, and highly cost-effective. However, in practice its utility has been more limited than expected. Extensive ground-truthing is necessary before this approach can be used with confidence for anything other than coarse-scale discrimination. Radio-tracking devices also developed rapidly during this decade with miniaturisation of radios and portable computers. However, arduous fieldwork remained the backbone of the monitoring effort although the advent of affordable helicopter transport and lightweight durable field gear opened up a new realm of possibilities.

In the 1980s, electronic plot-re-location devices and geographic information systems along with readily available powerful desktop computers and analytical packages combined to provide a monitoring information analysis package equal to the task posed by the now enormous database resulting from over 50 years of assiduous data collection. By the 1990s the monitoring system was now in the position of being able to efficiently analyse the data underpinning it. The issues were now how to integrate and make available numerous databases ranging from the huge to the minute, collected using different methods, on varying spatial scales, over different time intervals and held by different organisations.

A rapid-assessment methodology was developed by the DSIR in the 1970s to inventory reserves for the Department of Lands and Survey, in response to demand for efficient and reliable ways of assessing conservation land. This approach was broadened and systematised with the protected natural area surveys of the 1980s and 1990s. Now, with the biodiversity asset inventory and assessment demands of the Resource Management Act, and the generalised biodiversity survey needs of diverse organisations (e.g. local and regional councils, QEII trust, local community groups), there has been an expansion of interest in rapid survey methods. Unfortunately, dissimilar and often ad hoc techniques threaten to reduce the interoperability necessary if such assessments are to be anything more than local tools.

The future promises a significant increase in available technologies including molecular-based surveys, enhanced remote sensing of a much increased range of ecosystem attributes (Turner et al. 2003), automated or robotic collection of data, and direct sensing of basic ecosystem processes. The weak link in the medium future may be our limited understanding of functional relationships in biodiversity, rather than the absolute shortage of data or analytical power.

3.4 Monitoring and inventory by territorial local authorities

Responsibility for biodiversity per se (aside from biosecurity) outside of DOC land largely lies with the territorial local authorities (TLA: district and city councils and unitary bodies) and regional councils. While biodiversity issues have long been a concern of regional and local government, because of their control of various natural habitat reserves, it is only in the last decade that it has become prominent as one of a cluster of interconnected environmental issues they are required to consider. Rising public concern and interest in biodiversity is one of the main drivers but probably more important are the Biosecurity and Resource Management acts, which give them the rationale and authority with which to make policy and take action. Nevertheless, although the Resource Management Act in New Zealand makes explicit the legal relationship of biological diversity to development, and the role of the government organisations in carrying out its provisions, a review of the RMA concluded that environmental policy was difficult to execute in practice due to collaborative failures of regional and district councils and inadequate information provision (Berke et al. 1999).

The central government agency most closely identified with local government performance on environmental matters, and with national reporting on the environment, is the Ministry for the Environment. Membership of the OECD requires state of the environment reporting. New Zealand's commitment to environmental sustainability had previously been established through our signing of the Rio Declaration at the United Nations Conference on Environment and Development in 1992. In a 1996 review of New Zealand's environmental performance, the OECD highlighted the lack of consistent, high-quality environmental data. This is evident in the State of the Environment Report (1997), and initiated the development of the environmental performance indicators programme, which culminated in proposals for terrestrial and freshwater biodiversity indicators (MfE 1998; Froude 2003). These are designed for national and international reporting, and are largely dependent on information collected by local government. However, currently there is no implementation plan and detail is lacking as to who will carry out the monitoring, how it will be organised, and how it will be funded.

Biodiversity strategies

A major guiding influence at all levels of government has been the New Zealand biodiversity strategy (DOC & MfE 2000). However, the degree to which TLAs take on biodiversity issues varies markedly, and councils can easily minimise their involvement when ratepayers rank biodiversity preservation low relative to other environmental issues such as water, air pollution, and waste (Environment Waikato 1998). Therefore, the level to which biodiversity concerns are reflected in council thinking varies from very thorough and detailed plans (e.g. Environment Waikato) to a rather limited consideration (Westland District Council). We selected several regional councils (Environment Canterbury, Environment Waikato, Horizons (Manawatu-Wanganui) Regional Council) and city councils (Wellington City, Christchurch City) to gain an idea as to how councils were undertaking their environmental and biodiversity responsibilities.

All councils have a biodiversity strategy or plan, with defined outcomes, including in some cases detailed operational plans. Wellington's strategic outcomes are typical of the level at which the environmental and biodiversity outcomes are defined:

Biodiversity:	A range of plants and animals are protected in their natural habitats.
Ecosystems:	Land and sea ecosystems are protected.
Landscape and natural heritage:	Special features of the landscape and natural environment are recognised and protected. (Wellington City Council: Council Plan 2003/04)

However, some territorial authorities have more detailed strategies showing considerable insight and concern for biodiversity in their region. For example the Christchurch City Council (2002) aims to:

- Protect, and where appropriate restore, ecological heritage areas, in order to sustain the flora and fauna dependent on them
- Ensure activities are compatible with maintaining the dominant natural values of significant natural areas
- Promote environmental enhancement and rehabilitation of natural areas
- Maintain and enhance the integrity and diversity of natural ecosystems and habitats within the City
- Further extend and protect natural ecosystems and habitats
- Conserve biological diversity by protecting, enhancing and restoring the variety of species which make up this diversity, recognising particular responsibility for indigenous species within that diversity.

In contrast, others appear to have undertaken little work on developing a biodiversity strategy, and sometimes promote worthy goals that are unlikely to be achieved at the level of resource allocated. For example, the Manawatu District proposes to halt the decline of native biodiversity by the restoration of ecosystem functions throughout the District (Janssen 2002).

The announced biodiversity policies of regional government are, in practice, near identical with those of DOC. To support the strategies and plans, the more committed regional and city councils have developed criteria and indicator methodologies around some concept of ecological integrity or sustainability, to give a measurable framework for prioritising action and reporting on outcomes. Some (e.g. Horizons Regional Council) have adopted the international pressure-state-response framework. However, there are typically wide mismatches between stated goals and allocation of resources. In general TLAs and regional councils do not have the resources, the staff or the political support of the ratepayers to fully take on the biodiversity responsibilities alluded to in their plans.

Current inventory and monitoring activities

Most TLAs and regional councils have undertaken some basic biodiversity inventory. Maps of areas of forest and wetland have been obtained, and there is an intention to monitor gross changes at regular intervals. For instance, Environment Waikato has a regional indigenous vegetation inventory, has commissioned an estimate of historical vegetation (AD 1840), and monitors changes in the amount of native vegetation on land in the Waikato Region using data from satellite photographs (Land Cover Database). Horizons Regional Council has aerially mapped forest fragments and wetlands, but will shift to remote-sensing inventory in the near future. Indigenous bird and vegetation surveys are an established feature of the inventory schemes. Usually these are not comprehensive, but focused on dominant or important floral and faunal components. Other life forms such as invertebrates, fungi and lower plants do not feature to any great extent.

Action to reverse biodiversity decline focuses on reducing possums, fencing reserves, and controlling certain aggressive weeds in nearly all plans. Monitoring to establish the effectiveness of these measures varies greatly from region to region. In many cases this consists largely of 'input' measures. Wellington City Council has, for instance, activity performance measures such as:

- Hectares of weeds removed in areas identified as very overgrown with weeds (2003/04 target: two hectares of weeds cleared)
- The number of possums in possum management areas (2003/04 target: maintain or improve a trap catch percentage of 2 percent)
- The extent of animal/bird diversity within the Karori Wildlife Sanctuary (measured on a standard diversity scale from 1 to 10). 2003/04 target: maintain or improve a rating of 6)
- The level of diversity of plants within the Town Belt (targets have been set for native trees, conifers, grass and other mixed exotics).

A group of measures are reported as city indicators, such as:

- Abundance of selected: bird species (repeat measures at fixed locations, 5-minute bird counts)
- Plants that show the health of the city's ecosystems
- Weed species in parks and reserves administered by Wellington City Council.

At the other end of the biodiversity detail spectrum, Horizons Regional Council has 62 plant and 18 animal pests under control, containment, surveillance or listed as non-statutory problems, each with independent assessment of level of infestation, present risk, potential harm, and costed control options in regional animal pest management (2002) and regional plant pest management (2001) strategies. While many of these are mainly agricultural problems, a significant number are threats to important conservation areas. Monitoring of problems and outcomes varies according to the pest. However, the total funding allocated to monitoring (regional surveillance and site specific assessment) Horizons Regional Council is c. $160,000 for plants, and the total funding allocation for all animal outputs (including monitoring) is c. $700,000. Given that all pests are included, specific biodiversity monitoring funding is likely to be rather small, possibly less than $100,000.

A new biodiversity strategy is being prepared by Horizons Regional Council with a focus on changing the habitat shape of high-value conservation areas to give maximum interior protection to increase connectivity through external planting, and to enhance the presence of keystone species (selected birds and plants). This proposed strategy is supported by a natural ecosystem database (however, much of its core information is dated) and an intended pressure-state-response monitoring of native biodiversity and ecosystem functions. These include the following measures:

Pressure-

- Pests of indigenous habitats (19 plant pests under surveillance)
- Native timber harvest (volume and plans/permits)

State-

- Presence or absence of keystone species (monitoring of presence/absent of keystone and indicator birds at 20 sites in 3 high value conservation areas)
- State of vegetation in high value conservation areas (canopy browse plots in 11 HVCAs to determine effects of possum browse and control)

Response-

- Area of indigenous habitat protected through voluntary agreement
- Spending on control of rabbits, rooks, possums and goats; trap-catch data from 7 HVCAs.

Environment Waikato has a reduced set of biodiversity indicators (extent native vegetation, extent wetlands, river biology (freshwater invertebrates)) that are monitored, but has a detailed, fully costed pest management scheme, with a total of $620,000 assigned to monitoring and surveillance in 2001/02.

Like the other regional councils, Environment Canterbury has, under the Biosecurity Act provisions, implemented a regional pest management strategy (2002). From ecological survey results (including the Land Cover Database and the Protected Natural Area programme) it assesses areas on the basis of nine ecological factors, and has used a botanical/wildlife ranking system to define high-value environmental areas. A total of 17 plant and animal pests are to be controlled according to the risk to these areas. Exotic conifer wildlings are being mapped and monitored on a catchment-by-catchment basis for the whole area; *Hieracium* to be monitored annually on 10 control sites; surveillance and mapping for boneseed, wild thyme, *Phragmites, Egeria* and *Hieracium* throughout their range; and monitoring of abundance of plant, bird, invertebrate indicator species is to be done annually in areas where possums, mustelids, cats, deer, pigs, goats and wasps are being controlled. However, in the 2001/02 year, the total budgeted amount for the strategy was $170,000, of which $11,000 is designated for monitoring.

Summary

The TLAs and regional councils all show an awareness of the need to have biodiversity strategies, and the ones we examined all had inventory and monitoring schemes underway. However, the amount of funding devoted to such activities appeared small relative to the goals set out in the plans. It is clear that the TLAs place a great deal of reliance on pre-existing databases (such as the Land Cover Data Base) and ongoing efforts from central government agencies, most importantly DOC. From what could be seen from the plans, the emphasis is on cheap and rapid assessments and thus the contribution that could currently be made by the TLAs to a national scheme seems limited. Pressure is building, especially in the wake of the National Policy statement for Biodiversity on Private Lands, for TLAs and private landowners to do more. As implementation of these policies is likely to fall to TLAs and regional councils, the amount of resources devoted to inventory and monitoring of biodiversity to provide a reliable basis for this activity will have to increase markedly. The problem of integration of TLA and regional council databases within a national system will have to be addressed.

3.5 New Zealand Carbon Monitoring Scheme

Landcare Research and Forest Research were commissioned by MfE to develop a carbon monitoring system (NZCMS) for indigenous forest, scrub and soils in New Zealand to assist with this country's commitments under the Framework Convention on Climate Change to report on carbon stock changes in indigenous forest. It is overseen by the Climate Change Office, a business unit within the MfE responsible for leading the development, coordination and implementation of whole-of-government climate change policy.
The initial aims of this project were to:

- Establish the 1990 baseline description of New Zealand's indigenous forest, scrub and soil by area, vegetation class and carbon stock
- Define the requirements of an information management system and develop its framework
- Design a national system for monitoring carbon stocks in indigenous forest and scrub capable of providing carbon sequestration estimates with known error limits.

However, through DOC involvement in the oversight committee, it has broadened its scope to include non-carbon stock measurements, which now take up approximately two-thirds of the CMS team time when measuring a plot. It is the most comprehensive attempt to monitor vegetation biodiversity to date in New Zealand and, therefore, could act as a key part of any eventual national biodiversity monitoring scheme.

The CMS scheme began impletation in January 2002 and aims to complete the initial plot run within 5 years when it is hoped that the carbon stock in forests and shrubland will be measured to within a 95% confidence limit (within 5% of the mean). It uses a grid-based system of permanent plots to collect data relating to live biomass, woody debris and litter (Coomes et al. 2002; Payton et al. 2002). Nationally, 1400 permanent plots are located at the intersections of an 8-km grid in shrubland and forest determined from the Land Cover Database 1. Site characteristics are measured (altitude, slope, aspect, drainage, soil depth, physiography, surface stability) and coarse woody debris, ground cover, canopy height, and canopy percentage by species are estimated. Browse is recorded in three categories, and the presence noted of mammal, bird, reptile and invertebrate species that can be recognised by sight or sound. Cultural presence (logging, burning, tracks, grazing etc.) is also recorded. Biomass measurements are made from tree allometry and biomass harvests. Carbon stocks will be estimated first by using the plot data in regression equations and models, and then by multiplying carbon stocks per hectare for forests and shrublands by areas of these vegetation types derived from high-quality satellite imagery.

Forest plots have a nested design in which large trees are measured in large plots, and all trees in smaller plots. Trees greater than 60 cm in diameter within a circular plot of 20-m radius (0.13 ha) are tagged and measured for diameter and height. A plot of 20 m × 20 m (0.04 ha) centred on the circle has all trees greater than 2.5-cm diameter identified to species and tagged, and 15 randomly selected trees (selected from broadleaved trees, conifers, tree ferns and tall standing dead wood) measured for height and diameter. Plots are further subdivided into 16 subplots (5 × 5 m) within which saplings are counted by species, while seedlings within 24 circular plots (49-cm radius) are counted by species in three tiers. Non-vascular plants are also recorded from the ground up to a height of 2 m. A list of all vascular plant species (with cover classes) is obtained for each plot. National Vegetation Survey (NVS) databank permanent plots are used rather than establishing a new site whenever they are within 4 km of the grid intersection. The scheme is currently being enhanced by a 4 × 4-km grid system to provide extra information on carbon and biodiversity in plantations.

Problems that arose in setting up this system are instructive. It was clear from the outset that no one agency had the resources and knowledge necessary to set up the system. The programme was therefore a complex collaborative effort from the beginning. It was equally clear that pre-existing databases (NVS and National Soils Database) would ideally be used as a part of the new system. These complexities of dispersed scientific and managerial expertise, interagency rivalry and competition for funding, the need to use databases with different strengths and spatial characteristics, and to combine quite different sorts of carbon and biodiversity measurements in a single field effort, all made establishing the programme extraordinarily challenging for the participants.

Much planning went into determining exactly how and what would be measured, but little provision was made for the fate of the data after that. Even now it has not been settled how the collected data will be electronically captured, processed, and archived, and there is no system at present tailored to its requirements to permit analysis of the data. Some of the basic data (e.g. non-vascular species identifications) are yet to be obtained from collections made during the survey.

However, these problems aside, NZCMS is now operational, has been approved by an international oversight body, and will achieve its 5-year target for measurement of the initial plots. The establishment of a national, quantitative measure of carbon with known levels of precision was a quantum step for monitoring agencies in New Zealand. In large measure its successful initiation has happened because of the sustained efforts of key individuals at all levels who believed in the programme. If a permanent-plot monitoring system is to be part of a national biodiversity scheme, it is important to learn from the experience of setting up the CMS. The first step should be to examine the strengths and weakness of the CMS development process and implementation, in particular going beyond the official documentation to capture as much as possible of the social and institutional interactions that underlay it.

3.6 New Zealand Department of Conservation: current monitoring activities

DOC has the legislative mandate to conserve indigenous biodiversity, and is responsible for managing approximately 8000 million hectares or 30% of the New Zealand land area. The Department is primarily responsible for addressing a key Government Goal to ‘Protect and enhance the environment’. The Department’s vision is to ensure that ‘New Zealand’s natural and historic heritage is protected; people enjoy it and are involved with the Department in its conservation.’ DOC (among other agencies, e.g. MfE) has received additional funding over the past 5 years to implement the New Zealand Biodiversity Strategy (DOC & MfE 2000). Of particular relevance to the department is Goal 3 aimed at halting the decline in New Zealand’s indigenous biodiversity. Departmental outcomes aimed at addressing the Government goal, delivering on its vision and NZBS Goal 3 include:

‘New Zealand’s natural and historic heritage entrusted to the Department of Conservation is protected and restored’ (DOC 2004, p. 22)

To achieve this outcome several intermediate outcomes guide work in the department:
1) ‘The loss of natural heritage is halted

2) Threatened species are protected
3) Biosecurity risks are minimised' (DOC 2004, p. 22)

Key outputs have been selected to deliver on these outcomes (DOC 2004, p. 24).

Biodiversity monitoring enables the Department to demonstrate to government, the public and DOC staff at all levels achievement of desired outcomes for protection and restoration of biodiversity. Past and current departmental performance measures have reported on work undertaken to mitigate threats, number of species protection programmes and increased legal protection of representative examples of natural environments. To date, information derived from robust monitoring programmes demonstrating progress made on achievement of desired outcomes for protection of biodiversity has not been provided at a national level.

DOC spends about 50% of the funding from Vote: Conservation on managing natural heritage assets. These resources are mostly used to protect indigenous communities and species from threats posed by direct human action or exotic plants and animals. Inventory and monitoring projects within DOC have developed historically for a wide range of purposes, but are continued primarily to determine the degree to which conservation management at various levels succeeds in achieving biodiversity outcomes.

Overview of monitoring effort

Previous and extant biodiversity inventory and monitoring projects in the Department were compiled for this review to assess the context, range and type of monitoring being undertaken. Future work will include a more detailed analysis of these projects regarding coverage of environmental issues, resources, geographic distribution, alignment with the proposed framework, and relevance of the particular monitored activity to stated conservation goals at the project level.

More than 2300 separate current and past biodiversity monitoring projects were recorded in the survey. Local-level reporting on how the Department is performing in its key biodiversity protection role is largely based on management monitoring, with limited contributions from inventory and status and trend monitoring activities. Summary data for monitoring activities within selected categories of biodiversity, primarily based on work areas within the Department, can be found in Biological Monitoring in New Zealand's Department of Conservation, 2004.

Monitoring in DOC varies widely in scale, scope, stated objectives, biodiversity features that are measured, and the time frame over which the projects are delivered. The focus is strongly on management of biodiversity assets rather than quantification of biodiversity trends and status. The greatest monitoring effort is in vegetation communities (33%) with an emphasis on forests, followed by threatened plants (15%), birds (9%), animal pests (7%), weeds (6%) then invertebrates (6%). Monitoring on islands accounted for 11% and mainland islands 4% of all monitoring projects. A limited amount of monitoring occurs within other categories of biodiversity.

The most commonly stated objectives (classified according to type of monitoring – see Part II 5.2.2) are:

- To determine species distributions (**Inventory**)
- To determine population trends (**Status & trend**)

- To determine when management intervention is required (**pre-intervention**)
- To determine the effectiveness of a management action (**post-intervention** – to determine if immediate targets for reduction in pressure were achieved; **Outcome** – to determine if improvement in biodiversity asset status has occurred)
- To understand threatening processes (**Research**).

Biodiversity monitoring is most often undertaken in conjunction with specific management programmes to inform when intervention is required and to determine whether it has been successful. Threatened species monitoring is typically closely linked to threatened species recovery programmes. Some examples include evaluating blue duck or mohua nesting success and survival following pest control; evaluating the success of lizard translocations following rat eradications on islands. The majority (52%) of current species-centred projects use status & trend monitoring to improve on baseline information or review and set priorities for management.

Outside of species-focused projects, the most common monitoring type is post-intervention and outcome monitoring to determine if management interventions were successful. In predator control programmes post-intervention effectiveness is often assessed by comparison of indices of relative abundance of rodents, mustelids and cats under different management regimes (e.g. use of bait stations, trapping, aerial delivery of baits). Other examples of post-intervention monitoring include aerial counts to determine maintenance of thar at agreed densities; residual trap catch to assess the effectiveness of 1080 on reducing possum numbers; changes in possum trap catch to determine if pests are controlled to agreed levels to permit payment to contractor; change in cover to assess effectiveness of contractors in killing weeds.

Over the past few years there has been an increased emphasis on demonstrating an improvement in biodiversity asset status following management action. Examples include indigenous vegetation recovery following eradication of cattle and rodents or weed control; maintenance of forest composition and structure or canopy cover of indicator species in areas under sustained ungulate or possum control; change in seedling ratio index following goat control; change in forest invertebrate community composition following pest control; change in abundance of *Powelliphanta* species or rata litterfall following possum control.

Pre-intervention monitoring efforts are typically directed towards determining distribution and relative abundance of various pest species especially with regard to pest immigration rates and maintenance of predator-free status on islands, and in detection of newly invasive weeds. In the Department weed pre-intervention monitoring is directed towards invasive weed species that have not previously been recorded as naturalised in an area, or are of very limited distribution. The focus is on places that are vulnerable to weed invasion (e.g. reserve edges) or places with high conservation value.

Pre-intervention monitoring is used in a sophisticated way in several programmes. For example, in the mohua recovery programme mice indices and seed rain are used to assess the likelihood of a predator irruption. In general, a lack of understanding of basic ecosystem interactions prevents a wider use of effective pre-intervention monitoring.

The time frame for monitoring programmes ranged from less than 1 year up to 10 years, with the majority of initiatives reported having been in place for 1–3 years.

Ecological research is also conducted within or on behalf of the Department on a variety of issues including: development of new monitoring techniques; understanding predator irruptions in response to periodic masting events; determining the level of pest control necessary to protect threatened species populations; and to improve techniques (e.g. translocation, banding).

Specific techniques used to address the stated objectives vary with the type of data required. Broad groupings of monitoring techniques most often used by Departmental teams or contractors employed by the Department include:

- **Standard forest plot and grassland survey** methodologies line transects, cover estimates in fixed areas, photo points and use of exclosure plots to provide information on changes in stand structure and vegetation composition in the presence of herbivorous pests.
- **Protocols for indexing vertebrate/invertebrate abundance (**e.g. residual trap catch and wax blocks for possums; tracking tunnels for rodents and mustelids; kill trapping; spotlight counts for rabbits; chalk boards for cats; animal sign (e.g. faecal-pellet line surveys for ungulates); kiwi call counts; 5-minute bird counts; netting; trapping; spotlighting; electric fishing; acoustics; pitfall traps; weta boxes; malaise traps; pheromone traps; artificial covers; bat boxes) in areas under management to provide information on success of interventions.
- **Browsing surveys to document impacts on vegetation** (e.g. foliar browse index on indicator species to determine the success of possum control operations; seedling ratio index for ungulates) to determine when management intervention is required / to determine if improvement in biodiversity asset status has occurred.
- **Methods for estimating seasonal fluctuations in flowering and fruiting** (e.g. seed collected in seed traps quarterly) to anticipate predator irruptions/breeding in acutely threatened taxa.
- **Methods to provide information on population trends in abundance** (e.g. territory mapping; roost/colony counts, photos of individuals; burrow density; mark-recapture, distance sampling, aerial surveys for thar and marine mammals; intensive searches using grids/transects; marking and mapping of individuals).
- **Nest inspections; banding; radio telemetry**; video cameras, to provide data on demographic parameters such as productivity, mortality, sex ratio, dispersal, and survival.
- Radio telemetry using **Judas goats** in areas under management.
- Analyses of gut **contents** to determine diet preferences.
- **Hunter effort** in areas under management (e.g. kill/man-hour).
- **Tissue analyses in indigenous and exotic species** to determine cause of death.
- **Chemical residues in the environment** to determine level of contamination from pest control operations (e.g. herbicide residue in soil after herbicide application; pesticide residue in water after 1080 application).

Species (or assemblage) monitored and parameters measured varied with the stated objectives and type of data required. Broad groupings of species and or parameters most often measured by staff include:

- Index of abundance or distribution of animal pests (e.g. rodents, mustelids, cats, deer, thar, possums, goats, rabbits, hares, horses, pigs, hedgehogs, koi carp, and trout).
- Cover or abundance of plant pests (e.g. marram, wilding pine, old mans beard).
- Index of abundance, demographics or distribution of threatened species (e.g. various mud fish and galaxid species); invertebrates (e.g. Middle Island tusked weta,

Powelliphanta species, katipo spider); birds (e.g. mohua, kokako, saddleback, albatrosses, mollymawks, orange-fronted parakeets, kakapo, terns, kiwi, black petrels, NZ dotterel, takahe); herpetofauna (e.g. Otago and grand skink, tuatara); mammals (e.g. Hector's and Maui dolphins, bats); vascular plants (e.g. *Dactylanthus*, mistletoe, *Lepidium*).

- Species composition, cover or density of: vascular plants species in forests, grasslands, wetlands and dunes; invertebrates in forests; vertebrates/invertebrates in intertidal reefs; birds in forests.
- Cover or browsing occurrence on vulnerable plant species (e.g. mahoe, fuchsia, kamahi, rata).
- Number or weight of seed/litter produced by selected forest species (e.g. beech, rimu, pohutakawa, and rata).

Preliminary overview assessment

The Department inherited from its predecessor agencies a tradition of inventory and monitoring, which it has continued and strengthened. The number of projects currently being monitored is increasing, the expectation that biodiversity monitoring will be undertaken as a normal part of DOC's business has grown, and the expertise to carry it out has vastly improved. However, a number of factors have worked against DOC achieving a comprehensive and effective monitoring system by which progress towards Departmental goals could be more fully quantified and reported.

First, monitoring effort has been segregated within work areas in DOC, and there has been little interchange or coordination across these, which has hindered the development of a cohesive system. For example, threatened species monitoring is organised separately from that of pests and weeds, despite the persuasive logic of these activities being combined when causes of pressure are known. These historical splits between monitoring activities, which logically should be part of a single system of biota protection, were, until recently, intensified by funding under an output class structure. Activities tended to be organised on the basis of funding source, independently of broader Departmental goals.

A second factor is the highly variable temporal and spatial scales across which the monitoring is carried out, and the wide range of intensity of the monitoring from intermittent casual surveys to 24-hour surveillance. This has made it difficult to coordinate activities or to relate one set of monitoring results with another.

A third factor is that, for various reasons standardisation of data capture, archiving, and analysis has rarely progressed. Finally, (with the notable exception of weed monitoring) there has been no Departmental oversight in terms of national direction, guidelines, and standard operating procedures for monitoring, which has largely been driven by the needs of the particular project, and local enthusiasm and experience. Individual conservancies have adopted their own inventory and monitoring strategies, resulting in divergent methodologies and approaches. Local monitoring schemes are at risk of failure in an unstable funding environment without secure long-term resourcing.

At this stage, the review has highlighted several issues regarding the rationale for and utilisation of monitoring within DOC.

Poor linkages – As stated above, there are often only tenuous interactions between groups working on different aspects of biodiversity management, even though they share common immediate goals. Vertical linkages are also weak – importantly, monitoring results appear to have only a limited effect on management decisions in many cases; and feedback from management to monitoring groups is not consistent or frequent. Insufficient attention is paid to ensuring that there is a complete monitoring-management-decision cycle.

Reporting systems not integrated with monitoring systems – At all levels, lack of integration means that reporting of achievement and effectiveness tends to be more idiosyncratic and ad hoc than is desirable, and frequently independent of realistic assessments of the monitoring results.

Inappropriate methodology – The relation between the methods used and the biodiversity factor of interest is often weak, resulting in inappropriate methods for delivery on stated objectives. For example 5-minute birdcall counts are widely used to quantify bird populations, but there is little research to support this assumption.

Insufficient information collected – Often monitoring teams become focused on a limited repertoire of techniques and fail to collect the contextual information to assist interpretation. Without context the monitoring effort lacks all but immediate application and has a greatly reduced ability to address basic issues.

Poor targeting – Much of the current monitoring is focused on determining the immediate effectiveness of a management intervention. However, it is not until properly designed outcome monitoring is undertaken that the all-important biodiversity asset questions can be answered. Questions such as: Are we getting adequate recruitment in forests? Are there ancillary benefits from pest control regimes to other species? Is this management sustainable at its current level of effectiveness?

Neglect of certain ecosystems or species – There is little monitoring in non-forested ecosystems aside from some grasslands. Alpine, dune, freshwater and marine ecosystems are also relatively neglected. Some nationally threatened taxa receive little or no monitoring effort. For example, only 27% of nationally critical plant taxa and 40% of bird taxa are subject to monitoring.

Minimum quality control – DOC protocols have generally not been established and there is little formal quality control. Staff training, refresher courses, and assessment of methods are not carried out as often as would be desirable.

Data handling and storage is variable – There is an emphasis on physical collection of the monitoring data and little attention paid to data capture, archiving, analysis, and presentation and updating of findings.

Human resources neglected – There is insufficient staff training, staff exchanges, mentoring, and succession planning to maintain a quality monitoring programme.

Conclusions

DOC carries out by far the largest amount of biodiversity inventory and monitoring in New Zealand. Most of this is practical, management-focused activity, although a considerable amount carried out by the Department, or commissioned by it, has as a primary goal better understanding of underlying biodiversity processes, or improvement of methods. There is no doubt that this monitoring has a beneficial effect on the work of the Department. However, more than most other DOC activities, inventory and monitoring is sustained by committed, enthusiastic individuals. This is particularly evident with regard to inventory of threatened species and threatened species recovery, but it permeates across the Department. Inspired individualism is an insufficient basis on which to build a formal monitoring system to systematically address the biodiversity achievements of DOC. Excessive reliance on individuals without the support of a system makes the whole activity area vulnerable to staff turnover, demoralisation and lapses of professional judgement. Therefore, the shortcomings identified here are generally not those of the staff who carry out this monitoring but of (1) the higher-level, broad-scale integration support and utilisation of the flow of information and (2) support for the activity through research, training, protocols and career support.

The challenge is to transform the current system, which tends to be focused on disparate immediate and often short-term management concerns, into a much more comprehensive and responsive system that integrates across the Department and through all the management levels. A key component of this will be line management accountability for the quality, storage, analysis, maintenance, and result-implementation of monitoring.

3.7 Conclusions: observations and lessons from the history of monitoring in New Zealand

Observations

Little monitoring has been initiated or continued simply to provide baseline biodiversity data.
Monitoring from inception until the 1970s had in a policy sense an economic focus, although the motives of those running the programmes were typically various. From the 1970s onwards, monitoring has increasingly included more general environmental values although economic issues (biosecurity, agricultural pest control, disease) remain strong. Even the long-running gannet survey has been recently used to evaluate impacts of marine harvesting. Issue-free monitoring is therefore rare.

Monitoring has a tendency to perpetuate itself, regardless of changes in policy.
Monitoring has usually been closely connected with perceived environmental problems or resource issues. These issues become the focus of management actions which themselves engender a monitoring response. However, once the cycle of management action and monitoring is established, often the system self-perpetuates impervious to policy changes (Caughley 1988).

Much monitoring appears to be done, in part, because it was relatively easy to do.
Difficult (e.g. cryptic, soil-dwelling, speciose, taxonomically ill-defined) organisms have been late to be included in monitoring schemes, while abundant, taxonomically well defined, easily tracked organisms (trees, colonial sea birds) feature strongly. To some extent it appears that past monitoring choices have been swayed (probably unconsciously) by this factor.

Physical collection of monitoring data has a tendency to run far ahead of the ability of the system to archive and analyse.
In monitoring the focus tends to be on planning field seasons and retaining skilled personnel to carry out the work. Typically, staff responsible for analysis and reporting have other pressing tasks, and analysis of monitoring results has a low priority. A common refrain in, for instance, New Zealand Forest Service reports, was the failure to keep up regular reporting and analysis of the survey results (McKelvey 1995). This neglect is even apparent in the recently established New Zealand Carbon Monitoring Scheme.

Monitoring schemes, or the data archived from them, often end by addressing different issues additional to or replacing those for which they were originally designed.
As political perceptions, scientific understanding, or actual environmental conditions change, data collected for one purpose prove to be highly valuable for another. This should not of course be used to justify any type of monitoring in the future on the off-chance that it will eventually prove useful: marginal and opportunity costs apply here as much as in any other field. However, it suggests that when expensive, broad-scale monitoring is undertaken, standard, widely intercomparable methods should be preferred and a wide view of the sorts of attributes measured taken, in order to future-proof the data.

Monitoring information often either is not used or is poorly employed in making management or policy decisions.
This observation is based on the fact that much of the data are not analysed or reported on. Also, anecdotal or informal reports suggest that monitoring data are often not central to the decisions taken even when available, either because of other factors regarded as more important, or because of a lack of clear interpretation relative to the management decision being taken.

Changes in institutional structures pose great risks regarding loss of expertise, continuity of monitoring, and preservation of data.
We have mentioned the disruption and loss of institutional memory and expertise caused by the restructuring and employment uncertainties surrounding the formation of DOC in the 1980s, which resulted in the loss of some irreplaceable monitoring data. The lesson is that monitoring data have to rank as high as information generated by core institutional activities such as human resources and financial management, and the same consideration given to archiving and continuity.

The increasing demand for non-intensive, reliable, rapid assessment monitoring methods is leading to experimentation with non-comparable tools of low rigour.
Monitoring is often broad brush, and a variety of qualitative methods are frequently used in order to save resources which often is cost-effective when management needs only a very rough guide to action. The true cost of such an approach is that the trends may be related more strongly to the observer than any other factor; the results may be too variable to be useful; or the results cannot be used to compare with other areas. Where decisions about how to monitor are decided on a regional basis, the risk of non-comparable methods being used is high. While standardisation and quantification can result in significant opportunity costs with regard to the amount of data collected, these costs have to be balanced against the ultimate utility of the monitoring.

Implications

The core to any monitoring system must be an awareness of the environmental context that influences all biodiversity management.
It is important to develop a monitoring system that takes account of more than just the proximate factors believed to influence outcomes. This is difficult to achieve in a management-orientated organisation, where staff want to get on with the job, and framing a biodiversity monitoring programme to deal with the broader context seems an unnecessary luxury.

The need to understand many different organisms and their interactions, while taking into account their differing time constants, demands a complex monitoring effort.
If there is one single lesson that has come out of long-term studies it is that the inter-relationships between indigenous organisms, exotic pests and the environment are complex and unstable over time. From the management-related monitoring around intensively protected sites, we now know that single-focus programmes that ignore what may be initially regarded as subsidiary influences or factors tend to be inadequate in the long term.

Data archiving, analysis and reporting must be factored into the overall costs of new and ongoing monitoring.
A significant proportion of monitoring information has never been analysed, archived or reported on. Much monitoring appears to be have been initiated either because the situation seemed to call for it (e.g. when major changes in land use or tenure are projected), or knowledge of certain processes (weed invasion, grazing) seemed inadequate. However, it has been only rarely that sufficient ongoing funding is allocated for archiving, analysis and reporting. Even the well-supported CMS scheme has failed to prepare adequately for data archiving and analysis.

The monitoring effort must be clearly connected with management and policy.
Both internationally and nationally there are indications that monitoring is often poorly connected with management action and policy development. The way forward is to get commitment at all levels to using as well as producing monitoring data.

New Zealand monitoring must be comparable internationally.
If New Zealand monitoring techniques become too idiosyncratic and insufficiently based on internationally agreed principles, it raises the risk that best practice will not be used, and that the data will be rejected by international oversight committees concerned with implementation of international agreements, treaties etc.

PART II: REPORTING BIODIVERSITY: GOALS, DEFINITIONS, PRINCIPLES AND ISSUES

If a conservation agency is to be held accountable for the wise use of its resources and ultimate outcomes for biodiversity, it must have a reporting system that can satisfy the various stakeholders in the system. Ideally, it should be able to present an up-to-date, comprehensive overview of what biodiversity is present, how it is changing, and why, as a background for more detailed information as to how its activities are delivering benefits. This part of the report deals with the significant issues that confront those who set out to design an inventory and monitoring system to meet this need.

The total number of species present in even a relatively biodiversity-poor region is very large, and the interactions between those species and with the environment immense. As a result, there are an overwhelming number of entities and processes that could be inventoried or monitored. As well, conservation is a human enterprise, and society's needs and preferences must be taken into consideration. The monitoring literature is insistent that not everything can be measured or tracked and, therefore, choices must be made. Nevertheless, the principles behind the choices are not always apparent, and agencies can be accused of selecting entities that can be easily measured rather than those important to the conservation effort. In the following sections we look at international and national goals for biodiversity, the principles that can be derived from them, and how these might be translated into measurement choices.

4. Goals and principles

4.1 International and national goals

International conservation goals set the context for biodiversity inventory and monitoring. The multinational Convention on Biological Diversity agreement is the most comprehensive concerning these goals. It affirms the following:

> The objectives of this Convention, to be pursued in accordance with its relevant provisions, are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding (Article 1 CBD).

CBD working groups are establishing more detailed guidelines, but they are likely to continue this basic theme. It can be seen from this, and other international statements on biodiversity conservation, that although conservation of biodiversity is the major goal, the main concern is with wise, sustainable and fair use of that diversity. The statements reflect the view of many countries that conservation obligations should not come with too high a socio-economic cost.

National conservation goals are set by government policy at a high level, in broad abstract language. In general, they promote the idea of maintaining or extending the area of the nation dominated by natural, self-sustaining ecosystems for the intrinsic values inherent in these systems and the species that comprise them, and for the benefit and enjoyment of the citizens. For instance, the United States Department of the Interior has as one of its five broad goals: 'Protect the environment and preserve our nation's natural and cultural resources', which the National Park Service interprets in its mission statement as: 'Natural and cultural resources and associated values are protected, restored, and maintained in good condition and managed within their broader ecosystem and cultural context' (National Park Service 2000).

Or as expressed in the *National Strategy for the Conservation of Australia's Biological Diversity*: 'We share the earth with many other life forms that have intrinsic value and warrant our respect, whether or not they are of benefit to us…The goal is to protect biological diversity and maintain ecological processes and systems.' (Department of the Environment, Sport and Territories 1996)

These general sentiments are echoed in the New Zealand Biodiversity Strategy (Principle Three):

All New Zealanders depend on biodiversity and have a responsibility for its conservation and sustainable use beyond their own needs:

- To the needs of future generations; and
- To other species, life forms and ecosystems which have intrinsic value and warrant respect. (DOC & MfE 2000).

International and national goals are not designed to assist with practical conservation activity, but rather to affirm the place of biodiversity and its conservation in the nation's life and, at the same time, not inhibit legitimate human use of biodiversity. However, we need to examine carefully the meanings of the terms used, as they are fundamental in justifying conservation decisions. This is not a trivial matter: higher-level national goals legitimise lower-level actions and expenditure of public funds. Not to give meaning to these terms is to open the public conservation effort up to the critique that it is arbitrary, idiosyncratic and heedless of the broader public interest.

4.2 Implications of the goal statements

Intrinsic value

'Intrinsic value' of biodiversity refers to its value beyond those of the tangible services provided to humans or direct economic worth. In other words, biodiversity also has intellectual, aesthetic, and religious significance. However, 'intrinsic value' can also mean 'a worth beyond any other consideration than its existence'. The international consensus is, therefore, that every indigenous element of biodiversity is of value simply because it exists. There is a strong thrust in most strategy documents for a more inclusive adoption of this goal than is currently observable in practice.

The suggestion has been made with reference to the Department of Conservation Act, that this key term 'intrinsic value' is essentially meaningless (e.g. Hartley 1997), because biodiversity ceases to be 'intrinsic' when people make choices. As resources are limiting, people-centred opinions as to priorities in ecosystems or biodiversity necessarily convert an 'intrinsic' value to one based on 'what people value'. Hartley (and many others) are therefore arguing for an **anthropocentric** approach to conservation and denying the need to consider intrinsic value (in its most restrictive sense) at all. However, the concept of 'intrinsic value' is not invalidated by the need to make choices: the intent of the international and national statements is clear – all biodiversity is to be conserved simply because of the fact of its existence. No other justification is needed and everything would be conserved if it were possible. Furthermore, many conservation choices will be made not on the basis of some human-centred value, but on the objective value of a particular biodiversity element to other biodiversity components.

Burgman & Lindenmayer (1998) take the concept of 'intrinsic' (that is non-anthropocentric) value a step further, and make the important distinction between 'ecocentric' and 'biocentric' ethics. The **ecocentric** ethic, while adhering to the intrinsic value concept, accepts that environments, living things and ecosystems continue to evolve and change. As long as the broad ecological properties of natural communities are not permanently changed by human use or management, then that use or management is acceptable. The **biocentric** ethic argues for the value of all individuals. It implies that there is a duty not to harm any entity in the natural environment.

In practical terms, the biocentric view of conservation demands that both individual species and the assemblage properties of ecosystems be inviolate. The ecocentric view allows more latitude to ecological intervention and human use within limits. Conflict between ecocentric and biocentric views is endemic in nature conservation. Actual conservation practice here and abroad is an intricate mix of anthropocentric, ecocentric and biocentric ethics. Thus Burgman & Lindenmayer (1998) conclude:

> There is no single environmental ethic that one may use to argue for conservation priorities, and it is possible for utilitarian arguments to be in accord with other ethical values. No simple recipe exists for determining how biological resources can best be conserved and no single set of prescriptions will determine the appropriate land-use strategies that will best achieve the objectives of conservation.

In this document, we broadly follow an ecocentric approach.

Valuing biodiversity: commensurability and fungibility

If entities are 'commensurable' they can be measured by the same standard. Thus if the aim is to have more kiwi, greater cover of indigenous vegetation or whatever, areas can be compared according to an objective standard of number of kiwi, hectares of vegetation etc. In most human systems, commensurability is provided by money because this can be universally exchanged for many goods and services. However, as there is no market for most organisms or ecosystems, it is hard to see on what basis prices would be determined for these entities. Possibly the only way to estimate value is by determining how much we would be prepared to spend in order to retain a species at a certain population size or an ecosystem at a given extent. Attempts to put a dollar value on the conservation estate, while often promoted as the ultimate measure of conservation value, have failed to be adopted as there are formidable barriers in practice and considerable doubt as to their stability, objectiveness etc.

What about other approaches? One might think that species or ecosystems provide an ultimate measure: the more of them, the more value an area has. Certainly, the stress on diversity in both the academic literature and conservation publicity alike would suggest that some quantitative measure of diversity could be used as a currency substitute to measure the worth of an area. However, all schemes that aim to provide a single interchangeable currency or number for biodiversity run into the problem that species are not interchangeable. Individual species perform different and often multiple roles in ecosystem processes and are valued differently by humans. Some regions are of interest because they are species-poor; others because they are species-rich. Some genera are of great interest because they have but one unusual representative; others because they have many similar species. Formal attempts to assign biodiversity values through numbers or indices are therefore unlikely to have much widespread practical use.

Fungibility is an economic and legal term that expresses the idea that an object, specimen, good or service can be freely substituted for another in discharge of an obligation. It is important to note that ‘fungibility’ implies ‘interchangeability’, but only in the context of the obligation. Thus, an orange is fungible with regard to the obligation to provide a piece of fruit, but non-fungible with regard to the obligation to provide an apple. We suggest that this term be extended to conservation, the ‘objects, goods and services’ being the many aspects of biodiversity, and the ‘obligation’ being the goals of conservation activity. It captures the essential point that some elements of biodiversity can be substituted the one for the other in the pursuit of ultimate conservation goals, but that others cannot.

Much academic debate about the role of biodiversity centers on the degree to which species number is fungible with respect to valued ecosystem properties such as resilience (see Chapin et al. 2000). Many species appear to be fungible with regard to ecosystem function, with substitution appearing to maintain equivalent ecosystem function (Chapin et al. 2000). Some aspects of valued ecosystems can be maintained by a greatly restricted set of native species (e.g. most New Zealand forests flourish despite the massive reduction of browse-vulnerable plants), by non-natural indigenous elements (e.g. when native species are sourced outside of a region), or even by exotics (e.g. gorse as a nurse for forest regeneration or silvereyes as fruit dispersers). It has even been claimed that deer are at least partly fungible with regard to browsing because of the extinction of the herbivorous moa (Caughley 1983).

However, if the species composition itself is the object of conservation, it is clearly non-fungible. Furthermore, it is hard to see how these fungible and non-fungible components can be compared, as they lack a common currency. To give an example: there is no doubt that exotic forests can provide many basic ecosystem functions equivalent to native forests and may be, in fact, more resilient to certain stresses such as fire. However, we are, for the most part, not prepared to trade off native species against improved ecosystem capacity. It is not even clear that we would be prepared to replace one set of native species with another group that would improve certain aspects of ecosystem functioning.

Our conclusion is that attempts to devise some sort of biodiversity ‘currency’ or ‘index’ to value biodiversity and measure achievement appear to have failed, or are not widely adopted, mainly because species, ecosystems and processes are neither commensurable nor fungible. We suggest that the way forward is to set realistic conservation goals and report progress towards them through a multiplicity of measures.

Ideal state

The concept of ‘intrinsic value’, although valuable in setting broad policy goals, does not help in choosing what to measure, as it asserts only that every biodiversity element is worthy of preservation. We have seen above the difficulties that arise when an attempt is made to put a value on biodiversity. The only other option is to measure the degree to which an area, ecosystem, species complement, or process approaches an ideal state and use that as a goal against which progress can be objectively measured. It is accepted that this state will have many elements that cannot be traded off against each other, and it will necessarily be reported as an assortment of measures of independent attributes.

The terms ‘health’, ‘status’ or ‘condition’ are often used to refer to a current ecosystem state in relation to one regarded as ideal. Stephens et al. (2002) give a definition of ‘condition’ as:

> The similarity of contemporary biota to biota expected in the absence of human-induced disturbances. Condition is measured by an additive combination of several components, such as taxonomic composition, phylogenetic diversity, functional diversity, structural diversity and age diversity.

Internationally, ‘ecosystem health’ appears to be the most widely used goal-related term (except in Australia and New Zealand where ‘condition’ is more widely used).

The terms ‘health’ or ‘condition’ are often used as foci for biodiversity assessment but, because they rely on analogies with human health, it is difficult to link them to particular higher-level components of biodiversity. For example, ‘health’ is difficult to define in an ecosystem context. An ecosystem may be healthy according to any objective measure of its processes but, because it is dominated by exotics, might be in an undesirable state.

The United States National Academy of Sciences (2000) has therefore opted for ‘biological integrity’ and it appears to be a widely used and well-understood term (especially in aquatic systems). Biological integrity is:

> The capacity to support and maintain a balanced, integrated, adaptive biological system having the full range of elements (genes, species, and assemblages) and processes (mutation, demography, biotic interactions, nutrient and energy dynamics, and metapopulation processes) expected in the natural habitat of a region (Karr 1996).

The concept of biological integrity, therefore, does not hinge solely on absence of humans and their effects, although evidence as to the human-free state is important background information in many, but not all, ecosystems. Nor does it rely on rigorous comparison with a base state environment, although this too is useful in some circumstances. What it does depend on is establishing what the proximate goals might be for an area, region or nation – given all the available information – and establishing measures to assess how far away from the ‘ideal’ state an area or community is, how rapidly it is changing, and why.

However, ‘biological’ integrity highlights the organisms in an ecosystem while appearing to overlook the environmental components, even if abiotic aspects are included in the definition. ‘Biodiversity integrity’ has the same problem, although it may be preferred for strategic reasons related to widespread public acceptance and understanding. The National Parks of Canada have opted for 'ecological integrity', which is defined as:

> a condition that is determined to be characteristic of its natural region, and likely to persist, including abiotic components, and the composition and abundance of native species and biological communities, rates of change, and supporting processes. (Canada National Parks Act 2000)

In our opinion, this is the best descriptive term for the ideal conservation state.

Natural state or baseline

Reference states are normally defined historically by establishing a date before which the biota and constituent ecosystems approximated the ideal state. The prehuman condition is often used in regions where human settlement is relatively recent (i.e. within the last 1000 years). However, in most areas of the world, human settlement has a much longer history (tens of thousands of years), and in these countries the prehuman biodiversity condition is a relatively meaningless criterion for biodiversity conservation as it refers to a very different climatic and sometimes geographic setting. Moreover, because many major elements of biodiversity were extirpated by the first human settlers in most countries (e.g. the extinction of moa in New Zealand), there seems little practical merit in including them and thus establishing unattainable conservation goals. Using some distant past point in time also ignores the natural changes that have occurred since then, such as long-term soil development, and volcanic and tectonic events that are independent of humans. Only a limited amount of information can be recovered about distant points in time. In practice, historical baselines are inherently difficult to determine and are usually substituted for by extant weakly modified natural areas. For these reasons, many regard prehuman historical baselines as a distraction from the pressing concerns of the present instant of time (Bowman 1998). Despite these problems, historical or theoretical information of how a landscape without humans functioned in the past is regarded as an essential part of the mix that informs conservation internationally (United States National Academy of Sciences 2000). Difficulties arise only when this information is used as a rigid goal, rather than a guide.

A second and more common approach is to tacitly include the environmental modifications made by indigenous or preindustrial people by selecting a more recent benchmark. The CBD supports this approach and suggests for practical purposes that some date be selected representing a period before human impacts began to accelerate. They refer to this as the 'postulated baseline', which is usually located at some point immediately prior to industrial development. In the case of densely settled areas of the globe, such as Europe, the pre-industrial or early industrial state of the environment becomes the target as much as the unmodified environment. In New Zealand the signing of the Treaty of Waitangi in 1840 is often mentioned as a possible benchmark, before the direct (intensive land use and habitat modification) and indirect (pests, disease) effects of European settlement had begun in earnest. However, in practice, virtually no Maori-induced landscapes are preserved on that basis, and it is clear that the purpose of AD 1840 is merely to exclude the inconvenience of extinctions, rather than to encompass Maori landscape management.

A major problem with all biodiversity reference states based on the composition and/or condition of the biota at some point in time-past is that they ignore the fundamental changes humans have made at multiple temporal and spatial scales that have impacted both on the abiotic character and available biotic assemblages. These changes can range in scale from global increases in atmospheric $C0_2$ concentrations, regional extinctions of major biotic guilds, through to the local creation of novel communities involving participants with diverse and independent evolutionary histories. Although some of these changes may mimic environmental shifts and ecological interactions of the geological past, collectively they represent novel forcing factors shaping modern biodiversity.

Our conclusion is that baselines or goals for conservation have to be set specifically for each ecosystem, utilising all relevant information. The ecosystem needs to retain a natural character and its full complement of species, but 'ecological integrity' can be a characteristic of an ecosystem with many different states, as mentioned above. Important components of this baseline setting will be (White & Walker 1997):

- The natural range of variability
- Past states
- Natural change resulting from adaptation to changed circumstances (e.g. evolutionary responses, hybridisation)
- Inevitable change or loss that cannot be reversed or reversed easily (extinctions; climate change; soil loss)
- Allowance for people and anthropogenic elements (roading, tracks, non-invasive or tolerable exotics).

4.3 Implementing goals: national biodiversity principles

The discussion of biodiversity goals in the preceding sections still does not give any specific guidance of how to make choices in what is measured and managed. The New Zealand Biodiversity Strategy (DOC & MfE 2000) gives principles that DOC's conservation strategy should follow. The following are those that give specific guidance:

> **Principle Eight**: 'Biodiversity is best conserved in situ by conserving ecosystems and ecological processes to maintain species in their natural habitat'
>
> **Principle Nine:** 'Priority should be given to conserving indigenous species over introduced species when making management decisions'
>
> **Principle Eleven**: Requires a comprehensive approach 'all levels of biodiversity (ecosystems, species, and genetic)' and 'focused on the priority needs'

These principles are consistent with those established by other nations. For example Australia (Department of the Environment, Sport and Territories 1996):

> The goal is to protect biological diversity and maintain ecological processes and systems [And the operational principles (inter alia):] Biological diversity is best conserved in-situ. It is vital to anticipate, prevent and attack at source the causes of significant reduction or loss of biological diversity. Central to the conservation of Australia's biological diversity is the establishment of a comprehensive, representative and adequate system of ecologically viable protected areas integrated with the sympathetic management of all other areas, including agricultural and other resource production systems.

Note, however, that the Australian formulation specifically introduces the concept of managing the productive estate to enhance conservation values as well.

The problem with the New Zealand biodiversity strategy, and virtually all international and national declarations and strategies, is that they can be interpreted as demanding that all indigenous life elements at whatever level – ecosystem to gene – are of intrinsic value, and should be conserved wherever they now exist. Equally, all non-indigenous elements are seen as threats, even though countries may be economically dependent on them. They therefore give only weak guidance towards establishing priorities. In fact the language used sometimes deprecates current priority-based activities: 'Many populations of threatened species continue to decline as attention and funds are focused on a small number of highly threatened, and often most visually appealing, native species.' (DOC & MfE 2000, p. 39). On what basis and for what reason should funding be diverted from saving highly threatened and much-loved species to favour presumably less-threatened and less-appealing species? The Strategy is silent on this and many other issues concerning priorities.

How do other nations go about putting these ambiguous goals and principles into practice? International statements, as for instance in the CBD COP Decisions, give some guidance, but generally it is only in the various national biodiversity indicators and relevant measures themselves that the underlying principles for setting priorities become clear. Low-level indicators often seem ad hoc, and underlying principles are rarely stated, it is often unclear how low-level indicators relate to higher-level indicators and goals. This issue of priority setting is not well addressed in the international conservation literature. To give an example: the United States National Park Service Strategic Plan (National Park Service 2000) has 11 guiding principles – eight deal with people-centred or staff management issues; none deal with how to prioritise conservation actions.

Agencies will have to be explicit about why they are more concerned about some aspects of biodiversity than others. Any biodiversity inventory and monitoring strategy needs to make clear what it regards as of highest priority with a convincing rationale why. If it fails to do this, it will not win the wide consensus necessary to underpin its work, will be open to often-acrimonious debate on priorities, and possibly to legal challenge when property rights are involved.

We suggest, based on our general understanding of the priorities expressed in conservation goals and the monitoring and inventory decisions in a number of countries, the following principles to guide higher-level priorities.

Principles

The main goal of biodiversity conservation nearly everywhere is to 'halt the decline' or prevent 'degradation' or 'loss of ecosystem integrity'. These goals insist that there be a strong focus on active management. The issue is to develop principles that will result in the best outcomes for a given level of resource. Our suggestions are as follows:

Principle 1: *Effort should be directed towards ecosystems and species most at risk, while giving full consideration to principles 2–5.* This principle establishes that preventing extinction or extirpation is a major driver in the more generalised goal of preventing biodiversity loss.

Principle 2: *Broad-scale ecological integrity is essential to the maintenance of services and to the conservation of biodiversity elements that cannot be individually managed effectively.* Balancing principles 1 and 2 is crucial, as it demands a value judgement decision between certain loss of known biodiversity elements, versus probable loss of poorly known elements and deterioration of environmental standards in the future. The first two principles suggest that this balance should be struck explicitly.

Principle 3: *In establishing priorities, distinctiveness should be an important consideration.* Not all biodiversity is of equal worth for the genetic diversity it contains, the adaptations it encapsulates, and the places and environments it is connected with. Phylogenetic distinctiveness is but one aspect: the concept gives equal weight to endemism, novel traits, ecosystem role, and specialist habitat affinities.

Principle 4: *Effort should be focused on those elements of biodiversity that will give the greatest return on investment.* Because we are dealing with limited resources, the marginal value of different activities should be a major consideration. Most effort should go where there is a better than even chance of a positive outcome. This outcome has to be balanced against the potential conservation return in making the investment elsewhere.

Principle 5: *Effort should be focused on those elements that have the greatest effect on the largest number of other biodiversity elements*. This principle encapsulates the concept that many species or ecosystems have disproportionate effects on overall biodiversity. The species involved are often called ‘keystone’ or ‘ecosystem engineer’.

Principle 6: *Human preferences for certain types of ecosystems and taxa are a legitimate consideration in allocating inventory and monitoring resources, but should be balanced by consideration of principles 1–4.* This principle is anthropocentric (rather than ecocentric or biocentric), but recognises the inescapable reality that human preferences are strongly expressed in conservation.

If these principles are to be of any use in making choices, they have to exclude as well as include. What is excluded (from a conservation agency point of view, not necessarily from a more general research perspective)? Firstly, total inventory is not regarded as a priority. Secondly, generalised monitoring is limited. And thirdly, paying attention to elements about which little can be done is of little value, as is devoting resources to elements that are at little risk. However, these principles cannot be applied in a knowledge vacuum: they presume we already know sufficient about biodiversity to apply them, and this is not always necessarily so. Therefore, provision for acquisition of background knowledge has to continue. Which agency or organisation is responsible for ensuring the knowledge is available is debatable, but internationally it is typically a multi-organisational effort.

These operational principles guide the selection and application of (1) indicators obtained from inventory and monitoring programmes, (2) methods used to measure indicators and their sampling rates and (3) study areas for inventory and monitoring. However, issues connected with inventory and monitoring need further discussion.

5. Biodiversity inventory and monitoring

Inventory is a stocktake of what is present at a point in time. **Monitoring** establishes how the inventory changes with time and follows the processes that produce that change.

5.1 Inventory: how much is enough?

The key question with inventory is: How much do we really need to know? For a conservation agency there is also the question of what information it can safely leave to other agencies to collect. Basic physical, climatological and geological data in New Zealand and elsewhere is mostly collected and analysed by non-conservation central government agencies. While it is important that some of these measures be understood and reported by conservation agencies as they impact on biodiversity outcomes, they do not need further discussion here.

Internationally, inventory mainly concerns the legal conservation status of the national estate, the extent of various vegetation and landform types, and the variety and abundance of the biota. The first two are relatively straightforward and have been immensely assisted by recent technological developments. However, regarding the variety and abundance of the biota, many difficult questions are raised and this is the focus of this section.

Species inventory: purpose and progress

There are a very large number of distinct living organisms (estimated at between 1.5 and 8 million globally for described species; Wilson 2000). Even in a temperate country such as New Zealand the numbers are very large (c. 20 000 described species in the terrestrial biota; approximately 60 000 species remain to be described (DOC & MfE 2000). Only 12% (primarily vascular plants and vertebrates) of the New Zealand biota is regularly monitored in any systematic fashion.

Invertebrates make up the overwhelming majority of living organisms. In New Zealand they comprise over 70% of the described biota (60–65%; Stork 1988, but when undescribed species are added, the proportion may be as high as 90%; Kim 1993). Clearly, the total diversity of the biota cannot be understood without this component included, and the bulk of undescribed species largely falls within this group. Lower plants pose similar problems: for instance, there are 5800 species of fungi described in New Zealand.

The problems posed by these huge numbers of living things are:

- Many species have no scientific names
- The vast majority of those named have virtually no ecological information available beyond that which can be inferred from their relationships to those few species that do
- Nearly all are variable between individuals and populations
- Genetic information is lacking for nearly all species
- Each has a multitude of relationships with other species and with the abiotic environment.

International and national goals for conservation have declared that each and every native species is of intrinsic value. It is claimed that completion of a full inventory of the Earth's biota is one of the most urgent tasks facing nature conservation (Wilson 2003). Species are the independently evolved key working parts of biodiversity, and solid advances will depend on a detailed knowledge of species and their natural history (Wilson 2000). It is therefore argued that only by thoroughly documenting species so that those at risk can be identified and remedial action taken can we avert a species catastrophe. Even when much is already known about a biota, as is the case with North America and Western Europe, there is a constant refrain in the literature for more and better-focused information to achieve conservation goals. A name is of little value of itself; to be useful, a species inventory will have to include a minimum of distributional and ecological information.

Globally, progress in species inventory, even in the decade since the establishment of the CBD and the entry of biodiversity into mainstream policy agenda, has been slow. It has been forcefully argued that new technologies (Web-based taxonomy and DNA sequences) offer little to hasten progress, and have even detracted from real priorities.

> At the end of the day the real reason taxonomists have not yet completed the inventory of biological diversity is that any taxonomic specialists worth their salt know that there are no quick answers to the inventory shortfall, and to claim otherwise…is pie in the sky. (Scotland et al. 2003).

International initiatives in all-taxa biodiversity inventory

The potential of information technology and molecular techniques to accelerate the task of a full inventory of the taxon biodiversity of the Earth has led to optimistic predictions that it could be completed in 25 years (Wilson 2003). The impediments, it is argued, now are largely financial, not technological (Ronquist & Gärdenfors 2003).

There are initiatives under way in several nations to obtain complete all-taxa biodiversity inventories. For example, the Instituto Nacional de Biodiversidad in Costa Rica is undertaking a national biodiversity inventory, in part through training parataxonomists to assist specialists. Perhaps the most ambitious and advanced national all-taxa inventory is The Swedish Taxonomy Initiative. This programme (coordinated by Artdatabanken and jointly run by the Swedish University of Agricultural Sciences and the Swedish Environmental Protection Agency) was launched in 2002 with funding of €130 million and seeks to complete an inventory of Sweden's fauna and flora of multicellular organisms within 20 years, documenting and expanding the current list of 50 000 species. If successful, this will be the first complete national biodiversity census. Comprehensive, all-taxa inventories are under way at regional levels such as that of the Central Balkans National Park in Bulgaria, and the All-taxa Biodiversity Inventory, Great Smoky Mountains, United States National Park Service.

Do conservation agencies need to fund all-taxa biodiversity and genetic inventories?

There seems little question that all-taxa biodiversity inventories (ATBI) will eventually be a mandated national goal. There will also be calls for comprehensive 'tree of life' phylogeny programmes spurred on by availability of cost-effective molecular technology, and proposed as a matter of national urgency. The question facing conservation agencies is to what degree are they responsible for achieving such a goal, and how much time and funding should they invest in species inventory versus other priorities. In making this decision they have to balance the cost of obtaining new knowledge against the use to which it will be put. The smaller plants and animals are, the less likely they are to be named, and the time taken to identify specimens scales inversely with body size (Lawton et al. 1998). Taxonomic and ecological knowledge of smaller taxa is sparse, and conservation intervention therefore uncommon.

As there are probably more than 80 000 species within the country, and a few thousand exotics (DOC & MfE 2000) the task of developing a sufficiently detailed inventory so that conservation-useful information is obtained is unrealisable in the medium term.

It is worth reflecting that, even if we had perfect knowledge about the identity of each species, its ecological responses and interactions, we would still have intractable problems. To give an example: a detailed fungal study of 75 logs in a South Island mountain beech forest revealed 151 saprobic taxa in autumn, 80 in spring, with only 33 taxa widespread, and their occurrence only weakly related to the properties of the logs (Allen et al. 2000). Thus irregular fruiting (the most easily identified fungal part), seasonal flushes, and high beta-diversity would make comprehensive fungal surveys expensive and hard to interpret.

Ecological theory is weak as to how to put biosystematic information into conservation practice. Often, the question for a conservation organisation is if this ecological and taxonomic knowledge were available, would it markedly change current priorities? As funding for remedial action will remain strictly limited relative to areas where it could be usefully applied, the critical question is not how much do we know, but do we know sufficient to be sure that we are making the correct choices? And if so, would better identification technology and ecological understanding make intervention less costly and more effective?

Given that ATBI will largely concern small organisms, we have to conclude that it would have a relatively small effect on conservation practice. Successful conservation management has usually centred on the prevention of direct human activities that threaten species, or extirpation or reduction of threatening exotic biota, and intensive manipulation of populations when they are at a critical size. Taxon-specific intervention is usually undertaken for large organisms that can be easily identified, counted, measured and manipulated.

Internationally, biodiversity inventories are associated with universities, museums, or specialist taxonomic centres, and are only performed by conservation agencies alone at local levels. For instance, the ambitious ATBI of the Great Smoky National Park, United States, is a cooperative agreement between the park and the non-profit Discover Life organisation, which is partnered by universities, museum-based taxonomists, non-governmental organisations, and state and federal agencies. The Swedish ATBI is largely funded by central government and the EU.

Our conclusion is that, although there are advantages in having an ATBI, they are not sufficiently great for conservation agencies to reallocate effort away from other priorities. Conservation agencies should concentrate on gathering taxonomic and ecological information on those taxa under threat that offer some realistic hope of successful intervention. For the rest, they should cooperate with and encourage in everyway possible ATBIs at any scale from national to local, but resist primary responsibility.

Genetic-level inventory

With the international reporting mandate extending to 'genomes and genes of social, scientific or economic importance' the question arises as to what extent should a biodiversity inventory be also a genetic inventory? It is easy enough to make the statement that all genetically distinctive populations should be a focus of conservation effort, but this begs the question of whether their distinctiveness is relevant to the persistence and performance of that species. As with total-species inventory, we have to ask: what policy or management actions could be taken on the basis of comprehensive genetic information?

Genetic inventory has been carried out for some time in forests, with the goal of improving the stock, and more recently to understand the factors behind and consequences of declining populations of rare plants and animals. Advances late last century resulted in DNA sequencing, MHC (major histocompatibility complex), minisatellite, microsatellite, and RAPD (random amplified polymorphic DNA) procedures, that in total provide sophisticated analyses of metapopulation structure, hybridisation, and delineation of species, subspecies and races (Haig 1998). There are clear advantages for conservation through use of these techniques in identifying taxa, setting priorities and managing species recovery.

Genetic surveys of taxa are now often undertaken to measure population diversity within species. In part this is in response to a generally accepted policy that when restoration work is undertaken, organisms as close as possible to those originally in the neighbourhood are utilised. However, for conservation per se, we are not, primarily interested in how diverse the genetic make-up of the species or population is, but in how much quantitative genetic variation is present that is linked to ecologically important traits. It is this quantitative genetic architecture that determines how the species will respond to environmental changes and stresses. Molecular indicators are widely used on the assumption that they correlate with, and thus act as surrogates for, quantitative genetic variation. A recent meta-analysis has cast doubt on this assumption. Molecular and quantitative measures of genetic variation have only a weak correlation, and no significant relationship exists between measures for life-history traits or adaptive potential (Reed & Frankham 2001). To give an example: a detailed study of a vulnerable South American tree endemic has shown that neutral DNA markers failed to detect significant quantitative gene trait divergence related to drought tolerance (Bekessy et al. 2003).

The measurement of neutral genetic variation is relatively inexpensive and requires little knowledge of the target taxon. It is likely to become standard practice because of its low cost, and has many practical applications. However, knowledge of environmentally significant genetic variation is crucial for managing species, but this needs careful experimental and field studies. The conclusion of recent work is that decisions involving conservation genetics should not be taken solely on the basis of neutral genetic variation. Instead, a combination of other measures of environmentally related quantitative genetic variation or even measures of morphological variation should be used (Haig 1998; Bekessy et al. 2003). Whether or not this is worth doing for conservation management has to be assessed on a case-by-case basis for each taxon.

New approaches to inventory and monitoring

Increasingly it is argued that all conservation areas need as full as possible a documentation of total species richness. However, this is a clearly impractical goal for many elements of the biota. A number of other approaches are being tried which will permit some idea of the value of a given area for rapid biodiversity assessment (RBA) (Ward & Lariviere 2004)

1. *Higher taxonomic levels*. In this approach, order, family, or genus is used as a substitute measure for overall species richness. However, it remains to be proven if it is widely applicable (New 1996). Also, the higher the taxonomic level, the more likely there are to be a wide variety of ecological adaptations, trophic levels, and functional types – limiting the generality of the conclusions. And finally, the distinction between common and rare species and between exotic and native is lost, and information is therefore missing (Ward & Lariviere 2004) that will be important in determining the relative distinctiveness of a site.

2. *Taxonomic surrogacy*. Use of morphospecies or recognisable taxonomic units (RTU) has been advocated. There are two approaches: (a) RTUs can be used directly as an indicator of species richness or (b) they can be used to permit non-specialist labour to reduce the amount of specialist effort to obtain lowest possible taxonomic identifications. The problem with the first approach is that the RTUs tend not to be consistent across individual surveys, and the effort needed to make them consistent would, in effect, be close to the investment needed to formally name them. However, electronic methods of sorting using databases of images, specimen-based databases, and standard operating procedures have the potential to raise the resolution and lower the cost of the second approach.

3. *Taxon focusing.* This is the use of a range of approaches to identify a species or group of species that act as a surrogate for a wider range. Ward & Lariviere (unpubl.) suggest that the best way forward is taxon focusing, an approach chosen on the basis that it is more practical to study in detail a limited number of carefully chosen taxonomic groups than to deal with a much larger group superficially. For example, tiger beetles have been used in a major global biodiversity survey. This group showed considerable constancy in spatial patterns and taxonomic stability and it was considered that it could be reliably used, especially by non-scientific decision makers in conservation policy and management (Cassola & Pearson 2000). However, the procedure is hotly debated. There is little empirical evidence that use of ‘umbrella’ or ‘indicator’ taxa is much better for making conservation decisions than the use of taxa taken at random (Andelman & Fagan 2000).

4. *Molecular taxonomy* has made it possible to approach a complete biodiversity survey based on operational taxonomic units (OTU) (Blaxter & Floyd 2003). Specimens are assigned to a molecular OTU (MOTU) based on a DNA fragment usually sequenced by polymerase chain reaction. MOTU do not necessarily match taxonomic groupings established by other more conventional methods, but there is a great deal of congruence. Libraries of DNA sequences enable links to be made with conventionally defined taxa, and biological properties and other attributes assigned. This technique has been used for many years in bacterial and viral typing. Increasingly it has been extended to eucaryotic taxa and has been used to measure soil nematode diversity (Floyd et al. 2002). The advantages are considerable: reliable data can be derived from a single specimen, morphologically indistinguishable taxa can be separated, all stages and morphs can be linked, and a single technique used for all specimens (Blaxter & Floyd 2003).

5.2 Monitoring: principles, types and issues

Biodiversity monitoring and inventory can be seen as a multi-dimensional continuum, in which the scale can range from centimetres to the whole nation, the time interval of remeasurement from decades to milliseconds, the range of organisms dealt with vary from one to many, and the specificity of the measures from broad to highly specific.

In order to discuss monitoring, we have to make a distinction between type and purpose. Purpose is the reason for carrying out the monitoring, while type refers to how it is organised and carried out to meet specified aims. Purpose reflects an overlapping series of aims from collection of basic data, through observation of phenomena of interest, to focused monitoring to guide management, to research to understand systems.

Purpose of monitoring

The purpose of indicators and monitoring is succinctly summed up by the United States National Academy of Sciences (2000, p. 1):

> Developing indicators and monitoring them over time can help to determine whether problems are developing, whether any action is desirable or necessary, what action might yield the best results, and how successful past actions have been. To develop and implement sound environmental policies, data are needed that capture the essence of the dynamics of environmental systems and changes in their functioning.

There are therefore three separate monitoring purposes:

1. *Monitoring for changes in ecological status and integrity.* Here the question is: Are things changing and to what extent? It provides the bulk of the figures and indices for state of the environment reporting, and policy development, and some of the material for organisational audit. The main risks are spending too much effort in collecting data that have little intrinsic value, are not used for policy, but look credible in reports.

2. *Monitoring for management action.* This sort of monitoring answers questions such as: When should we intervene? What might we need to do? Have we been successful? How can we do better? When aggregated and assessed, the data provide basic information for audit purposes. The main shortcoming of this sort of monitoring is failing to adequately analyse and report the results, and therefore not actually using them in decision making.

3. *Monitoring for fundamental understanding.* This type of monitoring attempts to answer the questions: Do we understand what is going on? How can we predict the future? Can we apply this knowledge to biodiversity management? It is thus focused on multiple or generalised objectives and often the collection of long time-series (relative to the time-constant of the organism or phenomenon) data. Sustaining this type of monitoring is the main problem. Funding is often under pressure, it often depends solely on the enthusiasm of a few individuals and, especially when continued on without any visible output, can be viewed as competing with apparently more relevant projects.

Types of monitoring

We recognise clusters of monitoring activities sometimes centred on a particular purpose but often spanning more than one, and propose the following types as a framework.

1. *Inventory monitoring* is monitoring in which the activity does not imply any particular remeasurement timing. Typical examples are productions of floras and faunas, or geological mapping. Usually the goals are comprehensive documentation of the elements and complete spatial cover. In formal inventory, timeliness tends to be a secondary issue: typically projects will be delayed if the alternative is compromising accuracy or comprehensiveness. **Rapid assessments** and **casual surveys** can be regarded as a low-grade form of inventory where accuracy and comprehensiveness is traded off in favour of cost and timeliness. A major issue is whether or not in the long term such surveys are false economy.

2. *Status and trend monitoring* is where regular remeasurements are intended. The target may be an organism, a group of organisms with characteristics in common, or a more holistic attempt to capture a range of ecological elements. It is not necessarily plot based (most vertebrate surveys are not) but often is. The Forest Service permanent plots that have formed the core of National Vegetation Survey are the classic New Zealand example, but the long-running seal-rookery and sea-bird monitoring sites are others. It is rare for animal, vegetation, soils and climate to be measured simultaneously and comprehensively (although several examples exist in New Zealand), and we classify this more comprehensive activity as long-term research monitoring.

3. *Surveillance monitoring* is undertaken where the problem is well understood and the threat immediate. Monitoring is focused on a few organisms or processes, and the scale is appropriate to the scale of the threat. Examples are routine biosecurity surveillance for new pests or organisms, for escapes or expansions of pre-existing organisms such as from deer farms, or changing disease or pest pressure. Surveillance monitoring differs from status and trend monitoring in that it tends to be stratified on the basis of at-risk environment categories, relies on specialised techniques or surveys to detect presence, and is not as often plot or location based. Note surveillance monitoring depends heavily on structured protocols; informal surveys with weak protocols are more a feature of some kinds of management monitoring. Our concept of 'surveillance' here is broader than that of Froude (2003), in which it is defined as having only the purpose of detecting new-species arrivals.

4. *Management monitoring* can be subdivided into the following categories:

a. *Pre-intervention (Trigger and Assessment*): detecting and assessing the problem or pressure. **Trigger** monitoring is focused on establishing if intervention is necessary and **Assessment** monitoring is undertaken when it is important to quantify the success of the intervention. Pre-intervention monitoring has to be frequent enough (relative to the issue) to not miss crucial turning points and cost-effective enough to be sustained. It has to be rapidly followed by management action or policy change, if indicated, because the usefulness of the information rapidly decays.

b. *Post-intervention (Action and Outcome)*: **Action** assesses the success of the management action in reducing the pressure or altering the immediate situation. (Arand & Stephens (1998) refer to this as 'Results' monitoring but, as this is a synonym for 'Outcomes', we have replaced it with Action). **Outcome** monitoring assesses the success of the action in improving the outcome for the indigenous biodiversity asset of interest. Timing is again important to post-intervention outcome monitoring: if too soon, the value of the intervention will be underestimated; left too long, it simply enters the next cycle and becomes pre-intervention assessment and valuable information on the actual effects of the intervention is lost.

While this scheme might seem overly complex, it has the advantage of focusing attention on why the monitoring is being carried out, and therefore how it might best be structured.

Management monitoring is complex and difficult because it typically operates under funding, time, and expertise constraints and often in a public and politicised environment. Management monitoring is frequently sidelined by the apparent urgency of the problem. The timing of intervention is often more determined by political issues or availability of funding than by monitoring results, and there may be pronounced lack of interest in monitoring after the intervention. Typically, there is usually only a qualitative trigger for intervention, not a formal monitoring scheme; post-management assessment is often focused on the controlled organism or process, not on the outcome; and there are no proper controls. The key questions posed by manager and field staff alike are: How little can we measure on how few sites, and still get sufficient information to guide action, and establish effectiveness and outcome? It should be noted that much of the disenchantment with monitoring comes from the inability of rapid, informal techniques to provide unambiguous answers to such questions as: Did the action make a difference?

5. *Research monitoring* reflects the fact that all long-term ecological research involves monitoring. Research clearly draws on information derived from the other types of monitoring discussed here, but ecological research typically needs careful investigations at sites chosen for their potential to provide unambiguous answers. The questions asked may be wide and open-ended, or highly specific and focused. The scale may be broad, but typically there are relatively few sites involved. At some sites intensive, multi-dimensional, long-term research is proceeding. New Zealand examples are the Orongorongo and Craigieburn research sites, but a number of areas have had such concentrated ecological interest for so long that they could fall into this category (i.e. Murchison Mountains, Eglinton Valley). Internationally, such sites are valued as **Long-Term Ecological Research (LTER)** areas and allocated sustaining funding. Twenty-five countries now have formal LTER networks. Mainland islands in New Zealand are forming a new core around which LTER-like activities may develop. However, Mainland Islands are not representative of the New Zealand landscapes as a whole, and at the very least would have to be supplemented by more typical sites. Historically in New Zealand commitment to LTERs tends to fluctuate, and usually it is only the dedication of a few inspired individuals that keeps them going. That situation will have to change if long-term ecological research is to play an important role in the future.

Long-term value of monitoring data

It is often assumed that monitoring and inventory data increase in value with time, and loss of any data is to be regretted. However, this is not true for many types of monitoring, and the costs of archiving have to be considered against the changing value of information with time. From a management point of view, information value falls exponentially with time since last measurement (relative to the time constant of the organism or process). On the other hand, certain types of inventory data have a stable, high value for many different purposes. From a research point of view, information value of a time series rises steeply with remeasurement frequency and availability of ancillary data, but is insensitive to time since last remeasurement. Furthermore, long records of single organisms are of limited research use unless measurements of other variables are available.

The essential principle to be considered here is the time constant and stability of the organism, element or process. If the time constant is short, or the population fluctuates rapidly, it has to be measured frequently or the value of the data is slight. A fundamental split, therefore, has to be made not only between abiotic and biotic elements but also between different classes of biotic elements, which we will call **labile** and **stable** components.

Labile elements have short time-constants, are more variable in abundance, and are often more cryptic or fugitive and thus have to be measured indirectly or by indices. Examples are many insects, rodents and rapidly reproducing birds. Stable elements have long time-constants, are easily observed, can be tracked as individuals or quantitatively measured populations. Examples are trees, colonial marine animals, long-lived birds, and large indigenous invertebrates. The more labile an organism, the more difficult and costly it is to get a useful long-term record. Furthermore, there is less value in the long-term record unless there are excellent records of all the major biological and non-biological influences in a compatible format.

A comparison of two organisms, trees and mice, demonstrates the difference. With regard to trees, long-term monitoring records can be secured relatively easily and have lasting value: the individuals are immobile, and can be revisited; non-cryptic, so possible to have a complete census; time constants range between 150 and 1000 years, so measurement can be infrequent; other important environmental factors include soil and climatic variables that are routinely monitored or can be interpolated. For organisms such as mice, the situation for long-term monitoring is much more fraught. The individuals are mobile, cryptic, and become observer-shy, meaning census and re-location is near impossible; time constants are in the order of a few months, so remeasurement has to be frequent; other important factors (food availability, predator abundance, and local site weather) are almost as difficult to monitor as the mice themselves. Therefore, knowing mice were abundant in 1956 in a certain catchment is, by itself, not a very useful piece of information, whereas the same information for a tree species retains high value.

5.3 Indicators

Characteristics and selection of indicators: what to measure?

'Indicator' has become the generic term for a reporting measure derived from inventory or monitoring. However, it is a complex and somewhat slippery concept. Indicators are most often thought of as quantitative measures that 'indicate' something that either cannot be directly measured or would be too expensive to completely measure. A good example is 'net primary production': this is a true indicator as the conservation interest is not in the amount of primary production in the forest, but in what this can reveal about the growth status of the forest, itself the net product of a myriad of processes that could each be individually measured had we funds and time. However, many 'indicators' in fact consist of the element under consideration and are complete in their own way. For instance, maintaining the number of bird species in a region is a legitimate conservation goal in its own right, and number of bird species does not indicate this goal, it measures it directly. In the same way 'km sq. of indigenous forest cover' does not indicate the amount of forest cover: it is a measure of the amount of forest cover. However, it is true at the highest level all measures become indicators, as ecological integrity is an abstract conservation goal that cannot be measured directly. To take the examples above, the number of indigenous bird species in a region and the amount of forest cover are important features of ecological integrity, and thus are indicators for this purpose.

Indicators describe and summarise; they can be used for diagnosis and warning; and they can be used to monitor change. They have three key features (United States National Academy of Sciences 2000):

- They quantify information so that its significance is more apparent
- They simplify information about complex phenomena
- They are a cost-effective alternative to monitoring many individual processes, species etc.

Indicators are most useful if they are concrete and quantified. They should be management or policy relevant. They are most policy relevant if they can be interpreted in terms of environmental trends or progress towards policy goals. To suit national or regional purposes they must be aggregated into more complex entities, but still retain clear, concrete links with the phenomena being characterised.

The key questions for selecting indicators for monitoring are: What are the conservation issues? and What are the priorities within these? International agreements (CBD) and national requirements suggest three types of indicators to cover the range of issues:

- *Biodiversity status*: those that seek to determine biotic change of important environmental components at scales from species to whole landscapes, in particular those with policy relevance
- *Conservation effort*: those that deal with the steps taken to improve biodiversity, the resources allocated, and how efficient the measures are
- *Socio-economic impact*: those that document impact on society and societal response.

There is an almost limitless menu of taxa, processes and states that could be used to produce indicators. The choice of what to monitor is crucial, for two reasons. First, because conservation funding is always limited, the quality of the choices is highly important. And second, because by the very act of monitoring attention is focused on particular aspects of biodiversity and not on others. The rule is: what is measured is managed.

The cost and complexity of indicators, and the dangers of misdirecting conservation effort if they are badly chosen, mean that hard questions have to be asked of each one (Lund 1990; United States National Academy of Sciences 2000). These fundamental questions are listed in the assessment framework presented below.

Framework for selecting monitoring indicators

The question of what makes a good indicator is often addressed in the literature (e.g. United States National Academy of Sciences 2000; European Environment Agency 2002) and the MfE has developed its own framework (Froude 2003). On the basis of these, we have compiled this checklist to guide indicator selection.

- **General importance –** Does it relate to key processes threatening biodiversity? Does it measure or respond to important ecosystem or environment factors? Will it be useful in relating cause, effects and response?
- **Interpretability –** Is it mainly influenced by one or just a few well-understood factors? Will non-specialists intuitively understand the significance of the measure?
- **Policy relevance and suitability –** Does it relate to key policy goals in a measurable way? Is the factor measured of such basic practical conservation importance that it

would not have dysfunctional or distorting consequences if pursued as a policy objective?

- **International compatibility –** Is the indicator similar to or compatible with those used internationally? Indicators compatible with those developed elsewhere will assist intercomparability, reduce development costs and availability of technology, and facilitate standardised international reporting. The New Zealand conservation community is small and for most indicators will have to rely on conceptual and technological advances made elsewhere.
- **Conceptual basis –** Are the scientific principles underlying it well established? Is it based on a well-understood and generally accepted conceptual model?
- **Statistical properties –** Can it be measured in ways that are accurate, sensitive, precise and robust? Will it distinguish normal variation from variation outside the natural range? Is it likely to result in Type I errors (indicating change where none has occurred) or Type II (not indicating change, when it has occurred)? Will it be consistent over time? Can it be easily amalgamated to deal with various scales?
- **Robustness and reliability –** Is the scientific basis sufficiently well understood to ensure reliability? Are the techniques standard, well understood, widely applied and technologically undemanding? Are highly specialised instrumentation and skills needed? Are technological changes likely to render it obsolete or of little value in the near future?
- **Compatibility –** Is it compatible with past methologies and can it use archived data? Can it be used alongside other indicators to give better insights, indices etc?
- **Flexibility –** Could different agencies or contractors collect this indicator at different times or places without degrading its quality? Are specially trained teams, analytical facilities, or dedicated infrastructure required? Could timing of measurement vary to suit field schedules or budgets?
- **Cost-effectiveness –** Does the cost of collection and analysis match the importance of the measure? Are there cheaper or more effective measures that could address the same issue?

There are several other features about selection and use of indicators that affect the total suite that need to be considered in designing a monitoring system.

1. *Variability.* The cumulative effect of diverse local impacts on biodiversity may only be apparent at the regional level, or they might simply sink into regional background variability through aggregation (Schneider 1997). Temporal variation is important, because it is departures from some background norm, beyond the range of natural variability, that will be the key for action. Variability needs to be well characterised in relation to that expected in natural variability (Christensen et al. 1996).

2. *Timeliness.* What are the chances of having the right data at the appropriate moment to guide action? There is not a great deal of use in a monitoring system whose data can only be interpreted after many years of data accumulation. It is almost certainly better to gather data about fewer aspects but more intensively so the implications are clear, rather than few data about a great number of things, and fail to interpret them early enough to be of value for policy and action.

3. *Integration.* The more inclusive the list of taxa and habitats, the wider the methodologies and the more intricate the problems of integrating different data sets and obtaining economies of scale. To give an example: mensuration of trees needs good light and

verbal communication between team members; assessing vertebrate wildlife is often best done at dawn in silence. Woody vegetation can be assessed at any time (within reason); other plants and animals may be seasonal. There are standardised and comparable methods for assessing most plants; invertebrates need a large range of specialist techniques (i.e. canopy fogging, Malaise trapping, pitfall, funnel extraction etc.). Before adding a new indicator, this fundamental aspect should be considered**.**

4. *Type I and Type II errors; sensitivity of a monitoring system and marginal costs and benefits*. An indicator will suggest a change or impact is occurring or that it is not. If the indicator suggests a change has happened, when in fact it did not, this is called a Type I error. If the indicator suggests a change has not happened, when in fact it did, this is called a Type II error.

Actual state	**Indicator conclusion**	
	Change	*No change*
Change	Correct	**Type II** error
No change	**Type I** error	Correct

The conservation community has inherited a focus on Type I errors from prevalent scientific practice centred on not claiming significance from results that are in actual fact ambiguous or uninformative (Mapstone 1995). Therefore while Type I errors have a specified acceptable error rate (conventionally 0.05), it is rare for Type II error rates to be calculated. For practical conservation, however, Type I errors are less important than Type II ones. If a Type I error is made (e.g. a bird species indicated to be in decline when it isn't), unnecessary remedial activity might be undertaken with all the attendant expense and diversion from other worthy projects. However, if a Type II error is made (conclusion that the bird is not declining when it is) the outcome potentially is extinction.

Pacala et al. (2003) argue that this true-or-false classification is too simplistic, and suggested we should think of the situation as the relationship between the sensitivity of our environmental alarm system (monitoring in the current case) versus the costs and benefits. Benefits of increasing sensitivity rise steeply at first, and then flatten as pay-offs decrease and false alarms become more prevalent; however, the costs rise steeply, as obtaining more and more information about an increasing range of phenomena has an exponential relationship to effort. However, Pacala et al. (2003) argue that because the marginal benefits are so high, our environmental alarm systems are still too conservative.

5. *Statistical power*. Statistical power is a measure of the confidence with which we would have detected an effect if one existed (Burgman & Lindenmayer 1998). It is defined as one minus the Type II error rate. Power is proportional to the effect size (size of the change the indicator needs to detect) multipled by the Type I error rate, the square root of the sample size and the inverse standard deviation of the variability of the data. Its ability to distinguish accurately depends on the statistical power, which is a measure of the confidence with which one can conclude an effect would have occurred if in fact it had. Power analyses are crucial to the design of indicators and their correct interpretation. Low power may mean insensitivity and inconclusive results; high power may mean an overly sensitive assessment of change or very high monitoring costs (Fairweather 1991). Preliminary power analysis should be used to determine the sample size needed to detect change. Power analysis is not always straightforward and may need specially derived equations for many situations. Power analysis

is now regularly included in development of monitoring schemes (Macdonald et al. 1998; Toms et al. 1999).

5.4 Biodiversity monitoring and indicators: controversial issues

Below we discuss the more controversial aspects of biodiversity indicators in practice: species diversity indices; surrogates; rare and endangered species lists; invasive species; and genetic monitoring.

Species diversity indices

Species richness is an unweighted index of the number of species present in any unit of land. An indicator of total species diversity can be constructed by assigning a score to each type of land use, and computing the average score for a nation as a whole; that is, by multiplying each score by the number of square kilometres in its land-use category, summing the scores, and dividing the total by the number of square kilometres in the nation (United States National Academy of Sciences 2000). The index needs to be normalised by the species–area–power law relationship. All such equations have problems in practice because rare, non-sustainable species count as much as common non-threatened species. Abundance should therefore be taken into account, but too little is known about how to do this in practice (United States National Academy of Sciences 2000). A further problem is that a baseline species status must be fixed for each ecosystem, otherwise, if the baseline is adjusted through extinction, species diversity as calculated by the index will rise. The United States National Academy of Sciences (2000) therefore suggest that this scoring system be used only for a small number of easy-to-survey taxa of high aesthetic and recreational value.

Other indicators have been developed, for example the Index of Biotic Integrity (Karr et al. 1986), for use in aquatic systems. The IBI is based on qualitative ranking judgments of evaluators and additive scores based on the distributions and abundance of various indicators. However, such multifactorial indicators run into problems through the qualitative judgments involved and calibrating of multifactor indices (Reynoldson et al. 1997). They appear therefore to have a local value, but are of little use at larger or national scales (United States National Academy of Sciences 2000).

Species diversity indices will have value at local and regional scales for comparing and monitoring carefully defined areas, ecosystem types, and species as part of a baseline exercise. They should not be used for reporting at a national level because of inherent difficulties in their use at wide scales and lack of policy relevance.

Aggregated indices of biodiversity status

There is an international trend for nations to report environmental indicators alongside the more traditional indicators of social and economic health (World Bank 2004). Examples of well-developed (but not fully implemented) schemes are those of the *Environment and Sustainable Development Indicators for Canada* (National Roundtable on the Environment and the Economy (NRTEE) 2003) and New Zealand environmental performance indicators (MfE 1997). The biodiversity component of these schemes is referred to in different ways, but captures the idea of a stock of natural environmental capital that should not be degraded or depleted. At their most abstract and aggregated, a single index of environmental capital would be produced, akin to gross national product.

The issue of how far to aggregate individual indicators is a universal problem. Virtually every national document has discussion in some form about how to resolve the issue. Take, for instance, the discussion in the Executive Summary of *Environment and Sustainable Development Indicators for Canada* (NRTEE 2003, p. xix):

> Several important areas of disagreement did arise, however. One of the most contentious issues was whether and how to aggregate information about Canada's overall capital…The benefits of a single, aggregated indicator of national sustainability were weighed against the difficulty of monetizing all types of capital…Accordingly, the ESDI model includes discrete indicators of some aspects of human and natural capital…Because broad indicators such as overall forest cover failed to reveal important qualitative data, some felt strongly that more detailed indicators were required. Also, some program participants recommended including information about the "pressures" faced by the various stocks of natural capital.

Environment Canada (2003) in its national indicators has taken the approach of a single index as far as we have seen it done. For each indicator, for instance 'Biodiversity and protected areas', a number of components are measured – in this case *Percentage of total and strictly protected area in Canada* and *Change in status of reassessed species at risk*. A trend for the two components is presented for the last decade (70% increase in totally protected areas since 1992; a worsening in status of 33% of 402 assessed wildlife species, and an amelioration for 16% in the period 1985–2002). An indicator meter is calculated for the key component ranging from −100 to +100. As mentioned previously, the meter for this indicator was set at 70% improvement on the basis of the land status improvement. It is worth quoting in full the meter description:

> A meter is included for each environmental issue. Each meter reflects a trend over time for the indicator that best summarizes the environmental issue. It shows whether the indicator is deteriorating, remaining stable, or improving, and to what degree. Each graph depicting the data on which the meter is based appears first in its section and is accompanied by an explanation of how the trend was measured. In most cases, the meter calculations are based on a change over the past decade. The meters cannot be compared to each other. Each meter value should be seen only as a highlight of the rate of progress that is occurring in the issue. They do not allow comparisons of the relative importance of issues, and they do not show change with respect to specific, science-based thresholds. Furthermore, the meters provide a national roll-up and therefore do not represent regional variation. (Environment Canada 2003, frontispiece)

The obvious question, after a description like this that amounts to a product disclaimer, is how does a meter differ at all from the selected measure? It is also of interest that the meter description echoes the fungibility-of-measures problem reflected in the discussion in the Canadian EDSI programme. The fundamental question therefore is: Can aggregated indices ever be used for examining or reporting on biodiversity issues? And if so, what sort and to what level?

For a composite biodiversity index to be of practical use it should satisfy the following conditions:

- It should have a clearly stated and justified goal
- It should only include fungible measures with relation to the goal
- It should have a baseline and/or zero value from which deviations can be measured
- The value judgments involved should be external to the measures composing the index.

To give an example, the goal of having a more natural understorey in our native forests may need an index to compare progress in different areas of the country and nationally. Benchmark sites could be established and models used to predict what a natural understorey might be. Quantitative models could be developed then to assess monitored sites for deviation with regard to a site-specific baseline. Site indices – although obviously noisy because of natural disturbance, model uncertainty and the degree to which understorey species are fungible – could be used in various ways to compare years, sites, districts and national progress. The MCA system (Stephens et al. 2002) appears well suited to providing the technology for just this sort of activity. Moreover, the concept of understorey health or integrity is one that can be readily explained and illustrated.

However, even this simple example demonstrates potential problems with the idea. For instance, how could exotic species be included, unless as simple measures of how much space they deny to native species? But this might not capture the value we place on exotic-free forest, and it would perhaps seem wiser to have another parallel index. Consider then the next step, in which presence and abundance of birds is combined with understorey naturalness in a composite index. The goal is clear enough: a forest with plentiful native birds and a natural understorey. The problem is that the two measures cannot be reasonably traded off against each other, or combined in a meaningful fashion. An arbitrary weighting would have to be applied. Even if this weighting were described in the preamble to the index, the user of the index would have no idea if a certain intermediate value meant few birds – healthy forest; or many birds – unhealthy forest.

We therefore advocate the use of such indices only when more-or-less fungible biodiversity measures are included. In our opinion they are best used, therefore, on the same trophic level and to report on clearly defined issues. An ideal use, for instance, would be comparing the impact and value of animal control for a stated goal across wide areas. Even reporting at the highest level should mainly rely on concrete, discrete indictors.

Indicator or surrogate or proxy taxa

In actual international practice, outside of vertebrates and vascular plants, a much reduced list of organisms is monitored and inventoried, e.g. fungi with obvious fruiting bodies; diurnal, bright, attractive insects such as butterflies and dragonflies. However, it is not at all clear how these taxa relate to the broader conservation picture. Therefore, there is a large and growing literature on the use of species as indicators of total biodiversity. Key categories of such species (using the terminology of Noss (1990) and Andelman & Fagan (2000)) are:

- Widespread taxa that require such an area of habitat that their presence ensures that of others (*umbrellas*)
- Taxa that reliably stand in for many others (*ecological indicators*, *proxies* or *surrogates*)
- Taxa whose presence indicates the presence of high species richness (*biodiversity indicators*)
- Taxa ecologically essential to the functioning of an ecosystem (*keystones*)

- Culturally important taxa (*flagships*, *charismatics*)
- Taxa sensitive to anthropogenic change (*vulnerables*, *canaries*).

Andelman & Fagan (2000) claim that three classes of surrogate schemes are widely used: (1) flagships, (2) umbrellas, and (3) biodiversity indicators. Their conclusion is that the utility of surrogates for representing regional biodiversity is limited, as none of the surrogate schemes they investigated performed better than a comparable number of species selected at random from a database. They make the point:

> ...scientists and resource managers appear most interested in using conservation surrogates precisely because the systems they are trying to manage and protect are insufficiently known…We urge caution in adopting umbrellas or flagships as conservation surrogates until their usefulness as predictors of biological diversity has been more fully investigated. We believe the answers will rarely be obvious or consistent among systems. (Andelman & Fagan 2000, p.5959)

Clearly there is a need for more complete local inventory and conservation-focused research on smaller scales to clarify the linkages between indicator species and groups and the wider biodiversity situation.

Rare and endangered biota lists

There are now many national listings of rare and endangered biota according to category of risk and these are universally used as indicators, usually as status or trends statistics for:

- The total number of threatened/extinct species
- Number of threatened/extinct species per taxon
- The proportion of threatened/extinct species per taxon
- Changes in the number of threatened species per taxon.

Governments and non-governmental organisations produce these lists for three main reasons: (1) to assess potentially adverse impacts on species, (2) to help inform conservation priorities, and (3) as a component of state of the environment reports.

Possingham et al. (2002) argue that threatened species lists are used for purposes beyond their original intent, and that they tend to perform rather poorly. They show that lists differ in the ways they are constructed, how they incorporate management variables, taxonomic status, and how they assess recoverability and past and future trends in abundance. Correspondence between different lists tends to be low. In particular, they argue that threatened species lists fail to be useful in demonstrating changes in the status of biodiversity for the following reasons:

- Better taxonomic knowledge of some groups leads to increased representation of them as threatened taxa (e.g. birds)
- Uneven taxonomic or hierarchical treatment (some groups taxonomically more finely divided with regard to their phylogenetic distinctiveness)
- All lists, official or unofficial, substantially under-represent cryptic and small taxa, particularly invertebrates and fungi
- Significant bias towards large species and those closer to humans in evolutionary terms
- Variation in survey effort between groups and areas

- Changes in the lists more often reflect change in criteria used to specify status or new knowledge of status, rather than actual change in species abundance.

Burgman (2002), in respect to threatened plant lists, makes similar points to Possingham et al. (2002), but includes the following extra factors: (1) threatened species lists tend to concentrate emphasis on species that are the most attractive or visible, or naturally rare, more than those most likely to go extinct; (2) resources tend to be concentrated on these species, rather than on more wide-ranging problems concerning habitats and ecosystems which may yield a greater return in terms of extinctions prevented; and (3) rare and endangered species lists tend to focus on long-standing problems, hence extinction processes that may be unrelated to current threats. Burgman (2002) suggests that:

> …systems for listing threatened species create a feed-back loop, responsive to the subjective preferences of scientists, largely unresponsive to underlying true threats, self-perpetuating and accentuating bias with each iteration.

Both sets of authors argue that a wider view has to be taken of the problem of extinctions, and better tools developed for measuring changes in species abundance and threats. In particular, Possingham et al. (2002) suggest:

> In compiling reports on the state of the environment, record changes in knowledge and trends in populations and range separately from changes in status, and only use comprehensive and systematic assessments.

The literature has emphasised the importance of 'red lists' of threatened taxa, partly because of the stress in recent decades on species loss as the pre-eminent measure of biodiversity change (Wilson 1999). However, the suggestion has been made that the concept be extended to a 'blue list' subcategory consisting of threatened species with stabilised or increasing abundance (Gigon et al. 2000). The advantages in doing this are that it focuses effort onto the immediately endangered, gives an additional category for reporting conservation achievement (without taking the more formal and possibly dangerous step of delisting), and provides an opportunity for more uplifting reportage than the usual depressing red list news.

A recent review (Balmford et al. 2003) suggests that the focus be on analyses of trends in population sizes, numbers of populations, and habitat extent rather than on extinctions. Practical conservation goals will probably be best served at a large scale by pre-selecting a list of 'vulnerable' species about which sufficient is known to make their changes in status interpretable and policy relevant, and about which data can be collected with minimum effort. Going beyond this practice would need better justification than has been offered to date.

Invasive species monitoring

An increasing proportion of the global landscape consists of intricate mixtures of native and exotic species. Important questions are going to be asked about which to ignore, which to fight, and even what new species might have to be introduced (as in biocontrol) or encouraged (e.g. gorse) to achieve certain ecological outcomes (Chornesky & Randall 2003). Conservation monitoring has to become more sensitive to the degree of risk posed by exotic species, and the counterintuitive effects that occur when decline of an exotic species has negative effects on native biodiversity.

The primary focus in monitoring is on exotic invasive species. Typically there is in practice, if not in legislation, a laissez-faire attitude to many non-indigenous species, especially those of economic or social importance. However, the case for subtle and not so subtle negative environmental effects of many non-indigenous species regarded as benign is well documented (Lodge & Shrader-Frechette 2003; Townsend 2003) and there is a case for a wider rather than narrower concept of ‘invasive’.

National indicators generally include a measure for the number and trend of exotic versus native species in better-known groups. This figure is easy to obtain for vascular plants from the plot-based inventories that most countries have maintained for many years, but is possibly not too difficult a task for other well-known plant groups, especially those of economic importance. Invertebrates of agricultural, forestry or human-health significance are well known because dedicated surveillance schemes are now the norm (for recent New Zealand overviews see Goldson & Suckling 2003). The surveillance task is now being assisted in many countries by decision support systems that give some indication of what organisms are likely to become invasive. For instance, CLIMEX software (developed by CSIRO Entomology) is widely used internationally to predict potential distribution and relative abundance of species (insects, plants, vertebrates, pathogens) in relation to climate. When predictive models are combined with experienced surveillance staff and quantified risk assessment, monitoring and action tend to be well integrated.

However, the standard procedure of mapping distributions, predicting future range changes, modelling species spread, assessing impacts, developing management guidelines and screening species has a number of serious limitations (Hulme 2003). Lack of common mapping standards prevents accurate comparative assessments; coarse-resolution data overemphasise the role of climate versus land use or human population density; and climate envelopes tend to overestimate potential distributions. In the absence of a mechanistic understanding of the invasion process, correlative models tend to misinterpret risks posed by invasive species.

Even if surveillance and model information is available, the best decision support systems in this field give only a very general idea of which species are potentially troublesome invasives. It has even been suggested that invasiveness is essentially unpredictable due to highly specific habitat–organism interactions between invader and area of introduction (Radford & Cousens 2000). This unpredictability is worsened by the fact that globally very few introduced organisms become troublesome (Willamson 1996).

While the best opportunity for eliminating an invasive organism is when it is first detected and at low densities, there are rarely enough resources to attempt the elimination of all non-native organisms in natural areas. Monitoring systems therefore have to be carefully planned and calibrated. In particular, they have to focus on known threats; generalised categories of high-risk organisms; habitats of high invasibility; and incipient foci; and, most importantly, linked with adequate resources to undertake remedial action (Simberloff 2003).

Mack et al. (2000) emphasise the need to obtain data that will galvanise policy makers and the public, as few tools are as effective as time-series maps showing the course of an unfolding invasion. They also stress the need to collect more information about the population biology of immigrations that fail, as knowing what can be safely ignored is almost as important as knowing what needs immediate action. The same authors stress the need for a comprehensive approach toward managing invasive species:

> Effective prevention and control of biotic invasions require a long-term, large-scale strategy rather than a tactical approach focused on battling individual invaders. An underlying philosophy of such a strategy should be to establish why nonindigenous species are flourishing in a region and to address the underlying causes rather than simply destroying the currently most oppressive invaders. System management, rather than species management, ought to be the focus…A strategic, system-wide approach is particularly appropriate for conservation areas, although it is seldom undertaken. (Mack et al. 2000)

Internationally there is little sign of coordinated strategic monitoring except in high-risk economic pests and diseases. For instance, the Canada Wildlife Service reports after an exhaustive survey (Haber 2002) as follows:

- Few organised data sets available on invasive species in Canada
- Most Internet information is only informative textual material
- Establishment of standardised protocols for data entry and conversion of existing sets will take time
- Critical need for better access to information of all kinds on invasive species.

The United States National Invasive Species Council (2001) arrived at a similar conclusion: 'Unfortunately, inadequate planning, jurisdictional issues, insufficient resources and authorities, limited technology, and other factors often hamper early detection and rapid response in many locations.'

A recent report on biosecurity surveillance systems in New Zealand highlighted the problems created by fragmented databases, lack of inter-agency cooperation, and the absence of standards for data collection (MAF 2003). The conclusion of the review was: 'there is no easy way to obtain a comprehensive view of the organisms that live in New Zealand. Nor is there a common system by which existing databases can be updated with findings of new organisms or range extensions.'

Key issues therefore are establishment of adequate data management, provision of specific information and rapid response plans, and inter-agency cooperation. The need to alert, inform and engage the public in anti-invasive species activity is also stressed in the report. All of these issues lend themselves to production of indicators and measures for reporting.

Genetic monitoring

There is ongoing debate about the value of genetic information for the conservation management and recovery of critically endangered species with low population sizes (Caughley 1994; Haig 1998). A recent study of genetic diversity of rare taxa concluded that including genetic information in recovery plans would lead to a much higher number of populations needing to be conserved than ordinary conservation practice would suggest (Neel & Cummings 2003). Inbreeding depression can lead to an extinction vortex in which chance events have a devastating effect on weakened populations (Lacy & Lindenmayer 1995), although this is largely based on results from modelling rather than empirical evidence. Genetic inventory and monitoring may have to be seriously considered, but the context is unclear.

The situation is much more complex than it is often portrayed. As discussed earlier, neutral genetic markers have only weak correlations with quantitative genetic measures, which are much more laborious and expensive to acquire. ‘Neutral’ variability is lost very slowly from populations, and ‘useful’ variability much more slowly than that (Amos & Balmford 2001), which would suggest that a generalised threat through genetic erosion is possibly small, even in populations of limited size.

There is emerging evidence that inbreeding depression resulting from the mating of close relatives may be affecting population growth rates of retranslocated populations of some threatened endemic bird species on predator-free islands. In this case, genetic measures of relatedness are being used to limit the impact of inbreeding, but the whole topic needs a clearer research basis.

Until we know more about the functional significance of genetic features, routine genetic monitoring should only be undertaken as part of a research programme, rather than for general management purposes.

6. Conservation agency performance indicators

Most national reports are adequate at framing indicators and measures for the status of biodiversity. However, the question of how adequate their government agencies are in managing and reporting on biodiversity is usually not addressed. Two issues must be addressed: (1) Can the government and public trust their agencies to select adequate measures, and report comprehensively and fairly? (2) Are the agencies effective in their conservation interventions?

6.1 Trust

In these increasingly litigious times, agencies have to be careful that their monitoring systems, which often result in decisions that impact in a socio-economic sense, are:

- Based on a principled approach to conservation issues
- Transparent, as based on clearly identified and articulated measures around which there is a consensus as to their validity
- Credibly carried out and analysed by trained professionals
- Reported in a full and honest manner.

We have dealt above with the first two issues. However, the latter two issues concern trust by government and the public in the agency reporting biodiversity statistics and conservation achievement. Without this trust, monitoring is a waste of time and money. However, trust in public agencies appears to be waning in the Western world (Putnam 2000). An example, symptomatic of breakdown in trust, is the controversy engendered by the publication of Bjørn Lomberg’s *Skeptical Environmentalist* (Nature 423: 216–218; 2003). In Lomberg’s book – a runaway bestseller – it is claimed that environmental and biodiversity decline has been overemphasised by vested interests such as scientific researchers and government agencies. Trust is less about the scientific adequacy of measures and the professionalism with which they are measured, but the reasons for selecting them, and not others, and the way they are reported and used. If this aspect is not dealt with, excellent conservation achievement will be undermined.

Lack of trust is formalised in our governance structures. During the managerial reforms that swept the Western world in the late 1970s and 1980s, 'agency capture' became a key element. Agency capture theory is based on the observation:

> Opportunistic agents may disregard obligations to principals and take self-serving actions at the expense of those they are obligated to serve. In fact, possession of essential information often is asymmetrical: agents know more about their performance than principals do. This asymmetry exposes principals to the risk of capture: agents give principals the information that impels them to act in the interest of those who serve them. (Schick 1996)

Note that 'agency capture' is quite a different concept from 'agency corruption' and does not imply illegal actions. It may mean, for instance, that certain sorts of data or indicators are emphasised over others in order to achieve increased funding. Positive achievements may be highlighted, and negative ones concealed, in order to give the impression of better achievement than has in fact occurred.

Conservation agencies present a severe risk to government of agency capture. They are often vertically integrated to an astonishing degree. Typically they decide on what are the issues of importance to biodiversity and what actions, if any, to take. They then select adequate indicators and measures of biodiversity change, they organise the bulk of the monitoring, interpret the data, and directly present the indicators and other monitoring or assessment results to their principals (funders or government). In the reforms of the 1980s, the Department of Conservation was created as a single comprehensive entity out of an activity previously scattered among several organisations, presumably because issues of efficiency and focus were emphasised more than agency capture.

The particular risks conservation agencies run of losing public and governmental trust in both advising on and undertaking actions and being solely in charge of reporting outcomes are obvious. This aspect of trust and credibility in monitoring is well covered in the following extract from the United States National Academy of Sciences report (2000, p. 50):

> In addition to being based on credible measurements and calculations, the choice, motivation, and interpretation of indicators should be publicly trusted for them to be of greatest use. That means that the people and organizations who produce the indicators should be generally trusted. The committee cannot specify the best methods for achieving this goal, but notes that in at least some cases separating the responsibility for preparing indicators from responsibility for carrying out policies based on them seems to enhance trust in the indicators. For example the National Weather Service has no responsibility for environmental policies, and so, beyond some scientific questions about the nature and placement of its instruments, its statistics are generally widely respected and trusted. The importance of public trust in the indicators is even more critical if ecological indicators are to be used as input for a national assessment of the state of the nation's ecosystems.

Different countries are in very different situations with regard to trust in their agencies. Where the responsibility for biodiversity conservation is scattered among several agencies and there are well-funded quasi-governmental and non-governmental organisations concerned about biodiversity issues, the risk of agency capture is counteracted by the multiple sources of advice to government and the public, and the range and cogency of independent assessments. Most developed countries have large, well-funded, multi-tasked environment ministries, independent national park systems, and extensive native forests with multiple-use objectives run by forestry ministries (Canada, most European countries). European countries, moreover, have an international European-wide agency level that promotes and sets standards and monitors compliance, thereby giving an extra level of quality and objectiveness. However, in New Zealand, as the primary conservation responsibility falls largely to a single, centrally funded organisation, which has effective control over the entire conservation estate, the trust issue is of major significance.

There is no question that nearly all management-related monitoring has to be carried out by the management agency concerned. However, the trust issue centres on auditing that agency's management monitoring, and assuring the public that the wider measures of biodiversity change that demonstrate progress or the lack of it are reliable and reported without bias. Therefore, the trust issue can only be resolved by the public being assured that the monitoring agency is independent and disinterested.

Various models are available, and it is not necessary to set up a totally separate agency to ensure independence. The possibilities range from the status quo with improved guidelines, to a stand-alone agency. The least disruptive approach would be to set up an independent monitoring unit within DOC to manage auditing, establish protocols and collate and report results. It would have to have strict statutory safeguards with regard to its independence and freedom of action. An inter-agency biodiversity-monitoring unit, staffed by individuals seconded from several biodiversity organisations, with extensive operational and reporting independence, would be a further step along that path. Staff would thus have practical monitoring skills, and a good understanding of biological conservation activities, and retain links with the parent organisations. MfE currently is establishing a biodiversity monitoring programme, but lacks the resources and staff to undertake any credible audit-and-assessment function. It is possible the developing complexities of measuring and reporting biodiversity across so many jurisdictions might make some higher-level biodiversity policy and reporting agency inevitable.

6.2 Agency efficiency

Organisational performance indicators and reporting are not strictly part of the biodiversity monitoring and inventory system, but impinge on it so strongly that it is worth making some comments. A conservation agency must satisfy the public and government that it is functioning well as an agency. The generalised requirements of good organisational indicators are:

- The indicator must be homogenous: in other words, there cannot be too many disparate types included in a single indicator, especially if the mix changes with time
- The output measure should not be influenced by factors other than those directly influencing the system being evaluated
- The output information must be collectable at a reasonable cost
- The measure should not have dysfunctional consequences if used as a target by an agency

- The measures should be as few as is consistent with covering all significant aspects
- The inter-relationship between indicators must be understood, and trade-offs between them clarified
- There should not be undue focus on indicators that are easy to collect
- Nor should important aspects of the system be neglected because apposite indicators are difficult to frame.

Organisational indicators come in a variety of forms ranging from highly specific, quantifiable measures to subjective appraisals. Broad categories are:

- A narrative account of activities and outcomes from an organisational perspective (e.g. threatened species protection plans completed; exotic species elimination programmes undertaken)
- Successful establishment of new procedures or protocols
- Successful completion of research or reviews
- Achievement of performance targets; or as measures that stand in for aspects of progress.

Measuring and reporting on the effectiveness of conservation agencies in managing biodiversity is challenging. The previous discussions have highlighted the problems in defining goals (what do the public and government want out of the conservation effort?) and framing indicators (how can we reliably report on achievement?). To these we can add the fact that natural systems are highly variable, different elements within them have both very long and very short response times, and there are a multitude of causal factors, which are often imprecisely known. Scale issues are important, as for instance when biodiversity improves in a small intensively managed region, and declines elsewhere. And finally, indicators are often ambiguous and sometimes imprecise as to trend, and causation.

Hughey et al. (2003) argue that agencies have to address the questions of how should scarce resources have been invested and which investments in conservation have been most successful. Therefore, they suggest that cost-effectiveness analysis and cost-utility analysis have to be introduced, as has started with MCA analysis in DOC (Stephens et al. 2002).

Finally, an often unrecognised but major influence on the outcome of conservation activities is social behaviour (Wallace 2003). Externally, the interaction of agency staff with local and central government, conservation NGOs, economic interests and the public at large is crucial. Internally, leadership, communication, teamwork, dispute resolution, reconciliation of differing ideologies, and organisational culture strongly influence decision-making and participant interactions.

No definitive solution can be proposed for these problems in accurately reporting performance. Perhaps the best that can be achieved is to ensure independence, accuracy and comprehensiveness in the indicators and measures used, stress the long-term nature of the conservation enterprise, and carefully distinguish those changes that have resulted from deliberate management intervention from those that have not.

7. Socio-economic indicators

The international literature stresses that biodiversity performance indicators must be policy relevant and that societal awareness and response be included in the measures. It has been argued: 'ecosystem management needs to be reconceptualized from an approach driven by scientific understanding to one that takes account of the multiple sets of interests and values in the political economy as a whole.' (Bissix & Rees 2001)

However, international and national environmental policy is seen as being dominated by 'technocentric world views by which blueprints based on external policy interventions can solve global environmental dilemmas…policy making institutions are distanced from resource users' (Adger et al. 2001). Hence there are calls for a 'Public Ecology', which goes beyond the biology and the associated science to make it more effective in the realm of political decision making (Robertson & Hull 2001).

Typical socio-economic policy questions are: Is use of biodiversity components carried out in a sustainable way? Are biodiversity measures integrated into other sectors of society? Are financial means available for biodiversity conservation, and how are they spent? How much awareness is evident, how much participation of public and policy makers is occurring? (European Environment Agency 2002).

National reports under the CBD framework have to respond to questions with a socio-economic element such as:

Article 8: Traditional knowledge and related provisions
Article 10: Sustainable use of components of biodiversity
Article 11: Incentive measures
Article 12: Research and training
Article 13: Public education and awareness.

The Montréal Process has nearly 60% of its 67 indicators focused on socio-economic and organisational and research-orientated outcomes. Nevertheless, socio-economic indicators are the last to be thought of when developing a natural heritage monitoring system. Despite widespread and top-level acceptance of the thrust to engage the public in biodiversity concerns, indicators for societal response and engagement are not well developed in most countries, and indicators of socio-economic impact of conservation agencies are rare.

The LUCID project of the USDA Forest Service has taken a strong line on this issue in devising its monitoring programme for forests in state ownership. Its technical workshop summed up the feeling of participants:

> …sustainability is a social concept and one that is incredibly valuable in practical application even though its definition may be elusive. They agreed that sustainability cannot be achieved by any one group of people, at one scale, and certainly not by the Forest Service acting alone. They recognized that agency personnel need to act on multiple fronts, on multiple scales, and with internal and external partners across physical, conceptual and administrative boundaries;

> sustaining the fundamental systems contexts that sustain people is the surest way to move forward.

The final LUCID project lists 20 social and cultural indicators for national forests that include numerous measures for aspects such as collaborative stewardship, institutional and community capacity, social equity and social and cultural values. In the long term, public support is vital to a successful biodiversity conservation effort. Appropriate socio-economic indicators should be framed to indicate the impact and support or opposition the agency is creating in its pursuit of biodiversity goals.

The large proportion of land in New Zealand within the conservation estate, and the limited extent of sustainable economic activity permitted, could make such indicators and measures seem of secondary importance. However, the pressure to include under conservation management a greater area of fragmented natural habitat, more disturbed marginal areas, or areas recently managed for economic purposes greatly increases local community involvement on DOC land. Conservation activities can have a large impact on adjoining landowners and affected public, and their perceptions of conservation activities can significantly affect achieving biodiversity outcomes. Understanding the social context for conservation requires indicators that monitor perceptions, sustainable activities, and economic return from indigenous biodiversity.

PART III: A BIODIVERSITY INVENTORY AND MONITORING FRAMEWORK FOR NEW ZEALAND

8. Organisation of inventory and monitoring in New Zealand

8.1 National level monitoring: who should do it?

There can be no doubt that a comprehensive overhaul of New Zealand's biodiversity inventory and monitoring system is needed. The current system has grown piecemeal, largely in response to perceived environmental issues of the day, and has been developed by a range of agencies, many of which are no longer in existence.

In general New Zealand environmental agencies appear to be relatively poorly resourced in terms of inventory and monitoring and less advanced in terms of developing integrated systems compared to their equivalent organisations overseas. In particular, the Ministry for the Environment and Parliamentary Commissioner for the Environment do not have significant research and delivery capability or substantial data archiving capacity, compared to their sister agencies elsewhere. Local government agencies in New Zealand have a range of responsibilities and statutory authority to manage and report on biodiversity, but also appear to be under-resourced, and in fact rely on DOC and other central government agencies for much of their data and analysis.

DOC is atypical on a world scale in the breadth of its responsibilities (e.g. protection of indigenous biodiversity and historical resources, recreation management, biosecurity, fire control, and some commercial activities). This dominance of natural heritage management has been created in New Zealand by the concentration of conservation land in a single agency, the merging of National Park and public lands stewardship, the high proportion of conservation land in relation to our total land area, the limited use of public land for extractive commercial uses, and the relatively sparse human settlement adjacent to or within conservation land.

DOC therefore has the role occupied overseas by multiple agencies managing national parks, national forests, wildlife services and environmental protection plus, through default, much of the work load taken up by Environment Ministries elsewhere. In our view, it is imperative that DOC, as well as taking primary responsibility for reporting on its own activities and outcomes, engages with the task of reporting on generalised, national-level biodiversity status and outcomes.

Worldwide, countries are developing a systematic approach, centred around reporting on the state of the environment as a whole. From the international review it was apparent that most countries follow essentially the same approach, appointing an environment ministry to collate and report on available biodiversity information, but rarely to generate or fund the collection of the data from which this information is derived. Environment Canada, in setting up EMAN, has taken a further step, and developed an organisation to provide protocols and steer biodiversity monitoring by acting as a central node in a network of partners. However, as noted in the international review, the partners (for instance Parks Canada) make little mention of EMAN in their own documentation, nor to any national systems operated by other agencies. In Canada at least – and we suspect in other countries as well – the immediate concerns of the monitoring agency obviously take priority over contributions to multi-agency national biodiversity evaluations.

Unless a decision is made to have a recognised national, comprehensive inventory and monitoring scheme, which incorporates all central government agencies with a mandate for biodiversity and the large number of territorial authorities, the de facto situation will continue. Agencies will maintain independent biodiversity monitoring schemes and national-level reports will be assembled out of reporting designed for different purposes.

Our opinion is that there could be advantages in having a national scheme, comprehensive in coverage and centrally funded, for the following reasons:

- Biodiversity and its threats do not respect agency territorial boundaries;
- There is growing interest in preserving ecological integrity across the whole landscape, not just on public land managed for conservation;
- Systematic monitoring, based on standardised protocols and techniques and established in a way that maximises the number of co-occurring factors recorded, would probably result in the most information for a given quantum of funding;
- A national monitoring effort may assist with co-establishment of long-term ecological research to assist with the development of monitoring techniques and interpretation of monitoring results;
- Centralisation of effort in a single agency would assist with development of protocols, secure archiving of the information, and facilitate consistent reporting;
- If such a scheme was run by a single-purpose agency separate from the current agencies, it could also act as an environmental audit agency.

However, there are also problems inherent in centralisation of monitoring effort, in particular that run by a single purpose agency:

- The level of interagency agreement and cooperation needed to get such an effort underway may prove too difficult to achieve;
- A single-purpose environmental monitoring and reporting agency that could take responsibility for the national scheme would need expertise and resources that would undoubtedly remain with the territorial agencies. It would therefore be in a similar position to Environment Canada EMAN and MfE and not effective with regard to monitoring;
- If the agency failed to deliver what the territorial agencies needed, there is every likelihood that parallel monitoring systems would be developed;
- There is also a risk in allowing the monitoring effort to become detached from operational functions and relevant ecological research.

In our opinion, a national monitoring scheme should be established within the Department of Conservation, but supported by and accessible to other agencies with biodiversity responsibilities. We suggest that DOC establish its own national scheme, while paying attention to developments in the other agencies with major biodiversity responsibilities and keeping them informed. This national scheme with its initial focus on DOC-administered land should have the potential to be expanded to become a fully national inventory and monitoring scheme, because this will inevitably be required at some stage.

Many of the data archives that will be incorporated in such a monitoring scheme are already national, and a range of influences impacting on biodiversity on DOC land arise from outside. Importantly, evaluating the effectiveness of DOC management will require biodiversity information outside of the DOC estate. The proposed MfE indicators (Froude 2003) could be incorporated in such a scheme, and there is already extensive interagency cooperation on biosecurity, carbon monitoring and disease control schemes.

8.2 Internal management: 'Monitoring Central'

How should biodiversity and environmental inventory and monitoring be managed within DOC? Internationally, the trend is to establish a separate agency within the organisation to undertake the detailed work on developing a monitoring scheme, protocols and organising data archiving and reporting. We see advantages in this approach, which we will call 'monitoring central'. If set up with appropriate accountabilities, monitoring central will:

- Act as an advocate for inventory and monitoring within DOC
- Establish the outline of the national scheme including indicators
- Liaise with other interested agencies, territorial local authorities and universities
- Develop protocols and organise training
- Undertake, organise, and fund monitoring-related research
- Organise data archiving and retrieval
- Organise compilation and reporting of biodiversity measures.

8.3 How can a biodiversity inventory and monitoring system add value to the conservation management of DOC?

A biodiversity inventory and monitoring system must influence major decision-making processes at all levels within DOC if it is to gain the support necessary for development and long-term implementation. A comprehensive inventory and monitoring system can provide three main categories of utility for conservation activities:

1. A well-designed inventory and monitoring system will enable DOC to report on the difference it has made for a given amount of funds on achieving biodiversity outcomes for New Zealand. As we have emphasised from our reviews of the international literature, biodiversity and inventory programmes perform a function analogous to those provided by current financial accounting systems, and need to be accorded similar priority. The information provided for national accountabilities can also be used to fulfil international reporting requirements.
2. The system will also increase efficiency of conservation activities by identifying the best management/site combinations. This partly depends on understanding the current configuration of biodiversity in New Zealand, and the linkages between threats and biodiversity condition.
3. An inventory and monitoring programme will also demonstrate, where necessary, the imbalance between mandated obligations and the resources provided. Credible reporting allows assessment of whether current actions are sufficient to achieve the agreed conservation goals. This enables DOC and others to clearly identify where resources and/or management actions are insufficient. This role is critical in forcing prioritisation of management actions.

8.4 Indicators versus other approaches

The bedrock of any monitoring system is quantitative, repeatable measures. These are broadly referred to as 'indicators' but, as discussed above, they range from direct measures of biodiversity attributes to indirect proxies for complex processes or states. No inventory and monitoring system can do without them. However, beyond this fundamental basis there is a major *conceptual* divide between advocates of using aggregated and transformed measures as indices of an abstract state or condition of the environment and those who argue for use of multiple indicators reflecting a wide range of issues.

The different components of any indicator framework, from data elements through to spatial or functional aggregations of indicators, can all be used to inform policy and guide management, and their relevance will depend on the level and focus of interest within the organisation. Once the biological and environmental data become incorporated in models and spatially explicit, the indicators can be used to shape resource allocations and policy for biodiversity conservation.

Amalgamated indices of biodiversity for high-level reporting are rarely used internationally, and the few examples that we have seen appear to be conceptually and biologically problematic. Therefore, despite their potential shortcomings, we are left with the task of selecting indicators that can be used to reflect processes at different levels of biodiversity and across trophic interactions, while also making sense as high-level measures. In particular, we are looking for indicators that address the following three aspects:

- **Biodiversity status**: those that seek to determine biotic change of important environmental components at scales from species to whole landscapes, in particular those with policy relevance;
- **Conservation effort**: those that deal with the steps taken to improve biodiversity, the resources allocated, and how efficient the measures are;
- **Socio-economic impact**: those that document impact on society and societal response

9. Biodiversity assessment framework: outcomes and performance assessment

In this section we develop an explicit biodiversity assessment framework for long-term monitoring by DOC for the conservation of indigenous biodiversity in New Zealand. Based on the findings of our review we accept that a nationally applicable biodiversity assessment framework is necessary. We opt for the selection of a range of ‘indicators’ of long-term biodiversity condition in accordance with current international trends.

To provide a basis for indicator selection and evaluation we firstly describe the central outcome of conservation as maintaining ecological integrity, which is defined according to its basic components, and elaborated in a nested hierarchy of outcomes. Because the context for conservation is different in New Zealand from elsewhere, we also outline the distinctive features of conservation management in this country, derived from the DOC Statement of Intent, that need to be taken into account during the selection of indicators. The goals and objectives of biodiversity assessment also influence the type of indicators monitored, and this is discussed in a separate section. Finally, we set out what we consider to be the core indicators associated with biodiversity inventory and monitoring, indicating some of the parameters and attributes that might be measured, and the frequency and type of assessment required.

Our approach has been to construct a series of filters through which any indicator system should be assessed. Some of these are based on the character of the biodiversity; others reflect the conservation issues identified by DOC, while others are constrained by the pragmatic aspects of effective monitoring. We have found it very difficult to place all these processes in a single schematic framework, without oversimplifying the issues of biodiversity complexity, scale of measurement, and institutional intricacy.

9.1 Scope – national or DOC?

Because of the extent of DOC-anaged land in New Zealand any biodiversity inventory and monitoring programme developed for the Department will have many of the characteristics of a national New Zealand-wide biodiversity assessment system. Our approach has been to develop an indigenous-biodiversity-focused inventory and monitoring system that could potentially be applied nationally. Many, if not most, of the key biodiversity measures will be DOC's direct responsibility. However, because indigenous biodiversity is not restricted to Conservation lands, and the Department has responsibilities for threatened species wherever they occur, interagency collaboration will be essential. Importantly, there are critical processes affecting biodiversity on Conservation lands that are either outside DOC-managed areas or are the responsibilities of other agencies. Moreover, the state of indigenous biodiversity on private land is becoming increasingly important, especially in lowland environments, and must be incorporated in any credible national reporting schemes. The framework accepts that a robust inventory and monitoring programme will have a national focus, but recognises multi-agency contributions in the differentiation of responsibilities for different indicators. Nonetheless, the framework at certain levels has been designed specifically to meet DOC's requirements as derived from the Statement of Intent.

9.2 Framework structure

The aim of a biodiversity inventory and monitoring programme is to measure and report on features of biodiversity in order to assess progress towards defined biodiversity outcomes. The outcomes can be derived from legislative or policy documents and are usually qualitative goals that need to be translated at some level into quantitative statements. The quantitative statements in turn will have clearly defined performance measures that are used to indicate progress towards higher-level outcomes. The combination of outcomes and performance measures is essential to explicitly link national goals with actual inventory and monitoring measurements. To institutionalise the framework other components may be necessary, particularly linkages to policy, management responsibilities, and project activities.

The framework structure based on this rationale is set out in Table I.1. This will be referred to in the following sections where we apply the framework to biodiversity inventory and monitoring.

Table I.1. Framework for developing a biodiversity inventory and monitoring programme

Framework structure		
Type	**Level**	**Definition**
Outcome	National Outcome	National goal for biodiversity
	Targeted National Outcome	Critical components for achieving national outcome
	Outcome objectives	Key factors contributing to targeted national outcomes
Performance assessment	Indicators	Quantitative or qualitative parameters that can be assessed in relation to an objective
	Measures	Methodology and source of information for the indicator
	Elements	The data layer(s) that support a measure. Some measures are specific enough that the level of data element is not needed

9.3 Ecological integrity – the national outcome for conservation in New Zealand

Clear, precise goals are fundamental for any biodiversity monitoring and inventory framework and it is only in the last decade that organisations have been attempting to characterise biodiversity objectives beyond the general all-encompassing desire to maintain the full complement of genetic, species, and ecosystem diversity in a country, as set out in international agreements such as the CBD, and national statements such as the Biodiversity Strategy. However, although clear, such broad goals give no guidance to setting priorities as to what to monitor, given that numerous choices have to be made by DOC.

We suggest that the primary national outcome of conservation management at the highest level is to maintain **ecological integrity**, here defined as the full potential of indigenous biotic and abiotic features, and natural processes, functioning in sustainable communities, habitats, and landscapes. The term encompasses all levels and components of biodiversity, and can be assessed at multiple scales, up to and including the whole of New Zealand. At its simplest, ecosystems have ecological integrity when all the indigenous plants and animals typical of a region are present, together with the key major ecosystem processes that sustain functional relationships between all these components. At larger scales, ecological integrity is achieved when ecosystems occupy their full environmental range.

Other terms (ecological condition; biodiversity condition; ecosystem health; ecosystem status; biological integrity; biodiversity integrity) have been proposed as encapsulating conservation goals but all in our view fail to adequately convey the multiple dimensions or the potential outcome of a national biodiversity conservation strategy. As discussed in Section 4.2, the terms 'health' or 'condition' are often used as foci for biodiversity assessment but, because they rely on analogies with human health, are inappropriate for a biological system. Any 'idealised' state, based on either functional or compositional criteria, will be challenging to define and sustain. 'Health' cannot be defined, for instance, as an optimal functional rate of decomposition, carbon gain, or nutrient cycling, as each site will differ and, even if it were possible to link these functional aspects explicitly to biodiversity, the values would be impossible to defend. Similarly, an indigenous ecosystem with a high number of exotic plants and animals in it is 'sick' or in poor 'condition' only in the sense that we prefer exotics not to be there; as an ecosystem it may have high levels of diversity and functionality. If indigenous-species diversity is taken as an index of heath, and therefore adopted as a management or policy goal, poor outcomes might result if these can be only achieved under moderate disturbance levels. Naturally species-poor systems are not in any need of assistance to 'improve' their biodiversity. Finally, it is not necessarily appropriate to define an ecosystem as 'ill' or in 'poor condition' when a range of biodiversity and ecosystem processes might remain, and many ecosystem services are still provided.

Ecological, rather than biological integrity targets the highest level of biodiversity organisation (i.e. the ecosystem), explicitly includes abiotic components, and recognises the appropriate level for much of DOC's management activities as conservation concepts broaden beyond the protection of single species.

9.4 Targeted national outcomes – core components of a biodiversity assessment framework

Ecological integrity as a goal does not take us very far unless we are able to disentangle the key elements within the definition, and identify their significance for biodiversity. Two components appear to be fundamental: coverage of all hierarchical levels of biodiversity, and defining the major elements of ecological integrity.

Hierarchical levels

Conceptually, biodiversity is a nested hierarchy comprising genes, species, populations, and ecosystems. As Noss (1990) indicates, these multiple levels within biodiversity need to be addressed simultaneously in order to gain an accurate perspective of species and system status and changes. No single level of biodiversity is fundamental, although species are frequently seen as the most convenient management unit. In general, higher levels of organisation incorporate and constrain the behaviour of biodiversity at lower levels. The different processes, attributes, and critical spatial scales at each level need to be considered in developing a biodiversity inventory and monitoring system. Approaches and techniques for measuring populations within species will be different from those used to measure ecosystem processes and distribution. Our overall understanding of ecological integrity will depend on having some measures across all the different levels of biodiversity.

Elements

Ecological integrity is the product of an enormous number of interactions between genes, species, populations, ecosystems and the abiotic environment and the distinctive processes at all scales that result. We therefore have to simplify our approach and focus on what elements are likely to provide the best guarantee that integrity is being maintained. These form targeted national outcomes, which collectively define and contribute to our achieving the national outcome of enhancing ecological integrity. We suggest these elements are: indigenous dominance, species occupancy, and environmental representation.

1. *Indigenous dominance* is the level of indigenous influence on the composition, structure, biomass, trophic and competitive interactions, mutualisms, and nutrient cycling in a community. Our aim is have ecosystems that contain and are shaped by indigenous plant and animal species. While exotic species may be usually present, their influence should not be disruptive of indigenous ecosystem processes or threaten continued indigenous dominance. The cornerstone of continued indigenous dominance is self-regeneration, a feature that enables the community to perpetuate itself in the absence of active human intervention. The presence of natural regenerative processes operates to restore the community following disturbances and other perturbations. Structural dominants across major trophic levels are likely to be the key biotic components ensuring indigenous dominance.
2. *Species occupancy* is the extent to which any species capable of living in a particular ecosystem is actually present at a relevant spatial scale. The level of representation of all the plants and animals that could potentially occupy an ecosystem is an important aspect of biodiversity assessment, representing the outcome of past threats and past/present conservation management. This could be analysed both at the species or functional-type level, based on inventories of current biota and lists of extant species that should be in the region. The potential biota for a region could be compiled from a combination of sources including expert opinion, potential geographic range modelling, sub-fossil remains, and historical information. For biota that have suffered major declines and range contractions, this element would require conservation management to reduce the threats to enable reoccupation of their full environmental range.

3. *Environmental representation* refers to the abiotic aspects of ecosystems and measures the distribution of indigenous biota across environmental gradients derived from data layers based on climate, soils, and geology. It assesses the contribution of a site/area to ensuring a full range of environments is included within the protected natural area network, or at least with some form of biodiversity protection. Environmental representation, as indicated in the Biodiversity Strategy, is a major contributor towards ensuring potential biotic representation, and the presence of the full range of genotypes. In combination with the other two elements, it ensures that evolutionary potential can be maintained. Environmental representation can be assessed at multiple spatial scales, and will need to incorporate small-scale distinctive habitats such as wetlands, geothermal areas etc., which often have specialised biota.

These elements provide the targeted national outcomes forming the basis of ecological integrity, which can be summarised as the dominance of indigenous biomes, with a full suite of species able to survive in an area, across all the environments represented in New Zealand. They provide a framework for halting declines of species/ecosystems and maintaining safe-sites for the indigenous biota as a whole. Importantly, they do not fossilise the current or past state of the biota, but recognise that following human modification and environmental change the configuration of indigenous communities at any one locality might be quite different from that of the past. The elements allow for natural successional change and acknowledge that compositional shifts could occur (and be valued) in human modified environments. Healthy functioning ecosystems, in this context, are viewed as those dominated by a complete spectrum of indigenous species able to occupy a particular area, and are independent of any measure of relative levels of functioning.

The elements of ecological integrity identified above have equal priority although they may be assessed at different scales. Ensuring indigenous dominance at a site, in a habitat, or across a landscape is clearly a priority for maintaining ecosystem processes, and would always be a key goal for the conservation of biodiversity. Maintaining, or in most cases, restoring, occupancy of species in an area is also a major component of sustaining indigenous biodiversity, and should not be discarded merely because we do not have at the present time the predator control necessary to have, for example, the saddleback and kakapo occupying anything like their potential range. Environmental representation is also a key goal, and importantly, is now potentially measurable with the development of Land Environments of New Zealand (Leathwick et al. 2003).

These three elements translate into separate outcomes that contribute fundamentally to maintaining ecological integrity, and have been classified as targeted national outcomes. They are more readily quantifiable than the national outcome, and identify the key components of biodiversity under consideration.

Baselines against which ecological integrity is measured

The definition of ecological integrity adopted above to a large extent sidelines the issue of baselines or reference states, which are a standard feature of biodiversity inventory and monitoring systems in many countries. This is because our definition is concerned with higher-level goals that encapsulate any desired or potential ‘natural’ composition, without prescribing any particular composition or historical state. Our reason for this position was set out in Part II Section 1.2.4. Ecological integrity focuses on maintaining ecosystems dominated by indigenous species across a complete range of environments with full representation of extant species. Thus conservation is not burdened with the micro-management of sites to recreate some idealised past biodiversity assemblages, which are largely unattainable due to environmental shifts, past extinctions, and natural processes such as soil development etc.

9.5 Outcome Objectives – actions required to maintain ecological integrity

Ecological integrity provides a broad goal for the conservation of indigenous biodiversity, and we have discussed the three elements of indigenous dominance, species occupancy and environmental representation that ensure its survival. However, to make the concept directly relevant in the New Zealand context, and to ensure that the framework meets the current reporting requirements of DOC, a further tier of outcome focused objectives are required to specifically address the goals that the nation has declared important.

A major goal for DOC is to protect and restore New Zealand's natural heritage, which encompasses three national priority outcomes:

- halting decline in the state of protected areas
- preventing species loss
- adding key places to the protected-areas network including covenants and other forms of legal protection.

These outcomes directly address the requirements of the national Biodiversity Strategy and can therefore be seen as core to any national system as well. The three priority outcomes can be subdivided for clarification into five distinct conservation outcome objectives that are unlikely to change significantly over time, namely, preventing declines and extinctions; maintaining ecosystem processes; improving ecosystem composition; improving representation; and reducing the spread and impact of exotic/invasive species. Although the relative priority of, and conservation management approach to, these objectives might vary, they will remain central to the conservation management of biodiversity in New Zealand for many decades.

However, there are additional outcome objectives that need to be considered in the Zealand context, either because of their potential importance for causing changes to biodiversity or because they are imbedded in existing international agreements and reporting requirements on biodiversity and the environment. The four we have identified are predicting the biodiversity impact of global climate change; reducing environmental pollutants; sustainable use of indigenous biodiversity; and the extent to which the community is involved in conservation. Although it could be argued that these outcome objectives stray beyond the limits of previous biodiversity monitoring and reporting in New Zealand, especially as they include social factors, they embrace both international concerns and requirements, and take account of a growing national awareness of the importance of a strong societal dimension to achieving the goal of sustainable indigenous biodiversity.

On the basis of their central focus, seven of the nine outcome objectives can largely be clustered within one or other of the three targeted national outcomes as set out in Table 2A. Although current DOC organisational and policy frameworks result in the identification of outcome objectives, the biodiversity inventory and monitoring framework we are proposing strongly shapes their quantification and evaluation. Indigenous dominance is dependent on maintaining ecosystem processes, reducing the spread and impacts of invasive exotic pests, and limiting the effects of pollutants. These outcomes may also impact on the presence or absence of a particular species in a system, but in general we are primarily concerned with their effects on maintaining indigenous dominance across or within guilds. Preventing extinctions and declines and improving ecosystem composition are central for maintaining and restoring the occupancy of species in habitats and regions. Environmental representation of ecosystems, especially in lowland and montane areas, is fundamental for protecting a full range of genotypes and habitats for biota. Climate change becomes important when environments change in ways that limit representation of indigenous species.

Table II.2. Outcome framework for biodiversity inventory and monitoring programme

<table>
<tr><th>National Outcome</th><th>Targeted National Outcome</th><th colspan="2">Outcome Objectives</th></tr>
<tr><td rowspan="3">Ecological integrity</td><td>Indigenous dominance</td><td>1. Maintaining ecosystem processes
2. Reducing exotic spread and dominance
3. Limiting environmental pollutants</td><td rowspan="3">8. Sustainable use
9. Community in conservation</td></tr>
<tr><td>Species occupancy</td><td>4. Preventing extinctions and declines
5. Maintaining ecosystem composition</td></tr>
<tr><td>Environmental representation</td><td>6. Ecosystem representation
7. Climate change and variability</td></tr>
</table>

Sustainable use of indigenous ecosystems and species, and working with local communities to fulfil conservation goals, are relevant to all the targeted national outcomes, and are accordingly segregated from the others (Table 2). For example, community action may contribute towards restoring indigenous dominance in duneland systems by eliminating weeds, planting generalist indigenous woody species, and re-establishing indigenous species, while simultaneously expanding the environmental representation of areas set aside for biodiversity protection.

The outcome objectives are described in greater detail below.

Outcome Objective 1. Maintaining ecosystem processes

Ecosystem processes transfer energy and matter from one pool to another, usually as a result of interactions between organisms and their environment. The key processes involving organisms are primary productivity, decomposition, competition and herbivory/predation. Important abiotic aspects include nutrient cycling and water yield. They are fundamental characteristics of all ecosystems and changes in the rate of any particular process indicate alterations in pool sizes and can enable predictions about the future of the ecosystem. If critical processes fail or are substantially altered, ecosystems will be transformed, degraded or even lost.

Outcome Objective 2. Reducing the spread and impact of exotic/invasive species

Biological invasions in New Zealand are a major cause of indigenous biodiversity loss. Extinctions caused by mammalian predators have been well documented and mustelids, rodents, and possums continue to deplete populations of many indigenous animals. The impact of mammalian herbivores has been no less dramatic, causing shifts in understorey vegetation composition, and large population declines of palatable species. The spread and impacts of social insects has only recently become recognised as a major problem. Invasive plants continue to alter disturbance regimes, displace native species and vegetation, and modify ecosystem processes. The impact of invasive fungi and microbes is not well understood, but they are present in indigenous ecosystems.

Outcome Objective 3. Limiting environmental pollutants

Environmental pollutants are usually derived from point sources, and are most commonly associated with waterways and areas adjoining roads or industry. The main potential concerns for indigenous biodiversity in New Zealand are groundwater contamination by waste dump sites (mainly heavy metals), agricultural runoff (nitrates, phosphorus); soil contamination by toxins or heavy metals on mining and industrial sites; and the occasional spill of toxic chemicals from road and water transport. Eco-toxins associated with widespread use of some pest poisons may also require monitoring of indigenous plants and animals.

Outcome Objective 4. Preventing declines and extinctions

Preventing extinctions and population loss is fundamental for maintaining biodiversity. Threatened species have been at the centre of conservation management in New Zealand for over a century, initiated in large part by the extinctions and marked declines of many indigenous birds in the 19th century. Although biodiversity is now recognised as being broader than simply species' protection, there is an ongoing crisis as to the survival of many of our characteristic (large, flightless, low-fecundity) vertebrate and invertebrate species, especially on the mainland. Many highly threatened species have recovery programmes and some have published Recovery Plans, with regular assessments of population status, and involving active management of both threats and breeding capacity. Population and distributional changes in species not on the cusp of extinction are monitored less regularly.

Outcome Objective 5. Improving ecosystem composition

Species, functional groups, life-history stages, trophic diversity, and structural complexity are all aspects of the composition of ecosystems. Composition focuses attention on the biotic mix within an ecosystem, key biodiversity elements such as ecosystem engineers and keystone species, and stresses the need to ensure that all indigenous taxa have a safe place somewhere within the landscape, irrespective of their overall relative abundance.

Outcome Objective 6. Improving ecosystem representation

Ecosystems occupy a range of environments and factors such as climate, soils, topography, and disturbance regimes can be used to define them at different scales. The abiotic component can be used to identify areas with common features for those factors that are important for maintaining biota. The Land Environments of New Zealand (LENZ) provides a quantitative basis for defining similar environments at medium to large spatial scales. Plant community mapping is needed to provide a biota-specific assessment of the extent to which a given area supports indigenous cover. Other restricted yet distinctive environments (e.g. dunes, screes, wetlands, cliffs) need to be identified and considered on a more detailed basis as they bring with them numerous issues including a propensity for rapid change. Human impacts vary across environments, being most severe in warm, lowland, fertile environments. Preserving the widest possible range of ecosystem environments ensures the retention of a wide range of evolutionary potential.

Outcome Objective 7. Climate change and variability

Global climate change is potentially a major driver of large-scale biodiversity trends, although the causal linkages and processes may be poorly known. Increases in greenhouse gasses (CO_2, methane), mean annual temperature, and the frequency of extreme climate events (storms, drought, and frost) will all impact on the mortality, fecundity, and geographic range limits of many elements of biodiversity. Importantly, several factors will also influence land use, which affects many aspects of biodiversity conservation. Data for most of the abiotic components included in global climate change processes are already being routinely monitored and made available by other organisations (e.g. NIWA, MAF). The exceptions are certain environments and situations that are very poorly monitored for climatic factors. These include high-altitude sites, mountainous and forested environments and climates internal to the vegetation cover or in special environments such as screes, outcrops, and riverbeds. It is likely that automated, cheap climate station technology will come available, and conservation-specific environments should be monitored where a need is recognised. DOC will need to be able to access and integrate over time these factors with the other indicators being used, to identify potential mechanisms and processes that may be impacting on biodiversity in New Zealand. The majority of interactions are likely to be indirect and multifactorial, but distinguishing global climate change impacts from local factors will be important when identifying threats and considering management responses. It is also possible that new environments will arise in the future, and LENZ will have to be updated. Knowing the characteristics of these environments will be important for conservation goals and management.

Outcome Objective 8. Sustainable use of indigenous ecosystems

The CBD links the conservation of biodiversity with its sustainable use. In most other countries the extractive use of elements of indigenous biodiversity is taken for granted, especially the harvesting of animals and timber. In contrast to New Zealand, other countries frequently have large industries dependent upon using indigenous species, and conservation goals are therefore inextricably linked to the sustainable use of the resource. In New Zealand we have very few indigenous terrestrial species that are routinely harvested and there is strong legislation prohibiting their extractive use. An exception is sustainable harvesting of indigenous forest trees under the Forest Amendment Act (but in practice a small and diminishing volume is harvested) and hunting of a selected group of indigenous water fowl. In certain areas the cultural harvest of some elements of the indigenous biota is permitted. Because of the legal requirements under the Wildlife and National Parks acts, DOC cannot contemplate consumptive or commercial use of fully protected species. However, the concept of sustainable use is much broader than consumptive use, and can be applied to any human activity that regularly occurs in areas set aside for the conservation of indigenous biota, including tracks, huts, visitors, etc. The potential negative impacts of these activities can range from facilitating weed invasion and maintaining local rodent populations, through to the compaction of soil and the alteration of natural hydrological regimes. However, it must be acknowledged that public access to and knowledge of indigenous biota has a positive influence on support for conservation. The growing demand for recreational and commercial use of protected natural areas will increasingly require the Department of Conservation to maintain monitoring systems for these types of activities. Moreover, a National Scheme must necessarily include biodiversity on private land.

Outcome Objective 9. Community participation in conservation

Biodiversity conservation interacts strongly with many local communities, either through providing enhanced commercial/employment opportunities, or restricting certain activities. Sustaining indigenous biodiversity will in part depend on the support and co-operation of these communities. A growing feature of conservation in New Zealand is the importance of local communities in establishing biodiversity goals for protected natural areas. Community aspirations may maintain seral vegetation (e.g. montane tussock grassland), direct effort towards iconic indigenous species, accept responsibility for monitoring or restoration, or require improved tracking or access, all of which can have important ecological implications.

9.6 Performance assessment – indicators, measures and data elements

Criteria for reporting on progress towards achieving outcomes are dependent on the development of explicit indicators, which are in turn derived from measures and quantitative data layers. Indicators are therefore quantitative or qualitative parameters that can be assessed in relation to national outcome objectives. They have no implied direction, measurement, spatial or temporal scale, or reference value. Assessment of all indicators and measures is set out in Appendix 2 based on criteria derived from the reviews presented earlier in the document.

The reporting of ecological integrity nationally, at any outcome level, will depend in part on the integration of various indicators and measures, and a framework for this will be developed in Phase II of the project.

The primary aim of the Indicator Framework is to remove what is often an arbitrary and ad hoc approach to the recording of ecological integrity and its threats. Issues go in and out of fashion, but underlying threats and processes continue. The focus in the Framework is thus on making sure all important issues are covered, and that adequate data layers are either available or will be developed to address them. When interest is focused on some crisis, it is essential someone somewhere continues to look after the larger picture.

Reporting on ecological integrity to the nation and the international community is a separate process to the development and maintenance of the Indicator Framework and its associated measures and data elements. In some cases it is likely that an Indicator may be reported on directly – an example being Measure 1.5.1 *Land under indigenous vegetation* or Measure 4.2.1 *Number of acutely threatened indigenous taxa.* These are internationally recognised and reported and few would debate that changes in ecological integrity will result from changes in these measures. Others are issues on which the Department or the nation is unlikely to want to report on in relation to ecological integrity (e.g. Measure 7.1.1. *Climate averages, indices and extreme events*; Measure 8.1.2 *Amount and standard of huts, tracking and roading*) but are essential data layers to understanding what is happening with regard to other measures or indicators on which reporting is essential. Thus a report on ecological integrity either to Parliament or the Convention on Biological Diversity can be expected to have a mix of components from the Framework, structured or reorganised to address clear reporting requirements and issues of the moment.

Earlier in the report, we spoke of the need for trust. Essentially the issue is that the organisation reports its performance, and the state of ecological integrity, in as fair, honest and open a manner as possible. Not only must it be honest, it must be verifiably honest. And this is one of the undoubted advantages of having an Indicator Framework standing behind the report. Every factual statement or supposition in that report should be transparently and accessibly backed up by the Indicator Framework. Within reason, any interested party should be able to track, with little effort, the source of the data and come to their own conclusions as to its reliability, and do their own analyses. Over time, such a Framework will become a major research resource for both science, and conservation and socioeconomic policy in its own right.

9.7 Classification according to agency responsibility and current operability

The indicators, measures and data elements suggested are not all primarily DOC's responsibility and some are not readily available and operable. To facilitate their use and identify where further development is required we have categorised the measures according to two criteria. First, we have classified the measures according to whether or not DOC is totally, partially, or peripherally responsible for the data elements utilised in the measure/indicator (Responsibility). Second, we rate the measures on their current degree of operability (Status). The categories used are described in Table 3.

Table 3. Classification of proposed measures according to level of DOC responsibility and their current degree of operability

Classification for prioritisation of responsibilities and uptake of measures	
Responsibility/scope	
DOC 1	Largely concerns Conservation land or is a primary DOC responsibility. For the most part developed, organised, collected and analysed by DOC.
NAT 1	National measure, extending beyond DOC land, but the department will contribute and may assist with organisation, collection, collation and analysis of data.
NAT 2	Fundamental national data layer collected, collated, and analysed largely by other organisations.
Status	
O	Operational now or in the short term. Data elements defined, technical issues resolved, and historic datasets available.
D	Development required. Importance and usefulness to DOC defined, data elements identified but organisational and operational features require further work.
R	Research required. Potential useful measure, but data elements require further development, analysis, and research.
C	Consideration required. Interesting or novel measure, and may be used internationally, but utility for DOC requires further exploration.

The indicators we suggest are listed in Table 4, and are explained fully in Part IV.

Table 4. Summary of biodiversity inventory and monitoring framework with proposed indicators and measures. These are further described and evaluated in Part IV and Appendix 2.

Targeted National Outcome	**Indigenous dominance**			
Outcome Objective 1	**Maintaining ecosystem processes**		**Responsibility**	**Status**
Indicator 1.1	**Soil status**			
	M 1.1.1	Soil carbon status	Nat 2	C
Indicator 1.2	**Productivity**			
	M 1.2.1	NPP of natural terrestrial vegetation	Nat 2	O/D
	M 1.2.2	Mast flowering and fruit production	DOC 1	O
Indicator 1.3	**Water quality and yield**			
	M 1.3.1	Catchment water yield	Nat 2	O
	M 1.3.2	Water chemistry	Nat 2	O
	M 1.3.3	Stream invertebrate index	Nat 2	O/D
Indicator 1.4	**Ecosystem disruption**			
	M 1.4.1	Number, extent and control of fires	Nat 1	O
	M 1.4.2	Disease outbreaks	Nat 2	C
	M 1.4.3	Hydrological change	Nat 2	D
	M 1.4.4	Mass erosion	Nat 2	O
Indicator 1.5	**Land cover**			
	M 1.5.1	Land under indigenous vegetation	Nat 2	O
	M 1.5.2	Area under intensive land use	Nat 2	O
Outcome Objective 2	**Reducing exotic spread and dominance**		**Responsibility**	**Status**
Indicator 2.1	**Naturalisation of new weed and pest species**			
	M 2.1.1	Occurrence of self-maintaining populations of new potential environmental weeds and animal pests	Nat 1	D
Indicator 2.2	**Exotic weed and pest dominance**			
	M 2.2.1	Distribution and abundance of exotic weeds and pests considered a threat	Nat 1	O/D/R
	M 2.2.2	Indigenous systems released from exotic pests	Nat 1	O
Outcome Objective 3	**Environmental pollutants**		**Responsibility**	**Status**
Indicator 3.1	**Ecosystem levels of persistent toxins**			
	M 3.1.1	Accidental release and chronic contamination by chemicals	Nat 2	D
	M 3.1.2	Toxins in selected tissues of introduced wildlife and native species for which poisoning is suspected	Nat 2	D

Table 4 *continued*

Targeted National Outcome		**Species occupancy**		
Outcome Objective 4	**Preventing declines and extinctions**		**Responsibility**	**Status**
Indicator 4.1	**Extinct taxa**			
	M 4.1.1	Number of indigenous taxa presumed extinct	DOC 1	O
Indicator 4.2	**Status of acutely threatened taxa**			
	M 4.2.1	Number of acutely threatened taxa	DOC 1	O
	M 4.2.2	Number of acutely threatened taxa under active management	DOC 1	O
	M 4.2.3	Security of acutely threatened taxa under active management	DOC 1	O
	M 4.2.4	Demographic response to management at population level for selected taxa under active management	DOC 1	O/D
Indicator 4.3	**Status of chronically threatened taxa**			
	M 4.3.1	Number of indigenous chronically threatened taxa	DOC 1	D
	M 4.3.2	Number of chronically threatened taxa under active management	DOC 1	D
	M 4.3.3	Security of chronically threatened taxa under active management	DOC 1	D
	M 4.3.4	Demographic response to management of chronically threatened taxa under active management		
Indicator 4.4	**Genetic change in critically reduced species`**			
	M 4.4.1	Changes in quantitative genetic characters	DOC 1	C
Outcome Objective 5	**Ecosystem composition**		**Responsibility**	**Status**
Indicator 5.1	**Composition**			
	M 5.1.1	Size-class structure of canopy dominants	DOC 1	O
	M 5.1.2	Demography of widespread animal species	DOC 1	D
	M 5.1.3	Representation of plant functional types	DOC 1	D
	M 5.1.4	Representation of animal guilds	DOC 1	D
Indicator 5.2	**Occupancy of environmental range**			
	M 5.2.1	Extent of potential range occupied by focal indigenous taxa	DOC 1	D
Indicator 5.3	**Patch size/fragmentation of wooded ecosystems**			
	M 5.3.1	Degree of connectivity in transformed landscapes	Nat 1	D

Table 4 *continued*

Targeted National Outcome			**Environmental representation**	
Outcome Objective 6	**Ecosystem representation**		**Responsibility**	**Status**
Indicator 6.1	**Environmental representation and protected status**			
	M 6.1.1	Proportion of environmental unit under indigenous cover	Nat 1	O
	M 6.1.2	Proportion of environmental unit under indigenous cover and protected	Nat 1	O
	M 6.1.3	National change in extent and integrity of threatened naturally uncommon and significantly reduced habitats	Nat 1	D
	M 6.1.4	Proportion of threatened naturally uncommon and significantly reduced habitats protected	Nat 1	D
Outcome Objective 7	**Climate change and variability**		**Responsibility**	**Status**
Indicator 7.1	**Basic climate series**			
	M 7.1.1	Climate averages, indices and extreme events	Nat 2	O
Indicator 7.2	**Biological responses to climate change**			
	M 7.2.1	Extreme events and biological response	Nat 1	D
	M 7.2.2	Changing natural distributions of indigenous taxa	Nat 1	D
	M 7.2.3	Southern expansion of subtropical exotics	Nat 1	D
Outcome Objective 8	**Sustainable use**		**Responsibility**	**Status**
Indicator 8.1	**Recreational use of DOC land and its impacts**			
	M 8.1.1	Numbers and distribution of visitors in defined categories	DOC 1	O
	M 8.1.2	Amount and standard of huts, tracking and roading	DOC 1	O
	M 8.1.3	Impacts on ecological integrity of land used for recreation	DOC 1	D
	M 8.1.4	Recreational hunting and fishing effort	DOC 1	O
Indicator 8.2	**Economic use of DOC land and its impacts**			
	M 8.2.1	Number of concessions in defined categories, economic benefits and level of activity	DOC 1	O
	M 8.2.2	Volume of harvested material	DOC 1	O/D
	M 8.2.3	Impacts on ecological integrity of permitted activity	DOC 1	D
	M 8.2.4	Conservation benefits derived from concession activities	DOC 1	D

Table 4 *continued*

Targeted National Outcome		**Multiple TNOs**		
Outcome Objective 9	**Community participation in conservation**		**Responsibility**	**Status**
Indicator 9.1	**Community involvement**			
	M 9.1.1	Community consultation	NAT 1	O
	M 9.1.2	Participation in conservation	NAT 1	O
	M 9.1.3	Number and value of corporate sponsorships in conservation	NAT 1	O
Indicator 9.2	**Iwi partnerships**			
	M 9.2.1	Cultural partnership projects	NAT 1	O
	M 9.2.2	Cultural protection mechanisms	NAT 1	D
	M 9.2.3	Access to cultural materials	NAT 1	D
Indicator 9.3	**Eco-vandalism**			
	M 9.3.1	Degree of illegal activity	DOC 1	O
	M 9.3.2	Number of deliberate pest releases	NAT 1	O/D
Indicator 9.4	**Conservation profile**			
	M 9.4.1	Conservation and indigenous biodiversity in the written media	NAT 1	O
	M 9.4.2	Television and radio time devoted to indigenous biodiversity	NAT 1	O
	M 9.4.3	Web site useage	DOC 1	O
	M 9.4.4	Awareness and events	DOC 1	O

PART IV: DESCRIPTIONS OF BIODIVERSITY INDICATORS

In this section we describe the measures for each indicator in some detail, including a basic description of the measure, an explanation of why the measure is important to include, likely reporting frequency, possible data sources, ownership and responsibility for measure, and potential data elements. We follow this with a brief appraisal of how the indicators match with the New Zealand Terrestrial Biodiversity Indicators proposed under the MfE Environmental Performance Indicators Programme (Froude 2003).

10. Objective, indicator, and measure descriptions for inventory and monitoring

10.1 Outcome Objective 1: Maintaining ecosystem processes

Generalised ecosystem function is always at the top of the list of priority topics in environmental monitoring internationally but, in the absence of a clear threat such as pollution or acid rain, it is difficult to derive meaningful measures that will have policy applications. These indicators can be seen more as an underlying data level, essential to understand and model other aspects, but not of themselves of particular policy or management importance.

Synopsis:

Indicator 1.1	**Soil status**
Measure 1.1.1	Soil carbon status
Indicator 1.2	**Productivity**
Measure 1.2.1	Net primary productivity of natural terrestrial vegetation
Measure 1.2.2	Mast flowering and fruit production
Indicator 1.3	**Water quality and yield**
Measure 1.3.1	Catchment water yield
Measure 1.3.2	Water chemistry
Measure 1.3.3	Stream invertebrate index
Indicator 1.4	**Ecosystem disruption**
Measure 1.4.1	Number, extent and control of fires
Measure 1.4.2	Disease outbreaks
Measure 1.4.3	Hydrological change
Measure 1.4.4	Mass erosion
Indicator 1.5	**Landcover**
Measure 1.5.1	Land under indigenous vegetation
Measure 1.5.2	Area under intensive land use

Indicator 1.1 Soil status

Soil is fundamental to ecosystem health, and changes can be demonstrated to have occurred in soil carbon and nitrogen storage with exotic mammal pressure in New Zealand (Wardle et al. 2001). However, soils are also highly variable in space, and time-consuming to measure. Except for localised episodes of erosion or rapid degradation, it is unlikely to change rapidly enough either physically, chemically or biotically to make it worth deriving tracking measures or indices, other than those collected for other purposes. Internationally, soils are recorded in nation-scale inventories, and invariably reported on when plot based systems are used. Nutrient status of soils, and microbiological health are also often recorded by direct chemical measures or biological proxies. Erosion, acting at different scales and intensities has been harder to quantify.

Measure 1.1.1 Soil carbon status

Description:	Standard measures of soil organic matter, aggregated to a national scale.
Explanation:	Fundamental data layer for models and assessments of overall ecosystem function Soil carbon is a measure of soil health. Stable, aggrading soils tend to have large carbon stores, while those under extreme pressure tend to lose carbon. Soil carbon is being measured as part of the Carbon Monitoring Scheme (CMS), and thus will be a useful proxy for changes in soil health but also connect with climate change and Kyoto Protocol issues. Percentage soil organic matter can be derived from the base elements that constitute the carbon measure. Percentage soil organic matter is recommended by the US National Academy of Sciences (2000) study: *Ecological Indicators for the Nation*, and EMAP of Environment Canada. Carbon/Nitrogen ratios are a key ecological measure in soil studies. Carbon storage in forests as a total is measured in the MfE-DOC CMS programme, but is of marginal relevance as a key indicator.
Monitoring type:	Inventory. Data collected in the course of other surveys.
Reporting frequency:	Infrequent and following major reassessments.
Data sources:	CRIs, MAF, DOC, universities.
Ownership and responsibility:	Not determined. The Carbon Monitoring Scheme and Landcare databases are currently the most extensive repositories.
Potential data elements:	1. Percentage carbon mapped at a national scale. 2. Carbon:Nitrogen ratio mapped at a national scale.

Indicator 1.2 Productivity

Productivity measures are widely used internationally, partly because they are considered to be an overall measure of the functioning of a vegetated landscape, and partly because they are increasingly easy to derive from remote sensing.

Measure 1.2.1 Net primary productivity (NPP) of natural terrestrial vegetation

Description:	Remotely sensed indicator of NPP at 1-km resolution (although metre-scale resolution available).
Explanation:	Fundamental data layer for a range of applications. NPP is the difference between gross primary production and all types of plant respiration. Because plant-fixed carbon is the energy

	source and substrate for all other ecosystem functions, it is a basic and useful indicator of ecosystem function. Remotely sensed NPP indices will act as an indicator of the stress experienced by canopy species, and perhaps act as a generalised early warning of approaching problems due to canopy disruption and climate change. Long time-series are necessary to make sense of seasonal trends. Very widely used from a regional to global scale (National Academy of Sciences 2000).
Monitoring type:	Status and trend.
Reporting frequency:	Monthly.
Data sources:	Commercial international satellite companies. Fundamental data widely available. Specialist analysis CRIs or universities.
Ownership and responsibility:	Overseas government and private agencies.
Potential data elements:	1. Net primary productivity data is widely available. Satellites routinely evaluate chlorophyll densities on a daily basis to scales as small as 100 m^2, and models convert these images to estimates of NPP. 2. Satellite-based estimates of above-ground carbon can augment ground-based carbon measures (Coomes et al. 2002).

Measure 1.2.2 Mast flowering and fruit production

Description:	Monitoring of selected sites for flowering and fruiting intensity.
Explanation:	A key data layer for ecosystem function. Has been demonstrated to be a critical element in predator–prey cycles. However, highly variable in space and time. Recent analyses have demonstrated a close correlation between beech seeding and previous summer temperatures (Schauber et al. 2002), raising the possibility of accurate predictions 14 months ahead.
Monitoring type:	Status and trend.
Reporting frequency:	Yearly.
Data sources:	DOC, CRIs, universities.
Ownership and responsibility:	Multiple
Potential data elements:	1. Seed production of beech, *Chionochloa* tussocks, tall podocarp trees measured at strategic regional forest sites (can be predicted 12–14 months ahead by temperature measures). 2. Flowering (primordia development) – typically occurs 12–14 months ahead, and may be a sensitive direct measure of potential fruit production. 3. Research monitoring of fruit production in complex forests.

Indicator 1.3 Water quality and yield

Of crucial importance to aquatic organisms and an indicator of the ability of natural ecosystems to deliver services. The MfE has developed a set of freshwater indicators including measures for the condition of: river water quality; lake water quality; occurrence of native fish; macroinvertebrates in rivers; and wetland extent. Local government measure a wide range of indicators also. For instance, the Otago Regional Council has indicators for surface water quantity and quality, freshwater aquatic biology, and regularly surveys for flow, solid matter, nitrogen, nitrates, phosphorus, faecal coliforms etc. and a range of biological indicators including benthic macroinvertebrates, periphyton, fish abundance and channel morphologies (Caruso 1999).

Measure 1.3.1 Catchment water yield

Description:	Standard measure of water flow from selected catchments. A measure of how natural ecosystem condition is affecting downstream values. Interpretation of the data will be key, and will need hydrological and climatological input and long-term data sets. A very widely recorded measure internationally.
Explanation:	Needed to establish how DOC land is affecting ecosystem values elsewhere.
Monitoring type:	Status and trend.
Reporting frequency:	Automation of measuring devices means frequency is not a problem. Monthly might be best.
Data sources:	CRIs, local government.
Ownership and responsibility:	NIWA, local government.
Potential data elements:	1. Water flow from selected catchments.

Measure 1.3.2 Water chemistry

Description:	A number of chemical species and physical factors are routinely measured (e.g. nitrates, phosphorus, clarity, chlorophyll, temperature).
Explanation:	Needed to establish how DOC land management is affecting ecosystem values elsewhere. Water chemistry and physical factors have a major effect on suitability for agricultural and domestic use, but also for aquatic life. Very widely measured in New Zealand, in particular by local government.
Monitoring type:	Status and trend. Laboratory analysis.
Reporting frequency:	Depending on state of waterway.
Data sources:	CRIs, local government.
Ownership and responsibility:	NIWA; local government; DOC.
Potential data elements:	1. Nitrates, phosphorus, chlorophyll for major rivers exiting DOC land. 2. Nitrates, phosphorus, chlorophyll, and clarity for a range of typical lakes on DOC land.

Measure 1.3.3 Stream invertebrate index

Description:	Many biotic indices, variously based on rapid surveys or quantitative data, are available.
Explanation:	Needed to establish how DOC land management affects ecosystem values elsewhere A very large number of ways of monitoring stream biotic health through macrophyte and invertebrate indices have been developed as a result of the increasing stress on maintaining the ecological integrity of waterways (Norris 1999). A basic split is between indices based on objective standards, which are very widely used overseas and in New Zealand and often codified in legislation, and those which use reference sites, and comparison of biotic state via a modelling approach (Reynoldson et al. 1997). As waterway

	health is more of a concern outside of the DOC-administered estate than inside it, but waterways are almost invariably shared, it would appear that this measure will have to be standardised nationally to be effective.
Monitoring type:	Status and trend. Field survey.
Reporting frequency:	Yearly.
Data sources:	Local government, CRIs.
Ownership and responsibility:	Local government; NIWA.
Potential data elements:	Situation too complex and stakeholders too diverse for definitive suggestions as yet. Will require a national-level decision.

Indicator 1.4 Ecosystem disruption

Fire is a major disturbance for indigenous ecosystems that support few fire-adapted plants, and the relative extent of fire across environments is an important indicator of ecosystem disruption and vulnerability to loss of indigenous components and weed invasion. It is widely used internationally in fire-prone countries where time since last fire is a key management factor. Fire causes loss of nutrients and biomass, creating potential for increased soil erosion and will eliminate fire-sensitive organisms. Disease outbreaks both in animals and plants have the potential to induce major changes in ecosystem functioning. For instance, the quantity and quality of biomass can be changed, key taxa reduced in abundance, and shifts occur in food web structure.

Measure 1.4.1 Number, extent and control of fires

Description:	Extent of natural areas burnt, based on ground surveys or aerial photography.
Explanation:	Fire has a fundamental influence on ecosystem status and properties and must be measured for that alone. Fire on DOC-owned land, or fire from DOC land that affects other landowners (and vice-versa) will be a crucial input to assessing risks, DOC management, and community relations. A number of agencies are involved in fire control and collaboration of reporting extent of fires should be possible. Natural and human fires need to be included, and over time the data could be used to identify vulnerable environments, and loss of indigenous biodiversity in relation to fire return time and vegetation condition.
Monitoring type:	Inventory.
Reporting frequency:	Yearly.
Data sources:	DOC; National Rural Fire Authority; local government.
Ownership and responsibility:	DOC, National Rural Fire Authority local government.
Potential data elements:	1. Number and extent of fires, by conservancy and environment. 2. Potential burnt area avoided by fire control (Estimate: can be calculated for large fires from fire models).

Measure 1.4.2 Disease outbreaks

Description:	Area or proportion of population impacted or number individuals affected.

Explanation: An important indicator of stress and/or exotic impact, often at ecosystem level. Required to give context for policy and management decisions and will provide early warning of possible catastrophic disease outbreaks. It will need a formal observational network. Basic information will have to be analysed in conjunction with other factors, such as climate, Disease outbreaks have had a substantial effect on New Zealand ecosystems in the past. For instance, mass outbreaks of seal deaths in the subantarctics, canopy defoliation in beech forests, sudden decline of cabbage trees etc. Increasing trade intensity with numerous potential sources of disease and associated vectors, climate change, and human disruption of ecosystems will undoubtedly result in increased episodic outbreaks of diseases important to the biota.

Monitoring type: Surveillance.

Reporting frequency: Yearly.

Data sources: DOC; universities; MAF; Industry; local government.

Ownership and responsibility: Uncertain.

Potential data elements:

1. Mass mortality of indigenous or non-indigenous vertebrates. Unusual events, determined by species-specific criteria.
2. Occurrence of diseases in native birds, reptiles, and marine mammals. Data already collected to some extent by DOC.
3. Mass mortality of canopy trees. Careful definition required as tree mortality tends to be obvious for many years after death occurs, and natural senescence of tree cohorts is common.

Measure 1.4.3 Hydrological change

Description: Changes in water table at conservation-sensitive sites.

Explanation: Data needed for management and to provide a basis for policy at sensitive sites. Adequate soil water is crucial for the maintenance of many critical habitats including some swamp forest remnants, wetlands, and streams and springs. Agricultural abstraction of water is changing the groundwater regime at many sites with marked impacts on wetlands. Data will have to be analysed in conjunction with standard climatic data and water abstraction data.

Monitoring type: Status and trend.

Reporting frequency: Yearly.

Data sources: NIWA; regional authorities; DOC.

Ownership and responsibility: NIWA; regional authorities; DOC.

Potential data elements:

1. Changes in average water table depth at sensitive locations – for instance close to important wetlands, forest remnants. DOC stations might need to be established near sensitive sites.

Measure 1.4.4 Mass erosion

Description: Area and percent change in devegetated land surface as determined by remote sensing (radar and optical imagery) for selected areas.

Explanation: In the past much attention was given to erosion as it was thought to be caused by browsing and grazing. Careful analysis now suggests it is largely caused by physical events, such as heavy rainfall and earthquakes. Assessment of changes in erosion will give basic information as to turnover rates in vegetation, vulnerability to future changes, susceptibility to invasion by exotic plants. Analysis of the entire DOC estate would be very expensive, and initially at least, acquisition of imagery for high-risk areas is all that is necessary.

Monitoring type: Status and trend.

Reporting frequency: According to event or area.

Data sources: A range of private and government-owned international agencies (e.g. Radarsat, SPOT). Landcare Research is developing a range of interpretive tools for satellite imagery.

Ownership and responsibility: DOC.

Potential data elements:

1. Total change in bared land surface reported by affected area in the event of major storm or earthquake, and analysed according to previous vegetation cover.
2. Change in vegetation cover versus bare ground in chronically eroding areas.

Indicator 1.5 Land cover

A fundamental data layer, and one that is considered of basic importance internationally as without indigenous vegetation cover neither soil or above-ground indigenous biodiversity can be maintained. Will record extent to which land in non-indigenous cover is being reclaimed, and which environments remain below a desirable minimum.

Measure 1.5.1 Land under indigenous vegetation

Description: Proportion of land surface under various categories of indigenous cover, stratified according to environment.

Explanation: A decision has to be made as to what data layer will support this. There is some uncertainty as to the updating of the LCDB series. Expensive ground-truthing will be required for future updates as it is not possible to distinguish native/non-native categories remotely.

Monitoring type: Status and trend.

Reporting frequency: 5 yearly.

Data sources: Currently Land Cover Data Base.

Ownership and responsibility: MfE, Terralink.

Potential data elements:

1. Percent indigenous vegetation cover according to environmental categories.

Measure 1.5.2 Area under intensive land use

Description: Area of land categorised according to intensity of human usage and irreversibility of change.

Explanation: Some large areas of New Zealand fall into a semi-wild category where numerous opportunities for indigenous biodiversity remain. Others are effectively alienated. Other than the continuing degradation of natural habitats by predators (which affects mainly large-sized indigenous animals) destruction of

	indigenous biodiversity of all size classes and functional grouping can be mainly attributed to continuing intensification of land use (Meurk & Swaffield 2000).
Monitoring type:	Status and trend.
Reporting frequency:	5 yearly.
Data sources:	Land Cover Database; but will probably have to be augmented with more specific categories.
Ownership and responsibility:	MfE; Terralink.
Potential data elements:	1. Land area covered with permanent structures; intensive agriculture; pastoral; or with minimum human impact.

10.2 Outcome Objective 2: Reducing exotic spread and dominance

Exotic pest and weed pressure is the most damaging factor to ecological integrity in New Zealand (Craig et al. 2000; Veitch & Clout 2002). While the most important outcome is predation of indigenous animals, reduction of palatable species by browsing and replacement of indigenous vegetation by weeds, they cause significant disruption to all manner of intricate ecosystem processes ranging from NPP to soil biota status. As the various effects and interactions are poorly understood, good data on distribution and abundance of the primary agents are needed.

Synopsis:

Indicator 2.1	**Naturalisation of new weed and pest species**
Measure 2.1.1	Occurrence of self-maintaining populations of new potential environmental weeds and pests
Indicator 2.2	**Exotic weed and pest dominance**
Measure 2.2.1	Distribution and abundance of exotic weeds and pests considered a threat
Measure 2.2.2	Indigenous systems released from exotic pests

Indicator 2.1 Naturalisation of new weed and pest species

Good border security and effective surveillance mechanisms in central and local government make this indicator highly reliable as a global measure of progress in containing increasing novel pressure. There is a great deal of international evidence that early detection and management is the only feasible way of preventing spread (Mack et al. 2000).

Measure 2.1.1 Occurrence of self-maintaining populations of new potential environmental weeds and animal pests.

Description:	Updated list of new species meeting the criteria, with location and distribution. This measure is not intended to deal with the problem of already well established weeds and pests.
Explanation:	Measure of size and potential threat of exotics for policy. Basic data for sizing problem and demonstrating effectiveness of border control. Also provides management-relevant information. DOC already has good exotic pest and weed surveillance in place. Data layer for eliminations provided by conservancy control operations. Provides indication of effort and success. Tightly

linked with the New Zealand Biosecurity Strategy and Biosecurity Act.

Monitoring type: Inventory and surveillance.
Reporting frequency: Yearly.
Data sources: MAF, DOC, regional councils.
Ownership and responsibility: DOC, MAF, regional councils.
Potential data elements:

1. Standard list of potentially serious weeds and pests, mapped individually, with abundance scale. Extent and significant changes reported. Data layer provided by weed and pest surveillance team; scale and intensity of surveillance tailored for each weed and pest.
2. Eliminations (purposeful) of discrete populations, reported by species and conservancies, and total weed-elimination effort.

Indicator 2.2 Exotic weed and pest dominance

Exotic pest and weed dominance is of more importance than simple numbers of exotic species present because of the threat to indigenous persistence, realignment of ecosystem processes, and the destruction of socially valued aspects of ecosystems.

Measure 2.2.1 Distribution and abundance of exotic weeds and pests considered a threat

Description: Mapped distributions, abundances and eliminations recorded of most important pests that threaten ecological integrity.
Explanation: Tool for priority setting and quantifying threats to ecological integrity.
Monitoring type: Inventory and surveillance.
Reporting frequency: 1–10 years (species dependent).
Data sources: MAF, DOC, local government.
Ownership and responsibility: DOC
Potential data elements:

1. Mapped ranges of all exotic vertebrate pests, and selected environmental weeds and invertebrates (e.g. wasps, defoliating insects, invasive lianas) considered a risk.
2. Mapped abundance data (indices) at selected sites relevant to DOC management for: possum, deer, caprids, mustelids, rats, mice, rabbits and hedgehogs (hare?, pig?). (Data to be used primarily for correlation with other indicators of impact, and also for measurement of response to wide-scale control.)
3. Mapped abundance data for high-risk weed and invertebrate pests.
4. Eradication of specific infestations and resource expended (data layer provided by conservancy).
5. Broad-scale control operations: area, location and costs (data layer provided by conservancy); fundamental data layer to underpin others concerned with pest abundance and impact.

Comment: New populations of weeds and pests are occurring (animal pests not so regularly) either via escape or self-colonisation. Surveillance monitoring should provide an up-to-date indication of where the new populations are and demise of old infestations. A major concern of regional councils, which maintain databases on the problem but emphasise agricultural pests and few weeds but not consistently the environmental pests DOC is interested in (e.g. Environmental Waikato has some documentation).

Measure 2.2.2 Indigenous systems released from exotic pests

Description:	Area of indigenous systems with no significant predatory or browsing mammals
Explanation:	Increasingly this is seen as the only secure means of preserving indigenous ecosystems with totally intact ecological integrity. Allows quantifiable demonstration of effectiveness of management in conservation of indigenous biodiversity through removal of exotic pests.
Monitoring type:	Status and trend; management; surveillance.
Reporting frequency:	5 yearly.
Data sources:	DOC.
Ownership and responsibility:	DOC.
Potential data elements:	1. Area and location of sites free of significant impact of categories of mammalian pests (all, possum, rat, mustelids, deer, goats, hedgehogs, etc.). (DOC central data layer; documents growth of pest-free areas and mainland island movement.) 2. Resource cost of achieving and maintaining pest-free status at chosen level. (DOC central data layer; allows the reporting of cost versus outcome).

10.3 Outcome Objective 3: Environmental pollutants

While not as major a concern for DOC in New Zealand as it is in Northern Hemisphere countries, this issue ranks high with conservationists and the public alike. Effects on ecosystem functioning of toxins used in animal control are likely to be pervasive but are poorly understood (Innes & Barker 1999).

Synopsis:

Indicator 3.1 Ecosystem levels of persistent toxins

Measure 3.1.1 Accidental release and chronic contamination by chemicals

Measure 3.1.2 Toxins in selected tissues of wildlife

Indicator 3.1 Ecosystem levels of persistent toxins

Of all the issues that affect that section of the general public indifferent to core conservation issues, this probably alarms them the most. It is essential that DOC has good information on this issue.

Measure 3.1.1 Accidental release and chronic contamination by chemicals

Description:	Accidental release of toxic chemicals and locations and area affected by chronic chemical contamination.
Explanation:	This measure assesses the degree to which DOC land is at risk from pollution. It is of most of relevance to waterways and foreshore/inshore marine areas through assessing the risk posed

	by agriculture, industry, and shipping to freshwater and marine biodiversity.
Monitoring type:	Inventory, surveillance (as required).
Reporting frequency:	Annual.
Data sources:	DOC; regional councils; CRIs?
Ownership and responsibility:	DOC.
Potential data elements:	1. Number of spills, area affected, and damage caused by accidental release of toxic substances. 2. Chronic contaminated sites – number and area affected of old dumps, mine tailings etc. with the potential to affect biodiversity values.

Measure 3.1.2. Toxins in selected tissues of introduced wildlife and native species for which poisoning is suspected (for toxins on DOC pesticide advisory group priority list only).

Description:	Laboratory analysis of tissue collected.
Explanation:	Essential data layer addresses potential side effects of pest and weed control activities. Essential information of great interest to the general public as to potential influence on whole ecosystem of environmental chemicals, especially those used as toxins for animal and plant control. Useful for setting limits on toxin use.
Monitoring type:	Surveillance.
Reporting frequency:	Yearly. (Or as required, e.g when using new toxin for control work and on priority list.)
Data sources:	DOC, MAF, Ministry of Health, local government.
Ownership and responsibility:	DOC
Potential data elements:	Periodic surveys of a random selection of introduced species for priority toxins used in control work (e.g. first-generation anticoagulants).

Comment: Surveys have been carried out in the past on 1080 (not persistent), brodifacoum, and other toxin levels, and there is considerable experience available and ongoing monitoring to plan and integrate with this measure. DOC aims not to use persistent toxins, so when a new toxin is used a risk assessment is undertaken and monitoring protocol decided on by the DOC Pesticide Advisory Group.

10.4 Outcome Objective 4: Preventing declines and extinctions

A wide range of measures are used here by countries reporting to the CBD. Definitions used here follow the New Zealand standard classification (Molloy et al. 2002). A taxon is defined as: 'A taxonomic group of any rank, including all the subordinate groups; any group of organisms, populations or taxa considered to be sufficiently distinct from other such groups to be treated as separate units' (Lincoln et al. 1998).

Measures 4.1.1, 4.2.1 and 4.3.1 are basic inventories of taxa in different categories of threat. Measure 4.2.2 and 4.3.2 are indicators of the amount of effort being put into conservation management, while the remaining measures describe the outlook and efficacy of management for these threatened species.

Synopsis

Indicator 4.1. Extinct taxa
Measure 4.1.1 Number of indigenous taxa presumed extinct

Indicator 4.2 Status of acutely threatened taxa
Measure 4.2.1 Number of acutely threatened indigenous taxa
Measure 4.2.2 Number of acutely threatened taxa under active management
Measure 4.2.3 Security of acutely threatened taxa under active management
Measure 4.2.4 Demographic response to management at population level for selected taxa under active conservation management

Indicator 4.3 Status of chronically threatened taxa
Measure 4.3.1 Number of indigenous chronically threatened taxa
Measure 4.3.2 Number of chronically threatened taxa under active management
Measure 4.3.3 Security of chronically threatened taxa under active management
Measure 4.3.4 Response to management of chronically threatened taxa

Indicator 4.4 Genetic change in critically reduced species
Measure 4.4.1 Changes in quantitative genetic characters

Indicator 4.1 Extinct taxa

Increases in the number of extinct taxa is the most direct indication of irreversible change in ecological integrity. Usually a date is set in the immediate past to make sure that the baseline is not influenced by non-human or pre-nation state activities. In New Zealand the baseline is generally agreed as being the time of formal British assumption of power in AD 1840 (Hitchmough 2002; Molloy et al. 2002).

Measure 4.1.1 Number of indigenous taxa presumed extinct

Description:	List of extinct taxa.
Explanation:	Quantitative measure of a major conservation goal, and universally reported. Pre-European extinctions should also be listed separately.
Reporting frequency:	According to frequency of revision of New Zealand Threat Classification lists (5-year intervals, next revision 2005).
Monitoring type:	Inventory.
Data sources:	DOC, CRIs, universities, local government. Hitchmough (2002), subsequent revisions of Hitchmough (2002), and revisions endorsed by Recovery Groups (e.g. Bat Recovery Group, revision DOC DME File WSCCO-42341, or NZ Ornithological Society Checklist (baseline see: http://bird.org.nz/nzrbn.htm).
Ownership and responsibility:	DOC.
Potential data elements:	1. List of extinct taxa summarised by taxonomic group and time period in which the extinction occurred. Extinct within New Zealand is defined as 'not seen for 30 years despite presence of management effort'.

Indicator 4.2 Status of acutely threatened taxa

A large amount of resources is devoted to the conservation of acutely threatened taxa and they attract a great deal of public interest. They pose difficult problems for priority setting as well because of the irreversible nature of the failure should it occur. Given the sensitivities around potential extinction it is important that as much information is made available as to progress and outlook as possible. The number of endangered and vulnerable organisms is routinely reported by many countries through the IUCN Red List.

Measure 4.2.1 Number of acutely threatened indigenous taxa

Description: Number and proportion according to New Zealand Threat Classification list: nationally critical, nationally endangered, and nationally vulnerable (Molloy et al. 2002).

Explanation: Acutely threatened taxa should never be presented as a single number without an explanation as to those which have entered or left the list due to genuine change in conservation status. The main shortcoming of this measure is the frequent change in the status of some threatened taxa resulting from taxonomic revision. Such changes influence the number of each taxon in each threat category but do not reflect genuine changes in status. This issue needs to be dealt with carefully in subsequent reports. Proper documentation of changes will be required. Some categories may require explanatory qualifiers.

Relisting also results from increases in information about a taxon or increases in survey intensity (most often for data-deficient species), but again, not from genuine changes in status. Where new threatened species are added to the list in the future or status improves or changes, we might need to increase the number of columns on the report to show these different categories of change explicitly.

Reporting frequency: According to frequency of revision of New Zealand Threat Classification lists (5-year intervals, next revision 2005).

Monitoring type: Inventory; status and trend.

Data sources: DOC, CRIs, local government, universities.

Ownership and responsibility: DOC.

Potential data elements:

1. Number of indigenous taxa by acutely threatened categories according to broad taxonomic groupings and also environmental zone.
2. Changes in number of indigenous taxa in acutely threatened categories due to alteration in conservation status only.

Measure 4.2.2 Number of acutely threatened taxa under active management

Description: A summary of the effort being put into active conservation management of acutely threatened taxa. Active conservation management is divided into:

- **Under surveillance** only in order to detect change, where a taxon is being monitored in some way and the results are being used to signal when and where more active intervention is required;

- **Increasing knowledge**, where research or investigations are being undertaken in order to define threats or understand basic ecology etc.
- **Low-level intervention**: where management is currently indirect in the form of a contingency plan, such as an island predator invasion contingency plan.
- **Active intervention**: where management is at its most active and generally involves having specific business projects linked to outcomes (e.g. weed or predator control). Includes taxa managed as species assemblages, and is likely to include some monitoring and/or research.

Explanation:	This measure is needed to quantify the effort put into active management of acutely threatened species. Following indicators attempt to describe not only the outlook for managed taxa but also the extent of management, such as the number of Conservation Management Units or the extent of a species range or proportion of population being managed for each.
Monitoring type:	Inventory of DOC business plans and annual reports of other institutions.
Reporting frequency:	Annual.
Data sources:	Mainly DOC, but also local government. Biodiversity Recovery Unit for number of Recovery Plans. Recovery Groups and designated Lead Conservancies for species without Recovery Plans for information on type of monitoring.
Ownership and responsibility:	DOC.
Potential data elements:	1. Number of acutely threatened taxa according to categories outlined in the description.

Measure 4.2.3 Security of acutely threatened taxa under active management

Description:	A semi-quantitative assessment of the outlook of each actively managed, acutely threatened species based on Recovery Group outcome monitoring and reported as changes in security status.
Explanation:	All acutely threatened species should be under some type of management, whether it be surveillance, maintenance (passive or indirect) management or active intervention. Recovery Groups have a wide range of quantitative and qualitative assessments available to them and each recovery programme is likely to be different. This is an annual, best-information-available answer, provided by those closest to the species in question as to the success of this management. Managers can thus learn from successes and failures to improve security over time. The measure also highlights where management effort should be increase or improved. Similar indices are widely used internationally, but in a range of guises. Will be an essential data layer in quantifying success versus conservation investment.
Monitoring type:	Surveillance. A range of techniques may have to be employed such as census data, survival estimates from mark-recapture analysis or robust population indices.

Reporting frequency: Estimates are likely to be required annually for robust assessment of population trends in the highest categories of risk.

Data sources: Mainly DOC Recovery Groups and Lead Conservancies, but also Universities and local government.

Ownership and responsibility: DOC.

Potential data elements:

1. Status of managed acutely threatened taxa, presented as a categorical listing (i) highly improved, (ii) improved, (iii) unchanged, (iv) declined, (v) declining rapidly, or (vi) unknown.

Measure 4.2.4 Demographic response to management at population level for selected taxa under active conservation management

Description: Robust demographic data for intensively managed species, in terms of births, deaths and population size correlated to management effort and variability in factors responsible for declines. Can be actual current trend or predicted population trend with and without management. A simple index for each species could be derived from the underlying population data to enable an overview. Five methods can be described:

a) Complete census of number of individuals of a taxon (e.g. kakapo).
b) Complete census of number of populations in a taxon (e.g. *Atriplex hollowayi*).
c) Range (ha) of a taxon (e.g. mohua).
d) Predicted population from a rigorous population model (e.g. South Island long-tailed bat).
e) An indirect index of activity or change that has been calibrated against population response (e.g. kaka distance sampling).

Explanation: Will demonstrate return for the most intensive investment made in species conservation. Also will provide detailed information of species status for policy purposes, but is a complex index. Number of species under surveillance documents expanding effort and knowledge rather than failure. Therefore, changes in populations/numbers will be the key index of the success of active conservation management. Current monitoring effort is very patchy in terms of taxa, geographic coverage, and length of time series. The availability of conceptually valid and scientifically rigorous data is limited. Ultimately recovery should be expressed in terms of an ideal for the species, and not simply as increases against the initial pre-intervention state (Schemske et al. 1994).

Monitoring type: Management. A range of techniques will need to be employed such as census data, annual productivity measures, population viability (PVA) models, survival estimates from mark-recapture analysis or robust population indices, closely correlated to management effort.

Reporting frequency: Likely to be taxon-specific because of the large investment in developing appropriate reporting models. Unlikely to be annual because it often takes 3–10 years to develop robust indicators of population trend for longer-lived threatened species.
Data sources: Mainly DOC.
Ownership and responsibility: DOC.
Potential data elements: 1. Demographic data for intensively managed species.

Indicator 4.3 Status of chronically threatened taxa
Chronically threatened species are regarded as being of particular importance as they have not been reduced to critically small populations where conservation choices dramatically narrow because of lack of experimental capacity to identify causes of decline, and compromised genetics. A wide range of measures are used here by countries reporting to the CBD, and in local and provincial reporting in Canada and the United States. Definitions used here follow the New Zealand standard classification (Molloy et al 2002).

Measure 4.3.1 Number of indigenous chronically threatened taxa
Description: The number of chronically threatened taxa and proportion in each category (serious decline or gradual decline) and percentage change, according to the New Zealand Threat Classification System List.
Explanation: A broad policy-relevant measure as many of this group have recently had wider ranges and intervention may be more effective. The aim is to demonstrate change in the proportions in each category if warranted, with taxa moving from the more threatened to less threatened categories over time. Summary tables will need to be corrected for taxonomic reviews so that reports do not confuse changes that result from such reviews with real changes in the security of taxa.
Reporting frequency: According to frequency of revision of New Zealand Threat Classification lists (3-year intervals, next revision 2005).
Monitoring type: Inventory. Standard techniques.
Data sources: DOC, CRIs, universities. Hitchmough (2002), subsequent revisions of Hitchmough (2002), and revisions undertaken or endorsed by Recovery Groups.
Ownership and responsibility: DOC.
Potential data elements: 1. The number of chronically threatened taxa and proportion in each category (serious decline or gradual decline) and change.

Measure 4.3.2 Number of chronically threatened taxa under active management
Description: Number and proportion of indigenous taxa classified in the New Zealand Threat Classification list as in serious decline or gradual decline.
Explanation As for 4.2.2 (Acutely threatened taxa).
Monitoring type: Surveillance, supported by status and trend measures. Standard techniques.
Reporting frequency: Annual or *a*ccording to frequency of revision of New Zealand Threat Classification lists (3-year intervals, next revision 2005).

Data sources:	DOC, CRIs, universities, local government. Biodiversity Recovery Unit for number of Recovery Plans. Recovery Groups and designated Lead Conservancies for species without Recovery Plans for information on type of management.
Ownership and responsibility:	DOC.
Potential data elements:	1. Number of chronically threatened taxa under active management: A. Under surveillance, Increasing knowledge: where research or investigations are being undertaken in order to define threats or understand basic ecology etc. B. Low-level intervention; C. Active intervention.

Measure 4.3.3 Security of chronically threatened taxa under active management

Description:	Trend in security reported as number of taxa whose security is (i) highly improved, (ii) improved, (iii) unchanged, (iv) declined, (v) declining rapidly, or (vi) unknown. To describe the overall trend in the security of chronically threatened taxa since the last report after considering achievements/performance at all sites where the taxon is managed. A semi-quantitative assessment of the outlook of each actively managed, chronically threatened species based on Recovery Group outcome monitoring. Best presented as a categorical listing (number increasing, stable, and decreasing).
Explanation:	As for measure 4.2.3.
Reporting frequency:	Yearly.
Reporting Agency:	DOC.
Data Sources:	Mainly DOC Recovery Groups and Lead Conservancies, but also universities and local government.
Ownership and responsibility:	DOC.
Potential data elements:	1. Taxa whose security is (i) highly improved; (ii) improved; (iii) unchanged; (iv) declining rapidly; (v) unknown.

Measure 4.3.4 Response to management of chronically threatened taxa

Description:	Mapped range or demographic data for taxa classified as in New Zealand Threat Classification list as in serious decline or gradual decline.
Explanation:	As for 4.2.4. (acutely threatened species).
Monitoring type:	Status and trend.
Data sources:	Mainly DOC Recovery Groups and Lead Conservancies, but also universities and local government.
Ownership and responsibility:	DOC.
Potential data elements:	1. Changes in mapped range or demographic data for chronically threatened taxa that are actively managed.

Indicator 4.4 Genetic change in critically reduced species

Inbreeding depression can theoretically lead to an extinction vortex in which chance events have a devastating effect on weakened populations (Lacy & Lindenmayer 1995). However, neutral variability is lost very slowly from populations, and 'useful' variability much more slowly than that (Amos & Balmford 2001), which would suggest that a generalised threat through genetic erosion is possibly small, even in populations of limited size. Routine genetic analysis of merely small populations therefore may not be called for but genetic monitoring may be more relevant where reduction in population size has been major, sudden and under stressful conditions and particularly following prolonged population bottlenecks. At the moment there is insufficient information available to activate this indicator and measure in the near future, but it is included because it should have high priority for development.

Measure 4.4.1 Changes in quantitative genetic characters

Description:	A quantitative measure of factors known to be affected adversely by low population size and reduced genetic diversity.
Explanation:	Genetic assessment of critically reduced species is needed to properly manage and report on risk profiles. Survivorship of species that have gone through very low population sizes is compromised by alteration of the genetic structure of the species where many more deleterious genes are expressed. For critically endangered species with small population sizes, selected measures such as breeding success, genetically compromised young, growth rates, and disease status should be recorded to establish whether the programme is successful in ensuring the longer-term survival of the species. Although measurements can be made of genetic variability, and this used as a rough guide to the degree to which this change has happened, it is not a reliable guide by itself to the status of quantitative genetic characters that can be measured and directly affect the survivorship of individuals, and determine the evolutionary future of the species. Molecular and quantitative measures of genetic variation have only a weak correlation, and no significant relationship exists between measures for life-history traits or adaptive potential (Reed & Frankham 2001). Current knowledge is very limited and it is unlikely that DOC could report on a range of taxa in the near future. However, investment in increasing understanding of the genetics of massively reduced populations is continuing, and this measure is included.
Monitoring type:	Management.
Reporting frequency:	Yearly or once per generation as appropriate.
Data sources:	DOC, CRIs, universities.
Ownership and responsibility:	DOC.
Potential data elements:	Requires further investigation

10.5 Outcome Objective 5: Ecosystem composition

Direct human intervention and pests have degraded ecosystem composition. Change back from this state is likely to be slow, and the following set of indicators is about providing background information to guide an assessment of changes in composition. The key concept behind this indicator is the notion that there are functional plant types and animal guilds that should be expected in a region or patch if it is to be said to have ecological integrity. However, the identity and role of the components are important, so the requirements of such an indicator are not met by species diversity indices.

Synopsis:

Indicator 5.1 Composition

Measure 5.1.1	Size-class structure of canopy dominants
Measure 5.1.2	Demography of widespread animal species
Measure 5.1.3	Representation of plant functional types
Measure 5.1.4	Representation of animal guilds

Indicator 5.2 Occupancy of environmental range

Measure 5.2.1	Extent potential range occupied by focal indigenous taxa

Indicator 5.3 Patch size/fragmentation of wooded ecosystems

Measure 5.3.1	Degree of connectivity in transformed landscapes

Indicator 5.1 Composition

While ecosystem function can be maintained for most purposes by indigenous pressure-resistant and exotic species, and many threatened and endangered species have never occupied significant ranges or played important ecosystem roles, maintaining a balanced composition of the plants and animals typical and important to a region is a major conservation goal. The following measures are aimed at determining how well this goal is met.

Measure 5.1.1 Size-class structure of canopy dominants

Description:	Size-class structure of abundant trees can be represented as histogram plots at a range of scales from national to local.
Explanation:	Early warning at a range of scales of long-term changes/problems. Data from permanent-plot network: supplemented for rare or infrequent species. Certain species (e.g. Hall's totara, kohekohe, tree fuchsia) are thought to be under unnatural stress due to a complex of causes, often suggested to be browsing (Payton 2000). Imbalances between mortality and recruitment have been demonstrated at a national scale in New Zealand for some trees (Bellingham et al. 1999). While it is accepted that there will be no way of establishing 'optimal' size structures, national and ecosystem trends in populations of these species should be tracked, including changes in size-class structure of selected dominants as an early-warning system for possible ongoing problems or changes. A widely used measure in forested ecosystems in North America and Europe.
Monitoring type:	Status and trend. Survey field measurements.
Reporting frequency:	Changes slowly, so 5–10 years is appropriate.
Data sources:	CRIs, local government. NVS database major repository.
Ownership and responsibility:	Landcare Research.
Potential data elements:	1. All woody species in plot database. Size structure with diameter classes chosen individually for each species. Presented on scales from national to catchment depending on species distribution and nature of change.

Measure 5.1.2 Demography of widespread animal species

Description:	Recruitment and populations at sites can be represented as trend plots of local density, population size, and range, based on underlying population data. These can be nested within management treatments or along landscape development gradients, to understand mechanisms driving change.
Explanation:	Local or regional extinctions of previously widespread and common animals provide early warning of long-term changes/problems. Data from a permanent observation network of common bird and lizard species, for example, could identify shifts in composition for species that are slowly declining due to complex causes. Regional and national measurements provide early warning of declines or increases, long before active management is considered.
Monitoring type:	Combination of management, status and trend and survey field measurements.
Reporting frequency:	Taxon specific and changes slowly, so 5–10 years is appropriate.
Data sources:	CRIs, specialist bird/reptile societies.
Ownership and responsibility:	DOC.
Potential data elements:	1. Demographic or local abundance data for a suite of nationally widespread species. Presented on scales from national to regional depending on species distribution and nature of change.

Measure 5.1.3 Representation of plant functional types

Description:	Amalgamated data for trends in population structure of key functional types to capture broad trends obscured by species-specific data.
Explanation:	To obtain nationwide trends on subtle but ultimately important changes in ecological integrity. Many plant species do not have a nationwide distribution but, if grouped with species that react in a common way to environmental factors, can provide information on general trends. Use of plant functional types is` widespread in the modelling community (Walker et al. 1999) and is now essential to interactive modelling. It is possible that groups such as epiphytic bryophytes, ground bryophytes, and N-fixing lichens could qualify as significant functional types because of their importance to overall ecosystem processes.
Monitoring type:	Status and trend; data layer from other programmes.
Reporting frequency:	5-yearly or longer.
Data sources:	CRIs, DOC, MfE. NVS database; CMS scheme.
Ownership and responsibility:	Landcare Research.
Potential data elements:	1. Representation by functional groups (not necessarily non-overlapping): kauri; warm-temperate conifers; cool-temperate conifers; broadleaved warm-temperate tree angiosperms; broadleaved cool-temperate tree angiosperms; beeches; small-leaved shrubs; broad-leaved shrubs; forest climbers; shrubland climbers; forest herbs; open country herbs; forest graminoids; grasses; alpine shrubs; alpine

herbs; cryptogams. Analysed together and separately for indigenous and non-indigenous categories.
2. Representation by sensitivity to pressure (i.e. browse sensitivity categories).
3. Representation by ecosystem resource provision (i.e. nectar-bearing; fruit, nest-hole trees).

Measure 5.1.4 Representation of animal guilds

Description:	Representation of animal guilds on a functional, compositional or body-size basis.
Explanation:	There is concern that losses of certain animal guilds involved in key ecosystem services such as pollination, dispersal, and litter decomposition will lead to a serious degradation of ecological integrity. Other indicators capture the broad distribution of animal species, but give little idea as to whether they are operating in functional communities and guilds. They could therefore overestimate ecosystem functionality. There are a number of indices and techniques that focus on community-level organisation but further development will be necessary before they could be used with confidence.
Monitoring type:	Status and trend; research.
Reporting frequency:	5-yearly or longer.
Data sources:	CRIs, DOC, MfE.
Ownership and responsibility:	DOC
Potential data elements:	1. Abundance of invertebrates in trophic guilds (carnivores, herbivores, detritivores etc.) at selected representative sites. 2. Mapped presence/abundance of insect and vertebrate pollinators. 3. Mapped presence/abundance fruit-dispersing birds.

Indicator 5.2 Occupancy of environmental range

Species that are limited by adverse ecological factors, such as predators or habitat disruption, typically have very much smaller, atypical and fragmented ranges than those less affected. The extent to which they occupy their potential range can be regarded as a surrogate for cumulative pressure upon them, and this indicator is therefore widely used internationally. The ultimate baseline for a species' occurrence is its potential ecological range. However, as this potential range is often effectively unbounded, it is more common to use some version of its historical range, or modelling based on its historical range.

Measure 5.2.1 Extent potential range occupied by focal indigenous taxa

Description:	Present mapped extent or abundance of still-widespread taxa known to have had once larger, or more intensive occupied ranges.
Explanation:	This measure focuses on taxa before they are critically endangered, and will report on the hollowing out of significant taxa across the landscape. Shrinkage in area occupied by once-abundant species and still widespread (e.g. bellbirds, kahikatea) is a sensitive index of changing environment quality. Widely used as an indicator internationally. Changes should therefore be a solid indicator of improvement or degradation in

	ecological integrity. Focal species could be variously determined (size, importance in ecosystem functioning, public concern, value as indicator of a more general collapse of ecological integrity). A variety of techniques could be used – perhaps permanent-plot networks for the more immobile taxa, nationwide repeated plotless surveys for birds.
Monitoring type:	Status and trend.
Reporting frequency:	Determined by remeasurement of basic survey and surveillance of vulnerable species.
Data sources:	DOC, local government, CRIs, amateur groups.
Ownership and responsibility:	DOC.
Potential data elements:	1. Ranges and/or mapped abundances of highly significant taxa in relation to potential range as established through past occurrences and environmental envelope modelling (potential list includes all indigenous birds, frogs and lizards; browse-sensitive plants (mistletoes, fuchsia, *Elymus*); surface-dwelling invertebrates above a given size (weta, large weevils, molluscs); specialist dry country plants (i.e. some *Olearias*; *Pachystegia*).

Indicator 5.3 Patch size/fragmentation of wooded ecosystems

When the primary natural vegetation cover is broken up into small patches separated by wide distances of exotic- or disturbance-dominated landscape, the ability of indigenous organisms to spread from one patch to another is decreased, the rate of loss of indigenous species increases, and the ability of the patch to persist intact after disturbance or stress is reduced (Lindenmayer et al. 2000). Fragmentation is used as a primary ecosystem index in a number of overseas reporting schemes (e.g. Ontario Ministry of Natural resources 2002), but often at too wide a scale and too generally to have much policy relevance. However, although fragmentation is usually of little concern in tracts of natural ecosystems, it is when it results from unusual dieback of the primary canopy cover, or when a high proportion of the indigenous cover is supplanted by exotics. Here, measurement of a number of such areas, and degree and rate of change, may be important.

Measure 5.3.1 Degree of connectivity in transformed landscapes

Description:	Index recording patch size, and average distances between forest or scrub patches in landscapes where indigenous values are reduced to very low levels (transformed landscapes such as dairying areas), or where canopy collapse is occurring.
Explanation:	Measure of improvement or deterioration of key areas. While much of the landscape is now stable because it is in the conservation estate, changes will occur in recently acquired pastoral land and over the private estate. For DOC purposes, should be applied in areas where rapid change is an issue, such as rapidly recovering pastoral land or browse- or disease-affected canopies. Remotely sensed images can be analysed using a variety of algorithms to help predict the degree to which the patches are vulnerable to a variety of threats to their integrity. However, will need ground-truthing to establish degree of indigenous cover.
Monitoring type:	Status and trend.

Reporting frequency:	Depends on areas chosen. On transformed landscapes, long intervals of several years to a decade. In areas of canopy collapse, more frequently.
Data sources:	Commercial satellite remote sensing; local government, DOC. Land Cover Database.
Ownership and responsibility:	DOC/local government.
Potential data elements:	1. Number, size and area-to-edge ratios of patches of indigenous forest or tall shrubland patches in largely transformed landscapes or in those of particular conservation concern.

10.6 Outcome Objective 6: Ecosystem representation

Indicators as to the survivorship of intact ecosystems relative to their original extent and, more often, the legal protected status of such lands, are very widely reported internationally. For instance, over 80% of the nations reporting to the CBD use indicators relating to these factors. However, in developed nations like New Zealand, such measures change slowly, and can be regarded as inventory background information rather than indicators to be tracked and reported on at frequent intervals.

Synopsis:

Indicator 6.1 Environmental representation and protected status

Measure 6.1.1	Proportion of environmental unit under indigenous cover
Measure 6.1.2	Proportion of environmental unit under indigenous cover and protected.
Measure 6.1.3	National change in extent and integrity of threatened naturally uncommon and significantly reduced habitats
Measure 6.1.4	Proportion of threatened naturally uncommon and significantly reduced habitats protected

Indicator 6.1 Environmental representation and protected status

Internationally, this is perhaps the most widely collected and reported indicator. It is an essential inventory basis for other indicators, and it is now simple to collect at a coarse level through remote sensing. However, a great deal of further development will have to occur before anything other than general ecosystem-specific information will be able to be incorporated in these sorts of measures.

Measure 6.1.1 Proportion of environmental unit under indigenous cover

Description:	Percentage of LENZ environments in natural indigenous cover.
Explanation:	This measure is a quantification of the transformation of the New Zealand landscape and assesses the degree to which the potential for indigenous biodiversity is realised. Land Cover Data Base provides cover classes, and LENZ a convenient division of environmental space. (No correlation has yet been demonstrated between LENZ environments and indigenous biodiversity, but they are good indicators of potential for human transformations.) It will also provide a guide to acquisition policies. While not an indicator to be closely tracked, it is a powerful tool for informing policy decisions on the relative worth of various conservation lands.

Monitoring type:	Inventory. Data layers available from other programmes.
Reporting frequency:	10 years or on a rolling basis.
Data sources:	CRIs, MAF, DOC. Remote sensing data layers.
Ownership and responsibility:	Landcare Research/DOC.
Potential data elements:	1. Use of an environmental layer to stratify the landscape and then to assess the proportion of indigenous cover.

Measure 6.1.2 Proportion of environmental unit under indigenous cover and protected

Description:	Measure 6.1.1. with legal status layer included
Explanation:	To inform policy decisions on adequacy of protected land extent and the relative worth of various conservation lands.
Monitoring type:	Inventory. Data layers available from other programmes.
Reporting frequency:	10 years or on a rolling basis.
Data sources:	CRIs, MAFF, DOC. Remote sensing data layers.
Ownership and responsibility:	DOC.
Potential data elements:	1. Proportion of (6.1.1) which is predominately under indigenous cover and also protected.

Measure 6.1.3 National change in extent and integrity of threatened naturally uncommon and significantly reduced habitats

Description:	Detailed mapping of naturally uncommon and significantly reduced habitats using a variety of sources, and assessment of ecological integrity using habitat-specific techniques.
Explanation:	A critical factor in the preservation of certain suites of endangered and vulnerable species is specialised habitat. An example is the nationally imperilled sand dune habitat, which in an unmodified state is down to small patches, and the seasonal fluctuating pond habitat, home to over one-third of the flora, but in often highly developed settings. Work will have to be put into defining such habitats and devising objective measures for their total extent and integrity. Similar measures are used overseas, for instance the comprehensive Australian National Land and Water Resources Audit of the National Heritage Trust. Provides a measure of efficacy of protection and management
Monitoring type:	Inventory; Status and trend. (Remote sensing, aerial interpretation, ground-truthing.)
Reporting frequency:	5-yearly on a rolling basis.
Data sources:	DOC; regional government.
Ownership	DOC.
Potential data elements:	1. Dunelands and unstable alluvium. 2. Lowland bogs. 3. Lowland swamps. 4. Upland bogs. 5. Tarns and empheral lakes. 6. Dryland forest and shrublands. 7. Lowland rock outcrops. 8. Proportion of the above in some form of statutory protection.

Measure 6.1.4 Proportion of threatened naturally uncommon and significantly reduced habitats under protection

Description:	Derivation of Measure 6.1.3 with addition of protected area status.
Explanation:	Will permit accurate assessment of the degree to which these habitats are protected, and efficacy of the protection.
Monitoring type:	Status and trend.
Data sources:	DOC; regional government.
Ownership	DOC.
Potential data elements:	1. As in description and 6.1.3.

10.7 Outcome Objective 7: Climate change and variability

Climate change is not one of the top concerns for conservation of the natural environment in New Zealand, although it ranks more highly overseas. However, climate variability is important in the New Zealand context (Salinger et al. 1996), and if greenhouse climate change continues will become a major issue with large areas becoming permanently droughted, alpine areas transformed by upwards movement of woody biomes, and southwards movement of both indigenous and weed and pest species (Mitchell & William 1996).

Synopsis:

Indicator 7.1 Basic climate series
Measure 7.1.1 Climate averages, indices and extreme events

Indicator 7.2 Biological responses to climate change
Measure 7.1.1 Extreme events and biological response
Measure 7.2.2 Changing natural distributions of indigenous taxa
Measure 7.2.3 Southern expansion of subtropical exotics

Indicator 7.1 Basic climate series

Although this is the longest, and arguably the best scientific monitoring time series in the country, it is heavily geared towards human settlements, agriculture and aviation. In view of the importance of climate change and variability for ecosystem work, DOC needs to keep a close eye on how basic climate series are collected and possibly look to extend and augment the current network to better meet its own conservation-focused purposes.

Measure 7.1.1 Climate averages, indices and extreme events

Description:	Time series and statistical trends for basic climate factors and identification of extreme events (frost, drought, storms, excessive rainfall) according to objective criteria established for climatic regions.
Explanation:	An essential data layer that may need support if data are to be provided at a resolution relevant to some issues. The existing network will probably have to be augmented by stations in areas of particular concern to DOC, such as alpine and heavily forested regions.
Monitoring type:	Status and trend. Collected by specialised monitoring stations.
Reporting frequency:	Not reported by DOC; basic data layer.
Data source:	NIWA.

Ownership and responsibility: NIWA.

Potential data elements:
1. Rainfall – monthly and yearly averages.
2. Relative humidity – monthly averages.
3. Temperature – monthly and yearly averages.
4. Temperature – monthly absolute and mean minima and maxima.
5. Soil temperatures – monthly averages.
6. Insolation – monthly averages.
7. Soil water deficit – monthly averages.
8. Extreme cold events (intensity, duration and area affected).
9. Extreme dry events (intensity, duration and area affected).
10. Extreme storm events (intensity, duration and area affected).
11. ENSO pressure index and associated climate responses.

Indicator 7.2 Biological responses to climate change

Physical climate indicators are insufficient to determine the exact nature of biological change that might result. It is, for instance, essential to get some idea of how the various components of indigenous ecosystems will react, and how quickly to change. Therefore, monitoring of biological change that is likely to be climatically related is necessary, and is carried out extensively in the Northern Hemisphere. Changing variability is as important, particularly in the New Zealand context, and this will necessitate a sophisticated climate and biological understanding being brought to bear.

Measure 7.2.1 Extreme events and biological response

Description: Response of critical biodiversity elements to extreme events in conservation-sensitive regions.

Explanation: Essential information needed to help underpin interpretation of many other phenomena of conservation importance. Permanent climate change will, in part, happen as changing intensity and frequency of severe events. Early warning of likely biological reactions can be obtained therefore by observing change during or after such events. Retrospective monitoring has been done of extreme cold events and drought but it has never been systematic and always undertaken by individuals. At the very least, note should be taken of extreme drought and provision made to estimate drought-related plant mortality, and effects of severe winter events on birds.

Monitoring type: Surveillance, supported by status and trend and research monitoring.

Reporting frequency: Yearly.

Data sources: Depends on nature of events, but a large university and CRI involvement would be anticipated.

Ownership and responsibility: NIWA/DOC.

Potential data elements:
1. Drought and plant mortality.
2. Storm events and natural landscape response.
3. Extreme cold events and subsequent bird and tree mortality.

Measure 7.2.2 Changing natural distributions of indigenous taxa

Description: Monitoring results for selected indigenous taxa or biomes at altitudinal or southern limits.

Explanation:	It is anticipated that changing distributions of taxa will be strongly related to changing climates. Reliable trends are needed to anticipate future alterations of the natural environment. Climate change effects on the biota have a high degree of public interest. Should have sufficient basic science interest and publicity angles to attract substantial University and CRI involvement. Predicted impacts at and above timberline under warming climates warrants augmented monitoring of a range of life-forms. Best if integrated into a much wider ecological network.
Monitoring type:	Status and trend, surveillance, research. Combination of permanent sites, and survey.
Reporting frequency:	Variable, depends on degree of change observed, but at least 5-yearly.
Data source:	CRIs, universities, local government, DOC, NGOs (including OSNZ and NZPCN).
Ownership and responsibility:	Uncertain ?DOC/MfE.
Potential data elements:	1. Surveillance of northern indigenous taxa with potential for southwards spread. (Plot-based plant and animal network augmented by specialised investigation of areas where introduced indigenous taxa are spreading.) 2. Change along ecological transects from high alpine to timberline forest. Will require associated automated climate stations.

Measure 7.2.3 Southern expansion of subtropical exotics

Description:	Monitoring results for selected exotic taxa or biomes at altitudinal or southern limits.
Explanation:	Some of the worst weeds and pests are temperature-controlled. There is a huge potential for runaway damage to ecological integrity with this group, hence extra vigilance is required. A close watching brief is needed to anticipate future changes in their distribution. Of high public interest, and potentially of major conservation concern for certain species.
Description:	Mapped extension of temperature-sensitive exotic plants and animals.
Monitoring type:	Status and trend, surveillance. Will need purpose-designed surveys from time to time.
Reporting frequency:	Depends on organism; infrequent for trees, perhaps yearly for some insects.
Data sources:	Local government, MAF, DOC.
Ownership and responsibility:	DOC/MAF/MfE.
Potential data elements:	1. Mapped ranges/abundances of selected exotics with potential to do increased harm under a warming climate. Subtropical vines, successional shrubs, grasses (in particular nitrogen-fixing plants), ants, mosquitoes, hornets, fish.

10.8 Outcome Objective 8: Sustainable use

DOC land is used by recreationalists, agriculturalists, commercial interests and recreational hunters. There is also pressure for Maori access to traditional sources of material and food. In its narrowest sense, this is the ecosystem services provided by public lands. Sustainable use also interacts directly and indirectly with the ecological integrity of these lands.

Synopsis:

Indicator 8.1 Recreational use of DOC land and its impacts

Measure 8.1.1	Numbers and distribution of visitors in defined categories
Measure 8.1.2	Amount and standard of huts, tracking and roading
Measure 8.1.3	Impacts on ecological integrity of land used for recreation
Measure 8.1.4	Recreational hunting and fishing effort

Indicator 8.2 Economic use of DOC land and its impacts

Measure 8.2.1	Number of concessions in defined categories, economic benefit and level of activity
Measure 8.2.2	Volume of harvested material
Measure 8.2.3	Impacts on ecological integrity of permitted activity
Measure 8.2.4	Conservation benefits derived from concession activities

Indicator 8.1 Recreational use of DOC land and its impacts

While direct impacts of recreational use on biodiversity may seem minor, recreational activity is set to grow enormously over the coming years, with demand for resources and infrastructure that will have local, but potentially important effects. However, from a wider point of view, recreational use of DOC land is one of the few ways that New Zealand citizens interact with native biodiversity. Ensuring that these interactions are positive and enabling is one of the best ways of ensuring political support for biodiversity conservation. The economic importance of this access to biodiversity is growing rapidly, largely due to international and national tourism. On the positive side, good facilities and appropriate provision of information (signs, posters, maps, guides, books) will provide understanding and appreciation of biodiversity that will support efforts to conserve it. On the other hand, failure to provide suitable infrastructure to permit access, unnecessarily restrictive practices regarding access, unsatisfactory interactions by staff with the public and adjacent landholders, and debilitating and public struggles with concessionaires, will erode public support.

Measure 8.1.1 Numbers and distribution of visitors in defined categories

Description:	Numbers by conservancy or asset type; estimates of visitor source (extra-national, national, local), and activity type.
Explanation:	Measure of potential impact and economic worth to the country of DOC-hosted visitors.
Monitoring type:	Status and trend. Regular surveys. Visitor counts.
Reporting frequency:	Annual.
Data sources:	DOC. Tourism New Zealand.
Ownership and responsibility:	DOC.
Potential data elements:	1. Data about tourism, movement and economic impact collected by local and central government act as a basic element series.

2. Categories of visitors and types of visits devised as basic elements to help determine exact role that the conservation estate is playing in their decision-making.
3. Models can be used to derive useful estimates of flow-on effects of visitors to local and regional economies.
4. Visitor numbers at key sites stratified according to environment on DOC land.
5. Visitor satisfaction surveys.

Measure 8.1.2 Amount and standard of huts, tracking and roading

Description: Roading (km) in relation to ecosystem classes traversed. Density of track networks reported in classes.

Explanation: Important data layer to establish numerous other impacts. Amount of roading and tracking are important factors in determining impact of visitors and penetration by weeds and pests and fire threat. Essential data layer for models of potential spread of weeds, pests, and fire threats.

Monitoring type: Inventory.

Reporting frequency: 5-yearly.

Data sources: DOC.

Ownership and responsibility: DOC.

Potential data elements: As in the measure description.

Measure 8.1.3 Impacts on ecological integrity of sites used for recreation

Description: Quantification of changes in vegetation cover, site stability, and indigenous animal abundance in recreational sites.

Explanation: While in total area terms this is a minor impact, it is a major influence as far as the biodiversity that most visitors see, and can be crucial for vulnerable organisms subject to high visitor pressure (seal rookeries, albatrosses, scenic wetlands)

Monitoring type: Inventory. Status and trend.

Reporting frequency: 5-yearly.

Data sources: DOC.

Ownership and responsibility: DOC.

Potential data elements:

1. Trends for animals in high-visitor/small-area sites (breeding colonies mainly).
2. Aerial surveys of ground cover of ski fields.
3. Trends in vegetation plots in ski fields.
4. Bird abundance along high-use tracks.
5. Land disturbance and trampling associated with high-use tracks (track surveys?).

Measure 8.1.4 Recreational hunting and fishing effort

Description: Statistics, broken down by area, of type and number of wild animals harvested or killed.

Explanation: There are two aspects to consider, animal control benefit and visitor experience. Measures the effort expended in control of exotic game animals, and economic contribution of the DOC estate to the recreational hunting and meat industry. Has a localised, sometimes significant, but poorly documented

	influence on ecosystems. An important issue for a large number of individuals who are major users of remote areas of the estate, and at times of economic importance to local communities. There is a long-standing permit issue to consider and the possible removal of hunting permits in the future. Very patchy collection of data at present, low return rate and highly variable in quality. Low levels of compliance at present for reporting.
Monitoring type:	Status and trend. From filed returns where available; regular survey if not.
Reporting frequency:	Yearly.
Data sources:	DOC, Fish & Game (freshwater fish; game birds); Mfish (sea fishing).
Ownership and responsibility:	DOC.
Potential data elements:	1. Conduct a 5-yearly survey of patterns on DOC land (pigs; deer; game birds). 2. Consider purpose-driven collection of data, Thar plan; Kaweka deer etc.

Indicator 8.2 Economic use of DOC land and its impacts

DOC land is increasingly used for a range of economic activities involving wild animals, tourism, and extractive use of natural resources. Recognition of the economic value of DOC land to the nation's economy is dependent upon compiling these types of data. Other conservation outcomes may be derived from concession work through, for example, conservation advocacy and 'other' visitor opportunities.

Measure 8.2.1 Number of concessions in defined categories, economic benefit and level of activity

Description:	Number of concessions to utilise DOC land for commercial/economic purposes. Estimated value of same, no way of measuring this yet except what DOC is paid. Change in levels of actual use for selected activities.
Explanation:	Information to (a) establish worth of the DOC estate in a direct economic sense; (b) monitor trends in take that might negatively impact on ecological integrity.
Monitoring type:	Status and trend. Filed returns in conservancies; permissions database.
Reporting frequency:	Annual.
Data sources:	DOC.
Ownership and responsibility:	DOC.
Potential data elements:	1. Concessions to operate tourism/adventure/hunting operations on DOC land. 2. Telecomunication and power installations and access. 3. Grazing concessions. 4. Gravel and other mineral extraction. 5. Peat extraction. 6. Concessions for other economic activities. 7. Economic benefit to local and regional economies. 8. Change in levels of actual use for selected categories and activities.

Measure 8.2.2 Volume of harvested material

Description: Quantity of indigenous fish, birds, invertebrates, timber, other plant products taken from the natural estate.

Explanation: A small activity in the DOC estate, but one that should be documented. Information to (a) establish worth of the DOC estate in a direct economic sense; (b) monitor trends in take that might negatively impact on ecological integrity.

Monitoring type: Status and trend. Filed returns.

Reporting frequency: Annual.

Data sources: DOC.

Ownership and responsibility: DOC.

Potential data elements:
1. *Sphagnum* harvested.
2. White bait harvest.
3. Other harvested elements.

Measure 8.2.3 Impacts on ecological integrity of permitted activity

Description: Measures of impacts of harvesting on productivity and ecosystem processes.

Explanation: While harvesting of some organisms has been traditionally regarded as low impact, there is every reason to establish that this is actually the case. The same applies to the limited amount of mineral and gravel extraction permitted.

Monitoring type: Status and trend

Reporting frequency: Dependent on life cycle of organism. Probably 5-yearly.

Data sources: DOC.

Ownership and responsibility: DOC.

Potential data elements:
1. Population trend of fish species that provide whitebait.
2. Plot data for selection of sphagnum-harvested areas.
3. Surveys of rehabilitation/impact of mineral and gravel extraction.

Measure 8.2.4 Conservation benefits derived from concession activities

Description: Measures of benefits derived from select conservation activities such as conservation advocacy or 'other' visitor opportunities; weed control through grazing etc. measured through changes in attitudes/behaviours; targeted studies on priority activities.

Explanation: While DOC and others derive economic benefits from concession activities, the benefits to conservation need to be established.

Monitoring type: Status and trend. Targeted studies on priority activities.

Reporting frequency: Dependent on activity. Probably 1–5-yearly.

Data sources: DOC.

Ownership and responsibility: DOC.

Potential data elements
1. Surveys within an activity area identifying change in practices/attitudes/support for conservation.
2. Plot studies quantifying community composition for selection of grazing concessions.

10.9 Outcome Objective 9: Community in conservation

The Montreal Process has nearly 60% of its 67 indicators focused on socio-economic and organisational and research-orientated outcomes. Nevertheless, socio-economic indicators are the last to be thought of when developing a natural heritage monitoring system. The large proportion of land in New Zealand within the conservation estate, and the limited amount of sustainable economic activity permitted within this estate, must inevitably make such indicators and measures seem of secondary importance. However, the trend is towards a much greater area of land under some sort of conservation management although not necessarily designated as a protected area, and there is definitely much more pressure for recreational opportunities on protected lands. There is also a marked increase in dwellings in remote areas of high conservation value. All of this will increase the degree to which the community interacts with and impacts local biodiversity.

Synopsis:

Indicator 9.1 Community involvement

Measure 9.1.1	Community consultation
Measure 9.1.2	Participation in conservation
Measure 9.1.3	Number and value of corporate sponsorships in conservation

Indicator 9.2 Iwi partnerships

Measure 9.2.1	Cultural partnership projects
Measure 9.2.2	Cultural protection mechanisms
Measure 9.2.3	Access to cultural materials

Indicator 9.3 Eco-vandalism

Measure 9.3.1	Degree of illegal activity
Measure 9.3.2	Number of deliberate pest releases

Indicator 9.4 Conservation profile

Measure 9.4.1	Conservation and indigenous biodiversity in the written media
Measure 9.4.2	Television and radio time devoted to indigenous biodiversity
Measure 9.4.3	Web sites usage
Measure 9.4.4	Awareness and events

Indicator 9.1 Community involvement

Measure 9.1.1 Community consultations

Description:	Record of total number of consultative and information meetings regarding conservation land issues, and numbers of community involved. Broken down by national level, conservancy and area office.
Explanation:	Needed to help counter impression of DOC as unresponsive to local communities. Basic measure of fundamental interaction. Care will have to be taken that this is not treated as an output measure and interactions generated simply to fill quotas or expectations.
Monitoring type:	Status and trend.
Reporting frequency:	Yearly.

Data sources:	DOC.
Ownership and responsibility:	DOC.
Potential data elements:	As in description.

Measure 9.1.2 Participation in conservation

Description:	Number of volunteers (and work-day equivalents) of people participating on DOC-led volunteer projects; Number of Partnership projects (community-led and/or DOC and community partnerships) with either communities or landholders in biodiversity conservation.
Explanation:	Will demonstrate active rather than passive engagement of public with the conservation effort, and will provide a measure of DOC success in attracting meaningful participation. Restoration is an increasingly popular way of landholders or communities to demonstrate commitment to biodiversity. As such, it is a potentially useful adjunct to DOC's efforts to conserve lowland habitats. However, it is a labour and capital intensive approach to conservation and has had a high failure rate in the past. It is essential that systematic data be captured about these initiatives so that lessons can be learned for future efforts.
Monitoring type:	Status and trend.
Reporting frequency:	Yearly.
Data sources:	DOC; TLAs; NGOs.
Ownership and responsibility:	DOC.
Potential data elements:	1. Number of volunteers/work-day equivalents of volunteer contribution to conservation on DOC-led volunteer projects (could differentiate between types of community involvement, e.g. pest control, monitoring, maintaining tracks/huts etc.). 2. Number of partnerships with the community (community or DOC & community partnerships), e.g. Friends of / Trusts – formalised through MOUs or management agreements. 3. Number of sites/initiatives and total area stratified by environment managed through these arrangements. 4. Success in relation to restoration goals after standard period elapsed (variable cycle dependent on type of project).

Measure 9.1.3 Number and value of corporate sponsorships in conservation

Description:	Number and value of corporate sponsorships in conservation.
Explanation:	Corporate sponsorship, important in and of itself for conservation outcomes, is probably also a measure of the degree to which DOC and other conservation agencies have succeeding in keeping the biodiversity message in the forefront of the nation.
Monitoring type:	Status and trend.
Reporting frequency:	Yearly.
Data sources:	DOC; TLAs; NGOs.
Ownership and responsibility:	DOC.
Potential data elements:	As in description.

Indicator 9.2 Iwi partnerships

DOC has a close partnership with the tangata whenua. In many areas there is a requirement for maintaining traditional use of resources, and some areas are managed under a co-management agreement. Internationally, there is growing use of indicators that measure the degree to which indigenous people have traditional access to and sustainable use of natural resources in conservation areas. The following indicators are suggestions of the type of parameters that might be utilised. Final indicators and the data elements would need to be worked out via a consultation process with iwi.

Measure 9.2.1 Cultural partnership projects

Description:	Number and nature of DOC partnerships with iwi to ensure sustainable access to biodiversity resources or protection of biodiversity taonga.
Explanation:	Iwi are concerned to preserve cultural biodiversity resources both within and outside of the DOC estate. The most effective way of achieving this is through partnerships as they are more likely to achieve acceptable outcomes and to reduce compliance and enforcement costs for both parties.
Monitoring type:	Status and trend.
Reporting frequency:	Yearly.
Data sources:	DOC; TLAs; iwi.
Ownership and responsibility:	DOC/iwi.
Potential data elements:	1. Number of partnerships and extent of commitments according to primary cultural resource.

Measure 9.2.2 Cultural protection mechanisms

Description:	Use of cultural protection mechanisms to achieve biodiversity outcomes.
Explanation:	Iwi have a number of traditional cultural mechanisms that are deployed to protect for varying spans of time biodiversity resources that may be on the verge of, or over-exploited. These are effectively valuable biodiversity management tools that need to be developed and extended.
Monitoring type:	Status and trend.
Reporting frequency:	Yearly.
Data sources:	Iwi/DOC.
Ownership and responsibility:	Iwi/DOC.
Potential data elements:	1. Types of cultural protection mechanisms deployed in a year. 2. Area and duration of mechanism enforcement.

Measure 9.2.3 Access to cultural materials

Description:	Number of permits (or other suitable arrangements) and material-specific estimate of material taken from conservation land.
Explanation:	Iwi have traditionally had access to a wide range of natural resources, but expansion of conservation land has tended to make this access problematical. Formulation of sound policy in this area needs good data as to frequency and impact of extraction of cultural material.
Monitoring type:	Status and trend.

Reporting frequency:	Yearly.
Data sources:	DOC/Iwi.
Ownership and responsibility:	DOC–Iwi.
Potential data elements:	1. As in description. 2. From time to time monitoring of certain cultural material to establish sustainable levels of utilisation.

Indicator 9.3 Eco-vandalism

Measure of the level of acceptance within the community of the value of conservation activities and land, and indicates the level of threat posed by human-assisted reintroductions of pests following eradication or control operations.

Measure 9.3.1 Degree of illegal activity

Description:	Reports of (a) Legal action taken (b) actions of a nature designed to damage DOC's infrastructure or the ecological integrity of the natural estate.
Explanation:	Although it is inherently sporadic in nature, attention to this metric will help engage with the underlying issues. A long and consistent time series is needed to examine if there are trends, and what they mean. Worth monitoring, as eco-terrorism is a conceivable outcome of strong splits in community attitudes, as has already happened over animal rights and genetic modification. Is highly likely in the context of concession rights to valuable access to DOC natural resources suitable for developing tourist ventures, and perceived threats to individual rights.
Monitoring type:	Status and trend.
Reporting frequency:	Yearly.
Data sources:	DOC (Infringement fine system); Police.
Ownership and responsibility:	DOC.
Potential data elements:	1. Court proceedings and prosecutions; Number of warnings; Detected, but no outcome. 2. Vandalistic attacks on DOC-owned infrastructure. 3. Actions intended to degrade biodiversity (e.g. felling of trees, release of possums in possum-free areas).

Measure 9.3.2 Number of deliberate pest releases

Description:	Releases by species and conservancy.
Explanation:	Actions intended to enhance a recreational resource at the expense of biodiversity (release of deer, pigs, fish etc in new areas). Indicator of illegal pressure on pristine ecosystems by recreational users, and will give some guidance to where the problem is worst and how to combat it.
Monitoring type:	Surveillance.
Reporting frequency:	Yearly.
Data sources:	DOC, MAF, local government.
Ownership and responsibility:	DOC.
Potential data elements:	As in description.

Indicator 9.4 Conservation profile

Conservation of biodiversity does produce measurable economic and welfare gains for New Zealanders, but the largely urban-dwelling population has a relatively small exposure to indigenous biodiversity. Moreover, much biodiversity is essentially invisible to the public without a high degree of visual and written explication. The level of exposure of conservation in the media and through education or events is a useful criterion for assessing public access to relevant information and, in turn, their support for conservation.

Measure 9.4.1 Conservation and indigenous biodiversity in the written media

Description:	Number of articles concerning conservation/biodiversity according to media type, potential exposure and source. Communication via DOC publications.
Explanation:	Without a constant flow of stories, public interest and then support of conservation is likely to wane. It matters little from where the articles are sourced.
Monitoring type:	Status and trend.
Reporting frequency:	Yearly.
Data sources:	Press clipping services; publications produced by management services.
Ownership and responsibility:	DOC.
Potential data elements:	1. Articles imparting biodiversity information. 2. Articles concerning DOC's biodiversity management, negative and positive distinguished. 3. Number DOC publications provided /requested.

Measure 9.4.2 Television and radio time devoted to indigenous biodiversity

Description:	Television & Radio news and programmes concerned with indigenous biodiversity and its threats.
Explanation:	Television and radio are the most widely accessed source of information regarding indigenous biodiversity.
Monitoring type:	Status and trend.
Reporting frequency:	Yearly.
Data sources:	Professional media-monitoring services.
Ownership and responsibility:	DOC.
Potential data elements:	1. Television and radio news items concerning indigenous biodiversity. 2. Television and radio news items concerning DOC's biodiversity management. 3. Television and radio programmes devoted to indigenous biodiversity.

Measure 9.4.3 Web site usage

Description:	Type of DOC web site use and measure of intensity.
Explanation:	Internet access is now a primary way biodiversity-relevant data are obtained and this can only increase in the future. Web site usage thus records the type and amount of interest in biodiversity. Could potentially be expanded to a larger selection of agencies providing biodiversity information (i.e. TLAs, CRIs, NGOs etc.).
Monitoring type:	Status and trend.
Reporting frequency:	Yearly.

Data sources: DOC.
Ownership and responsibility: DOC.
Potential data elements:
1. Overall web site accessing.
2. Downloads of biodiversity relevant information

Measure 9.4.4 Awareness and events

Description: Awareness and event services provided by DOC.

Explanation: Public awareness campaigns or programmes, events and education programmes are important mechanisms for information sharing, raising awareness, and increasing public access to relevant information and, in turn, their support for conservation.

Monitoring type: Status and trend.

Reporting frequency: Yearly.

Data sources: DOC.

Ownership and responsibility: DOC.

Potential data elements:
1. Number education initiatives.
2. Number events provided.
3. Surveys identifying proportion of public awareness campaigns leading to demonstrated change in practices/attitudes/support for conservation.
4. Proportion of participants surveyed rating events as effective at meeting their objectives.

10.10 Comparison of proposed biodiversity inventory and monitoring indicators with proposed MfE Terrestrial Biodiversity Indicators

MfE has produced a detailed report (Froude 2003) outlining a set of proposed indicators for terrestrial and freshwater biodiversity, based on a series of workshops and consultations. It provides a list of potential indicators and parameters, primarily for terrestrial environments, which in this document are largely equivalent to Measures/Elements.

In the following, alignments between the MfE indicators and those proposed in this document are outlined.

MfE-1: Change in the extent of vegetation cover classes and selected habitat types
Parameters:
(i) Change in extent of vegetation cover classes;
(ii) Change in extent of selected habitat types

MfE-1 (i) matches Indicator 1.5 Land cover, and the Measures 1.5.1 Land under indigenous vegetation and 1.5.2 Areas under intensive land use. Both intend to use Land Cover Data Base 2. However, in this document land cover is integrated with LENZ physical environment layers to depict biodiversity changes across environments.
MfE-1 (ii) is addressed by Indicator 6.1 Environmental representation and protective status, and the Measures 6.1.1 Proportion of environmental unit under indigenous cover, 6.1.2 Proportion of environmental unit under indigenous cover and protected, 6.1.3 National change in extent and integrity of naturally uncommon and significantly reduced habitats, and 6.1.4 Proportion of threatened aturally uncommon and significantly reduced habitats protected. The latter deals with

threatened or much reduced habitats, and will depend on the application of LENZ and a new classification framework for restricted habitats.

MfE-2: Change in the biodiversity condition of selected terrestrial ecosystems in habitats compared with potential, historic and current baselines

Native birds

(i) Change in distribution of indigenous terrestrial bird species by presence in 10 000-m grid squares (national) and within critical areas 1000-m grid squares (local);
(ii) Change in the abundance of indigenous terrestrial bird species in selected/representative locations;
(iii) Change in the phylogenetic distance of indigenous terrestrial bird assemblages nationally and for selected/representative locations.

Native vegetation

(iv) Change in proportion of each canopy species in each habitat or vegetation type;
(v) Change in the proportion of the cover of each tier that is alien by habitat or vegetation type;
(vi) Change in the proportion of the cover of each tier that is alien weighted by the impact of each weed species, by habitat or vegetation type
(vii) Change in the density of seedlings and saplings by species by forest type
(viii) Change in the proportion of low, medium and highly palatable species in seedling and sapling size by vegetation type.

MfE-2 i–ii are included in Indicator 5.1 Composition, Measure 5.1.2 Demography of widespread animal species, and there it is clear that native birds would feature amongst the data elements.
MfE-2 iii has no comparable Indicator or Measure in the DOC biodiversity and inventory programme. However, if required, phylogenetic distance is readily calculated from a combination of compositional-information and phylogenetic-relatedness measures.
MfE-2 iv–viii have no direct equivalents amongst the Indicators and Measures in this document, although this would depend in part on how they were derived. For example, **MfE-2 iv** and **vii** could be calculated from Indicator 5.1 Composition, Measure 5.1.1 Size-class structure of canopy dominants, based on density rather than cover data. Similarly, **MfE-2 vii** and **viii** could be obtained from the same indicator, using a subset of the data. **MfE-2 viii** could be a component of Indicator 5.1 Composition, and Measure 5.1.3 Representation of plant functional types.

MfE-3: Change in the gross habitat fragmentation of indigenous vegetation cover

Fragmentation is included in Indicator 5.3 Patch size/fragmentation of wooded ecosystems, and Measure 5.3.1 Degree of connectivity in transformed landscapes. The MfE report states there is insufficient evidence to develop a parameter. Although there are numerous indices of fragmentation, any direct link between these and biodiversity components is often unknown.

MfE-4: Change in the extent of habitats without alien species

(i) Change in the number and hectares of terrestrial habitats where it is confirmed that there are no browsing mammals;

(ii) – no alien mammal predators

(iii) – selected alien invertebrates are absent

(iv) Change in the number and hectares of mainland habitats subject to long-term intensive and comprehensive pest management and monitoring programmes designed to keep pest numbers to very low levels.

MfE-4 i–iv are similar to Indicator 2.2 Exotic weed and pest dominance, Measure 2.2.1 Distribution and abundance of exotic weeds and pests considered a threat, and Measure 2.2.2 Indigenous systems released from exotic pests. **MfE-2 iv** focuses on inputs or management actions, rather than biodiversity attributes or outcomes.

MfE-5: Change in the status of threatened species

(i) Change in the number of taxa in each threat category in the New Zealand threatened species classification;

(ii) Change in the number and percentage of taxa in each broad taxonomic group that is extinct.

MfE-6: Change in the distribution of selected threatened taxa

MfE-5 i-ii and **MfE-6**, because of DOC's legislative responsibilities, are comprehensively covered in Indicators 4.1 Extinct taxa, 4.2 Status of acutely threatened taxa, 4.3 Status of chronically threatened taxa, and 4.4 Genetic change in critically reduced species, and their associated Measures.

MfE-7: Change in the distribution of ecological weed species

(i) Change in the distribution of all terrestrial weed taxa formally identified by management agencies for surveillance, eradication, containment or exclusion;

(ii) *Change in the distribution of terrestrial weed taxa identified by scientists as posing most risk to New Zealand biodiversity values.*

MfE-8: Change in the distribution and abundance of selected animal pests

(i) Change in the distribution of terrestrial animal pest species subject to national containment policies;

(ii) Change in the relative density of terrestrial animal pest species subject to national containment policies;

(iii) Change in the distribution of possums;

(iv) Change in the relative density of possums.

MfE-7 i–ii and **MfE-8 i–iv** are included within Indicator 2.1 Naturalisation of new weed and pest species, Measure 2.1.1 Occurrence of self-maintaining populations of new potential environmental weeds and pests, and Indicator 2.2 Exotic weed and pest dominance, Measure 2.2.1 Distribution and abundance of exotic weeds and pests considered a threat.

MfE-9: Change in the area and percentage of each of New Zealand's different environments, ecosystems and habitats under legal protection

(i) Change in the area (hectares) and % of natural vegetation cover classes under legal protection;

(ii) Change in the area (in hectares) and % of selected habitat types under legal protection;

(iii) Change in the percentage of the potential extent of each indigenous vegetation cover class under legal protection;

(iv) Change in the area (in hectares) and % of each land environment under legal protection.

MfE-9 i–iv are included to varying extents in Indicator 6.1 Environmental representation and protected status, Measures 6.1.1 Proportion of environmental unit under indigenous cover, and Measure 6.1.2 Proportion of environmental unit under indigenous cover and protected. Indicators in this document are primarily based around environmental units, indigenous cover classes, or uncommon habitats, but could encompass broader habitat classes if these could be quantitatively measured across the landscape.

MfE-10: Change in the extent of legally protected lands under Maori or private tenure

MfE-10 has no equivalent in the DOC biodiversity inventory and monitoring programme, which is limited to Crown land.

The MfE terrestrial environmental indicators overlap to a considerable extent with many of the indicators developed for the Department of Conservation in this document. Of the indicators and parameters proposed, all are nearly directly matched with equivalents in DOC's Indicator and Measures set. It would be relatively straightforward to include most of the proposed MfE indicators in the biodiversity indicators outlined in this document.

The MfE document in general takes a narrower definition of biodiversity, and excludes consideration of soil factors, primary production and processes in general, and of course the agency-specific indicators and measures included in DOC's inventory and monitoring programme. The difference between the two proposals, aside from the wider scope of DOC's biodiversity inventory and monitoring programme, lies mostly in the greater detail in some indicators in the different systems (e.g. NHMS pays more attention to threatened species; MfE to legal protection status), and the overall structure of the indicator framework. The biodiversity inventory and monitoring programme is designed specifically to meet DOC's outcome objectives, and is set within an explicit framework of higher-level goals derived from the New Zealand Biodiversity Strategy. The MfE system appears to have no framework structure above the indicator level, and does not have at present an implementation timetable or process.

11. Acknowledgements

Many people have contributed to the ideas and information presented in this report. We thank the Department of Conservation staff that attended the Multi-scaled Biodiversity Inventory and Monitoring Programme User Specifications Workshop in Hamilton (8 October 2002), and all those who participated in the Monitoring Symposium held at the New Zealand Ecological Society Conference in Invercargill (31 August 2004).

We acknowledge input from Colin O'Donnell, Hilary Aikman, Pam Cromarty, Andy Thompson, Leonie Fechney, Eric Dorfman, Kerry Hilliard and Elaine Murphy on indicator and measure descriptions.

We specially thank our international review team – Ian Watson (Department of Agriculture, Western Australia), Donald McLennan (Parks Canada, Quebec, Canada), Leah de Forest (Parks Canada, Quebec, Canada), and Rod Applegate (Department of Lands, Planning, and the Environment, Darwin, Australia) who kindly shared their experience and insights into developing and sustaining biodiversity and inventory programmes.

John Sawyer (DOC) and Rob Allen (LCR) reviewed an early version of the report, and other colleagues assisted with different aspects.

The compilers are grateful for the contribution of other work-group members in the development of the ideas presented in the report. All have made constructive contributions, and taken part in memorable debates and discussion.

12. References

Adger, W.N.; Benjaminsen, T.A.; Brown, K.; Svarstad, H. 2001: Advancing a political ecology of global environmental discourses. *Development & Change 32*: 681–715.

Allen, R.B. 1992: RECCE – an inventory method for describing New Zealand vegetation. *Forest Research Institute Bulletin 176.* Forest Research Institute, Christchurch, New Zealand.

Allen, R.B. 1993: A permanent plot method for monitoring changes in indigenous forests. Manaaki Whenua-Landcare Research, Christchurch, New Zealand.

Allen, R.B.; Buchanan, P.K.; Clinton, P.W.; Cone, A.J. 2000: Composition and diversity of fungi on decaying logs in a New Zealand temperate beech (*Nothofagus*) forest. *Canadian Journal of Forestry Research 30*: 1025–1033.

Amos, W.; Balmford, A. 2001: When does conservation genetics matter? *Heredity* 87: 257–265.

Andelman, S.J.; Fagan, W.F. 2000: Umbrellas and flagships: Efficient conservation surrogates or expensive mistakes? Proceedings of the National Academy of Sciences 97: 5954–5959.

Arand, J.; Stephens, T.1998: Measuring conservation management projects - Definitions, Principles and Guidelines. Department of Conservation, Wellington.

Atkinson, I.A.E. 1975: A method for permanent transects in vegetation. *Tuatara 21*: 81–91.

Balmford, A.; Green, R.E.; Jenkins, M. 2003: Measuring the changing state of nature. *Trends in Ecology and Evolution 18*: 326–330.

Bascand, L.D.; Jowett, G.H. 1981: Scrubweed cover of South Island agricultural and pastoral land. *New Zealand Journal of Experimental Agriculture 9*: 307–327.

Bascand, L.D.; Jowett, G.H. 1982: Scrubweed cover of South Island agricultural and pastoral land. 2. Plant distribution and managerial problem status. *New Zealand Journal of Experimental Agriculture 10*: 455–492.

Batcheler, C.L.; Craib, D.G. 1985: A variable area plot method for assessment of forest condition and trend. *New Zealand Journal of Ecology 8*: 83–96.

Bathgate, J.L. 1973: Summary of Questionnaire returns. Pp. 103–113 in Orwin, J. (Ed.): Assessment and management of introduced animals in New Zealand forests. New Zealand Forest Service, Forest Research Institute, Wellington, New Zealand.

Bekessy, S.A.; Ennos, R.A.; Burgman, M.A.; Newton, A.C.; Ades, P.K. 2003: Neutral DNA markers fail to detect genetic divergence in an ecologically important trait. *Biological Conservation 110*: 267–275.

Bellingham, P.J. 1996: Surveys and monitoring of vegetation. Landcare Research Contract Report LC956/026 for the Department of Conservation. Landcare Research, Lincoln, New Zealand.

Bellingham, P.; Stewart, G.H.; Allen, R.B. 1999: Tree species richness and turnover throughout New Zealand forests. *Journal of Vegetation Science 10*: 825–832.

Berke, P.R.; Crawford, J.; Dixon, J.; Ericksen, N. 1999: Do cooperative environmental planning mandates produce good plans? Empirical results from the New Zealand experience. *Environment & Planning B. Planning & Design 26*: 643–664.

Bissix, G.; Rees, J.A. 2001: Can strategic ecosystem management succeed in multiagency environments? *Ecological Applications* 11: 570–583.

Blaxter, M.; Floyd, R. 2003: Molecular taxonomics for biodiversity surveys: already a reality**.** *Trends in Ecology & Evolution 18*: 268–269.

Bowman, D.M.J.S. 1998: The impact of Aboriginal landscape burning on the Australian biota. *New Phytologist 140*: 385–410.

Brady, S.J.; Flather, C.H. 1994: Changes in wetlands on nonfederal rural land of the coterminous United States from 1982 to 1987. *Environmental Management 18*: 693–705.

Brockie, R. 1992: A living New Zealand forest. David Bateman, Auckland, New Zealand.

Bull, P.C.; Gaze, P.D.; Robertson, C.J.R. 1985: The atlas of bird distribution in New Zealand. Ecology Division DSIR/NZ Wildlife Service/Ornithological Society of NZ, Wellington.

Burgman, M.A. 2002: Turner Review 5. Are listed threatened plant species actually at risk? *Australian Journal of Botany 50*: 1–13.

Burgman, M.A.; Lindenmayer, D.L. 1998: Conservation biology for the Australian environment. Surrey Beatty, Chipping Norton, Australia. Pp. 380.

Canadian Council of Forest Ministers 2000: Criteria and indicators of sustainable forest management in Canada: National Status 2000. Canadian Forest Service, Ottawa.

Caruso, B.S. 1999: Environmental indicators: issues and use for resource management in Otago. Holt, A. Dickinson, K., and Kearsley, G.W. 65-73 1999. Dunedin, University of Otago. Environmental Indicators. Proceedings of the Environmental Indicators Conference.

Cassola, F.; Pearson, D.L. 2000: Global patterns of tiger beetle species richness (Coleoptera: Cicindelidae): their use in conservation planning. *Biological Conservation 95*: 197–208.

Caughley, G. 1983: The deer wars: The story of deer in New Zealand. Heinemann, Auckland, New Zealand.

Caughley, G. 1988: Control of wild animals. Pp. 101–103 in Newton, A.E. (Ed.): The future of New Zealand's wild animals. Seminar 2000: Proceedings. New Zealand Deerstalkers Association, Wellington, New Zealand.

Caughley, G. 1994: Directions in conservation biology. *Journal of Animal Ecology 63*: 215–244.

Chapin F.S. III and 11 others. 2000: Consequences of changing biodiversity. *Nature 405*: 234–242.

Choquenot, D.; Ruscoe, W.A.: 2000: Mouse population eruptions in New Zealand forests: the role of population density and seedfall. *Journal of Animal Ecology 69*: 1058–10790.

Chornesky E.A.; Randall, J.M. 2003: The threat of invasive alien species to biological diversity: setting a future course? *Annals of the Missouri Botanical Gardens 90*: 67–76.

Christchurch City Council 2002.: Draft Biodiversity Strategy. Christchurch, Christchurch City Council.

Christensen, N.L.; Bartuska, A.M.; Brown, J.H.; Carpenter, S.D.; Antonio, C.; Francis, R. Franklin, J.F.; MacMahon, J.A.; Noss, R.F.; Parsons, D.J. Peterson, C.H.; Turner, M.G.; Woodmansee, R.G. 1996: The report of the Ecological Society of America committee on the scientific basis for ecosystem management. *Ecological Applications 6 (3*): 665–691.

Cockyane, L. 1898: On the burning and reproduction of subalpine scrub and its associated plants; with special reference to Arthur’s Pass district. *Transactions of the New Zealand Institute 31*: 398–418.

Cockayne, L. 1899: A sketch of the plant geography of the Waimakariri River basin, considered chiefly from an oecological point of view. *Transactions and Proceedings of the New Zealand Institute 32*: 95–136.

Cockayne, L. 1922: An economic investigation of the montane tussock grasslands of New Zealand. 12. The regrassing experiments in Central Otago. Part 1. An account of the depleted area in relation to the experiments. *New Zealand Journal of Agriculture 24*: 321–334.

Cockayne, L. 1928: The vegetation of New Zealand, 2nd edn. Engelmann, Leipzig, Germany.

Cockayne, L.; Calder, J.W. 1932: The present vegetation of Arthur’s Pass (New Zealand) as compared with that of thirty-four years ago. *Journal of Ecology 20*: 270–283.

Coomes, D.A.; Allen, R.B.; Scott, N.A.; Goulding, C.; Beets, P. 2002: Designing systems to monitor carbon stocks in forests and shrublands. *Forest Ecology and Management 164*: 89–108.

Craig, J.; Anderson, S., Clout, M.; Creese, B.; Mitchell, N.; Ogden, J.; Roberts, M.; Ussher, G. 2000: Conservation Issues in New Zealand. *Annual Review of Ecology and Systematics 31*: 61 - 78.

Darby, J.T. 1989: Sea bird monitoring in New Zealand. Pp. 235-239 in Craig, B. (Ed.): Proceedings of a Symposium on environmental monitoring in New Zealand with emphasis on protected natural areas. Department of Conservation, Wellington, New Zealand.

Department of Conservation (DOC) 2004: Department of Conservation Statement of Intent 2004–2007, presented to the House of Representatives: C.13 SI (04). Department of Conservation, Wellington, New Zealand.

Department of Conservation (DOC); Ministry for the Environment (MfE) 2000: The New Zealand biodiversity strategy February 2000. Department of Conservation & Ministry for the Environment, Wellington, New Zealand

Department of the Environment, Sport and Territories 1996: National strategy for the conservation of Australia's biological diversity. Department of the Environment and Heritage, Canberra, Australia. www.deh.gov.au/biodiversity/publications/strategy/

Dickinson, K.; Mark, A.; Lee, W. 1992: Long-term monitoring of non-forest communities for biological conservation. *New Zealand Journal of Botany 30*: 163–179.

Dymond, J.R.; Shepherd, J.D. 2004: The spatial distribution of indigenous forest and its composition in the Wellington region, New Zealand, from ETM+ satellite imagery. *Remote Sensing of Environment 90*: 116–125.

Efford, M. 2000: Possum density, population structure, and dynamics. Pp. 47–61 in Montague, T. (Ed.): The brushtail possum: biology, impact and management of an introduced marsupial. Manaaki Whenua Press, Lincoln, New Zealand.

Elliott, G.P.; Merton, D.V.; Jansen, P.W. 2003: Intensive management of a critically endangered species: the kakapo. *Biological Conservation 99*: 121–133.

Environment Canada 2003: Environmental signals: Canada's National Environmental Indicators Series 2003. Environment Canada, Toronto.

Environment Waikato 1998: Taking the pulse: highlights from the Waikato State of the Environment Report. Environment Waikato, Hamilton, New Zealand.

European Environment Agency (EEA) 2000: Environmental signals 2002 - Benchmarking the Millennium. Copenhagen, European Environment Agency, Environmental Assessment Report No 9.

European Environment Agency (EEA) 2001: Environmental signals 2001 - Environmental Assessment Report No 8, European Environment Agency, Copenhagen.

European Environment Agency (EEA) 2002: Delbaere, B. 2203. An inventory of biodiversity indicators in Europe 2002. Luxemburg, European Environment Agency. European Union Technical Report 92.

European Environment Agency (EEA) 2003: European Environment Agency 2003. Europe's environment: the third assessment. Copenhagen, European Environment Agency.

Fairweather, P.G.; Napier, G.M. 1998: Environmental Indicators for National State of the Environment Reporting: Inland waters. Australia: State of the Environment Environmental Indicator Report. CSIRO Land and Water, Canberra, Australia.

Fairweather, P.G. 1991: Statistical power and design requirements for environmental monitoring. *Australia Journal of Freshwater Research 42*: 555-567.

Firbank, L.G.; Smart, S.M.; Crabb, J.; Critrchley, C.N.R.; Fowbert, J.W.; Gladders, P.; Green, D.B.; Henderson, J.; Hill, M.O. 2003: Agronomic and ecological costs and benefits of set-aside in England. *Agriculture Ecosystems & Environment 95*: 73–85.

Floyd, R; Abebe, E; Papert, A, Blaxter, M. 2002: Molecular barcodes for soil nematode indentification. *Molecular Ecology 11*: 839–850.

Fraser, K.; Burrows, L. 2000: Changes in the density and local distribution of red deer and their impacts on vegetation in the Arawhata Valley (South Westland) between 1969 and 1999. Landcare Research Contract Report LC0001/047, Landcare Research, Lincoln, New Zealand.

Froude, V.A. 1999: Review of national databases relating to land, water and biodiversity, Ministry for the Environment, Environmental Performance Indicators Programme. MfE, Wellington, New Zealand.

Froude, V.A. 2003: Proposed monitoring and reporting protocols for the New Zealand terrestrial biodiversity indicators. Ministry for the Environment, Wellington, New Zealand.

Gibb, J.A.; White, A.J.; Ward, C. P. 1985: Population ecology of rabbits in the Wairarapa, New Zealand. *New Zealand Journal of Ecology 8*: 55–82.

Gigon, A.; Langenauer, R.; Meier, C.; Nievergelt, B. 2000: Blue lists of threatened species with stabilised or increasing abundance: a new instrument for conservation. *Conservation Biology 14*: 403–413.

Goldson, S.L.; Suckling, D.M. 2003: Defending the Green Oasis: New Zealand biosecurity and science. New Zealand Plant Protection Society, Christchurch, New Zealand.

Haber, E. 2002: Invasive species of Canada Survey 2002: an assessment of resources and needs. Canadian Wildlife Service, Environment Canada.

Haig, S.M. 1998: Molecular contributions to conservation. *Ecology 79*: 413–425.

Hartley, P. 1997: Conservation strategies for New Zealand. New Zealand Business Roundtable, Wellington.

Hay, R.; Robertson, H.; Clout, M.; Efford, M. 1989: Monitoring native landbirds. Pp. 225–234 in Craig, B. (Ed.): Proceedings of a Symposium on environmental monitoring in New Zealand with emphasis on protected natural areas. Department of Conservation, Wellington, New Zealand.

Herkenrath, P. 2002: Birds and the convention on biological diversity: can ornithologists and bird conservationists make a difference? *Bird Conservation International 12*: 99–106.

Hitchmough, R. 2002: New Zealand Threatened Classification System lists. Threatened Species Occasional Publication 23: Department of Conservation, Wellington. 2002:

Holloway, J.T.; Wendelken, W.J. 1957: Some unusual features of sample plot design. *New Zealand Journal of Forestry 7*: 77–83.

Horizons Manawatu-Wanganui. 2002: Regional animal pest management strategy. Palmerston North, Manawatu-Wanganui Regional Council.

Horizons Manawatu-Wanganui. 2001: Regional plant pest management strategy. Palmerston North, Manawatu-Wanganui Regional Council.

Hughey, K.F.D.; Cullen, R.; Moran, E. 2003: Integrating economics into priority setting and evaluation in conservation management. *Conservation Biology 17*: 93–103.

Hulme, P.E. 2003: Biological invasions: winning the science battles but losing the conservation war? *Oryx 37*: 178–193.

Hunter, G.; Mulcock, C.; Gibson, R. 2003: We mustn't lose the plot - community-based tussock grassland monitoring: a review of the REDIS initiative.

Innes, J.; Barker, G. 1999: Ecological consequences of toxin use for mammalian pest control in New Zealand – an overview. New Zealand Journal of Ecology 23: 111–127.

Janssen, H. 2002: Native biodiversity information: Issues and options for the Manawatu District. Report No. 2002\EXT\532, Horizons.mw, Palmerston North.

Karr, J.R.; Fausch, K.D.; Angermeier, P.L.; Yant, P.R.; Schlosser, I.J. 1986: Assessing biological integrity in running waters a method and its rationale. INHS Special Publication, 5.

Karr, R.J. 1996: Ecological integrity and ecological health are not the same. Pp. 97–109 in Schulze, P.C. (Ed.): Engineering within ecological constraints. National Academy Press, Washington, D.C.

Kelly, G.C. 1972: Scenic reserves of Canterbury. *Biological Survey of Reserves Report 2*. Botany Division, DSIR, Wellington, New Zealand.

Kelsey, J. 1997: The New Zealand experiment – a world model for structural adjustment. Auckland University Press, Auckland, New Zealand.

Kim, K.C. 1993: Biodiversity, conservation, and inventory: Why insects matter. *Biodiversity and Conservation 2*: 191–214.

King, C.M. 1983: The relationship between beech (*Nothofagus* sp.) seedfall and populations of mice (*Mus musculus*), and the demographic and dietary responses of stoats (*Mustela erminea*), in three New Zealand forests. *Journal of Animal Ecology 52*: 141–166.

King, C. M. (Ed.) 1990: The handbook of New Zealand mammals. Oxford University Press, Auckland, New Zealand.

Lacy, R.C.; Lindenmayer, D.B. 1995: A simulation study of the impacts of population subdivision on the mountain bushtail possum *Trichosurus caninus* Ogilby (Phalangeridae, Marsupialia) in southeastern Australia. 2. Loss of genetic variability within and between subpopulations. *Biological Conservation 73*: 131–142.

Landsberg, J.; Crowley, G. 2004. Monitoring rangeland biodiversity: plants as indicators. *Austral Ecology* 29: 59–77.

Lawton, J.H.; Bignell, D.E.; Bolton, B.; Bloemers, G.F.; Eggleton, P.; Hammond, P.M.; Hodda, M.; Holt, R.D.; Larsen, T.B.; Mawdsley, N.A.; Stork, N.E.; Srivastava, D.S.; Watt, A.D.1998: Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forests. *Nature 391*: 72–76.

Leathwick, J.R.; Wilson, G.; Rutledge, D.; Wardle, P.; Morgan, F.; Johnston, K.; McLeod, M.; Kirkpatrick, R. 2003: Land environments of New Zealand. Landcare Research, MfE, David Bateman, Auckland, 183 pp.

Lincoln, R.; Boxshall, G.; Clark, P. 1998: A Dictionary of ecology, evolution, and systematics. Second Edition, Cambridge University Press.

Lindenmayer, D.B.; Margules, C.R.; Botkin, D.B. 2000: Indicators of biodiversity for ecologically sustainable forest management. *Conservation Biology 14*: 941 - 950.

Lodge, D.M.; Shrader-Frechette, K. 2003: Nonindigneous species: ecological explanation, environmental ethics, and public policy. *Conservation Biology 17*: 31–37.

Lomberg, B. 2001: The skeptical environmentalist: Measuring the real state of the World. Cambridge University Press, Cambridge.

Lund, H.G. 1990: The platonic verses and inventory objectives. Pp 1–7 in LaBau, V.J.; Cunia, T. (Eds): State-of-the-art methodology of forestry inventory. USDA Forest Service General Technical Report PNW-GTR-263.

Lund, H.G.; Rudis, V.A.; Stolte, K.W. 1998: Plots, pixels, and partnerships: prospects for mapping, monitoring, and modeling biodiversity. In: Dallmeier, F.; Comiskey, J.A. (Eds): Forest biodiversity, research, monitoring, and modeling: Conceptual background and Old World case studies. Smithsonian Institution, Washington D.C.

Macdonald, D.W.; Mace, G.; Rushton, S. 1998: Proposals for future monitoring of British mammals. Department of the Environment, Transport and the Regions, London.

Mack R.N.; Simberloff, D.; Lonsdale, W.M.; Evans, H.; Clout, M.; Bazzaz, F.A. 2000: Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications 10*: 689–710.

MAF 2003: Ministry of Agriculture and Fisheries 2003, An Independent review of New Zealand's Biosecurity Surveillance Systems. Wellington, Ministry of Agriculture and Fisheries.

Mapstone, B.D. 1995: Scalable decision rules for environmental-impact studies – effect size, Type-I, and Type-II errors. *Ecological Applications 5*: 401–410.

Marshall, W. 1963: The ecology of mustelids in New Zealand. *DSIR Information Series 38*. DSIR, Wellington, New Zealand.

Martin, M.E.; Aber, J.D. 1997: High spatial resolution remote sensing of forest canopy lignin, nitrogen, and ecosystem processes. *Ecological Applications 7*: 421–443.

Masters, S.E.; Holloway, J.T.; McKelvey, P.J. 1957: The national forest survey of New Zealand, 1955. New Zealand Forest Service, Wellington, New Zealand.

McKelvey, P. 1984: Provisional classification of South Island virgin indigenous forests. *New Zealand Journal of Forestry Science 14*: 151–178.

McKelvey, P. 1995: Steepland forests. Canterbury University Press, Christchurch, New Zealand.

McKelvey, P.; Cameron, R.J. 1958: Design for a forest study. *New Zealand Journal of Forestry 7*: 116–122.

Meurk, C.D.; Buxton, R.P. 1991: A New Zealand register of permanent vegetation plots. DSIR Land Resources, Christchurch, Contract Report 91/35 (prepared for Department of Conservation; held at Landcare Research, Lincoln, New Zealand).

Meurk, C.D.; Swaffield, S.R. 2000: A landscape ecological framework for indigenous regeneration in rural New Zealand-Aotearoa. *Landscape and Urban Planning 50*: 129–144.

Ministry for the Environment 1997: Environmental performance indicators: proposals for air, freshwater, & land. Ministry for the Environment, Wellington, New Zealand.

Ministry for the Environment 1998: Environmental performance indicators – proposals for terrestrial and freshwater biodiversity. Ministry for the Environment, Wellington, New Zealand.

Mitchell, N.D.; William, J.E. 1996: The consequences for the native biota of anthropogenic-induced climate change. In Green house: coping with climate change, *eds*. W.J. Bouma, G.I. Pearman, & M.R. Manning, pp 308-324. CSIRO Publishing, Melbourne.

Molloy, J.; Bell, B.; Clout, M.; de Lange, P.; Gibbs, G.; Given, D.; Norton, D.; Smith, W.; Stephens, T. 2002: Classifying species according to threat of extinctions: a system for New Zealand Threatened Species Occasional Publication22. Department of Conservation, Wellington.

Myers, S.C.; Park, G.N.; Overmars, F.B. 1987: The New Zealand Protected Natural Areas Programme – a guidebook for the rapid ecological survey of natural areas. New Zealand Biological Resources Centre Publication No. 6. Department of Conservation, Wellington, New Zealand.

National Academy of Sciences (USA) 2000: Ecological indicators for the Nation. National Academy Press, Washington D.C.

National Land & Water Resources Audit 2002: Australian terrestrial biodiversity assessment 2002. Land & Water Australia, Canberra.

National Park Service 2000: National Park Service Strategic Plan FY 2001 – 2005. Office of Strategic Planning, National Park Service (U.S. Department of the Interior), Denver. CO, USA.

National Roundtable on the Environment and the Economy 2003. The state of the debate on the environment and the economy: Environment and sustainable development indicators for Canada. Ottawa, Canada.

NatureServe 2002: States of the Union: Ranking America's Biodiversity. Report prepared for the Nature Conservancy. NatureServe, Arlington, VA, USA. (www.natureserve.org/Reports/stateofunions.pdf)

Neel, M.C.; Cumming, M.P. 2003: Effectiveness of conservation targets in capturing genetic diversity. *Conservation Biology 17*: 219–229.

New, T.R. 1996: An introduction to invertebrate conservation biology. Oxford University Press.

Nicholls, J.L. 1976: A revised classification of the North Island indigenous forests. *New Zealand Journal of Forestry 2*: 105–132.

Noss, R.F. 1990: Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology 4*: 355–364.

Norris, R.H. 1999. Environmental indicators: recent developments in measurement and application for assessing freshwaters. Holt, A., Dickinson, K., and Kearsley, G.W. 10: 1-49. 1999. Otago University. Environmental Policy and Management Research Centre Book Series. 1999:

Omerod, S.J.; Watkinson, A.R. 2000: Birds and agriculture – Editor's introduction. *Journal of Applied Ecology 37*: 699–705.

Ontario Ministry of Natural Resources 2002: State of the Forest Report, 2001. Ministry of Natural Resources, Peterborough, Ontario.

Pacala, S.W.; Bulte, E.; List, J.A.; Levin, S.A. 2003: False alarm over environmental false alarms. *Science 301*: 1187–1188.

Panel on the Ecological Integrity of Canada's National Parks 2000: Conserving ecological integrity with Canada's National Parks. Volume II: Setting a new direction for Canada's National Parks. Parks Canada Agency, Ottawa.

Partridge, T.R.; Whaley, K.J.; Hunter, G.G. 2002: Pest plant control monitoring techniques for regional and district councils. Part 1. Monitoring Framework. Landcare Research Contract Report LC0001/076, Landcare Research, Lincoln, New Zealand.

Payton, I.J. 2000: Damage to native forests. Pp. 111–125 in Montague, T.L. (Ed.): The brushtail possum: biology, impact and management of an introduced marsupial. Manaaki Whenua Press, Lincoln, New Zealand.

Payton, I.J.; Newell, C.; Beets, P. 2002: Sequester: a national carbon monitoring system for New Zealand's indigenous forests, shrublands, and soils. Part II – Forest and shrubland data collection. Landcare Research Contract Report JNT0001/124, Landcare Research, Lincoln, New Zealand.

Possingham, H.P.; Andelman, S.J.; Burgman, M.A.; Medellin, R.A.; Master, L.L.; Keith, D.A. 2002: Limits to the use of threatened species lists. *Trends in Ecology and Evolution 17*: 503–507.

Putnam, R.D. 2000: Bowling alone. The collapse and revival of American community. Simon & Schuster, New York.

Radford, I.J.; Cousens, R.D. 2000: Invasiveness and comparative life-history traits of exotic and indigenous *Senecio* species in Australia. *Oecologia 125*: 531–542.

Reed, D.H.; Frankham, R. 2001: How closely correlated are molecular and quantitative measures of genetic variation? A meta-analysis. *Evolution 55*: *1095–1103*

Reynoldson, T.B.; Norris, R.H.; Resh, V.H.; Day, K.E.; Rosenberg, D.M. 1997: The reference condition: a comparison of multimetric and multivariate approaches to assess water-quality impairment using benthic macroinvertebrates. *Journal of the North American Benthological Society 16*: 833–852.

Riney, T.; Watson, J.S.; Bassett, C.; Turbott, E.G.; Howard, W.E. 1959: Lake Monk Expedition, an ecological study in southern Fiordland. *DSIR Bulletin 135*: 1–75.

Robertson, D.P.; Hull, R.B. 2001: Beyond biology: towards a more public ecology for conservation. *Conservation Biology 15*: 970–979.

Roche, M.M. 1990: History of New Zealand forestry. New Zealand Forestry Corporation in association with GP Books, Wellington, New Zealand.

Ronquist, F.; Gärdenfors, U. 2003: Taxonomy and biodiversity inventories: time to deliver. *Trends in Ecology and Evolution* 18: 269–270.

Ruscoe, WA; Goldsmith, R; Choquenot, D. 2001: A comparison of population estimates and abundance indices for house mice inhabiting beech forests in New Zealand. *Wildlife Research 28*: 173–178.

Rutledge, D. 2002: Landscape indices as measures of the effects of fragmentation: can pattern reflect process? Landcare Research Contract Report LC0102/161 (prepared for the Department of Conservation). 27 p.

Salinger, M.J.; Allan, R.; Bindoff, N.; Hannah, J.; Lavery, B.; Lin, Z.; Lindsay, J.; Nicholls, N.; Plummer, N.; Torok, S. 1996: Observed variability and change in climate and sea level in Australia, New Zealand and the South Pacific. In Greenhouse: coping with climate changes, *eds*. W.J. Bouma, G.I. Pearman, & M.R. Manning, pp 100-126, CSIRO Publishing, Melbourne.

Saunders, D.A.; Margules, C.; Hill, B. 1998: Environmental indicators for national state of the environment. Biodiversity Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Schauber, E.M.; Turchin, P.; Simon, C.; Lee, W.G.; Allen, R.B.; Payton, P.R.; Wilson, P.R.; Cowan, P.E.; Brockie, R.E. 2002: Masting by eighteen New Zealand plant species: the role of temperature as a synchronizing cue. *Ecology 83*: 1214-1225.

Schick, A. 1996: The spirit of reform: Managing the New Zealand State Sector in a time of change. Report to the State Services Commission and the Treasury, New Zealand.

Schemske , D.W.; Husband, B.C.; Ruckelshaus, M.H.; Goodwillie, C.; Parker I.M.; Bishop, J.C. 1994: Evaluating approaches to the conservation of rare and endangered plants. *Ecology 75*: 584-606.

Schneider, R. 1997: Ecological diversity monitoring framework. Draft for Discussion (#6). Department of Ecology, University of Alberta, Canada.

Scotland, R.; Hughes, C.; Bailey, D.; Wortley, A. 2003: The Big Machine and the much-maligned taxonomist. *Systematics and Biodiversity 1*: 139–143.

Scott, D. 1965: A height frequency method for sampling tussock and shrub vegetation. *New Zealand Journal of Botany 3*: 253–260.

Simberloff, D. 2003: Eradication – preventing invasions at the outset. *Weed Science 51*: 247–253.

Smyth, A.K.; James, C.D. 2004: Characteristics of Australia's rangelands and key design issues for monitoring biodiversity. *Austral Ecology29*: 3–15.

Star, P.; Lochhead, L. 2002: Children of the burnt bush: New Zealanders and the indigenous remnant, 1880–1930. Pp. 119–135 in Pawson, E.; Brooking, T. (Eds): Environmental histories of New Zealand. Oxford University Press, Auckland, New Zealand.

Stephens, T.; Brown, D.; Thornley, N. 2002: Measuring conservation achievement: concepts and their application over the Twizel area. *Science for Conservation 200*. Department of Conservation, Wellington, New Zealand.

Stewart, G.H.; Johnson, P.N.; Mark, A.F. 1989: Monitoring terrestrial vegetation for biological conservation. Pp. 199–208 in Craig, B. (Ed.): Proceedings of a symposium on environmental monitoring in New Zealand with emphasis on protected natural areas. Department of Conservation, Wellington, New Zealand.

Stork, N.E. 1988. Insect diversity: facts, fiction and speculation. *Biological Journal of the Linnean Society 35*: 321–337.

Taylor, R.; Smith, I.; Cochrane, P.; Stephenson B.; Gibbs, N. 1997: The state of New Zealand's environment 1997. MfE and GP Publications, Wellington. (www.mfe.govt.nz/publications/ser/ser1997/front.pdf)

The Heinz Center 2003: The state of the Nation's ecosystems. Summary and highlights. The H. John Heinz III Center for Science, Economics and the Environment, Washington D.C.

The Nature Conservancy 2002: Conservation by design: a framework for mission success. The Nature Conservancy, Arlington, VA, USA.

Thomson, A.P. 1946: Design for a forest survey. *New Zealand Journal of Forestry 5*: 191–199.

Toms, M.P.; Siriwardena, G.M.; Greenwood, J.J.D. 1999: Developing a mammal monitoring programme for the UK. BTO Research Report No. 223. British Trust for Ornithology, Thetford, UK.

Townsend, C.R. 2003: Individual, population, community, and ecosystem consequences of a fish invader in New Zealand streams. *Conservation Biology 17*: 38–47.

Turner, W.; Spector, S.; Gardiner, E.; Fladeland, M.; Sterling, E.; Steininger, M. 2003: Remote sensing for biodiversity science and conservation. *Trends in Ecology and Evolution 18*: 306–314.

Veitch, C.R.; Clout, M.N.; (*eds.*) 2002: Turning the tide: the eradication of invasive species. Proceedings of the International Conference on Graduation of Island Invasives. IUCN Species Survival Commission No. 27 Gland, Switzerland and Cambridge, U.K.

U.S. National Invasive Species Council 2001: National Management Plan: Meeting the invasive species challenge. www.invasivespecies.gov/council/nmptoc.shtml

Walker, B.H.; Kinzag, A.; Langridge, J. 1999: Plant attribute diversity, resilience, and ecosystem functions. The nature and significance of dominant and minor species. *Ecosystems 2*: 1 - 20.

Wallace, R.L. 2003: Social influences on conservation: lessons from U.S. recovery programs for marine mammals. *Conservation Biology 17*: 104–115.

Warburton, B. 2000: Monitoring possum populations. Pp. 132–142 in Montague, T.L. (Ed.): The brushtail possum: biology, impact and management of an introduced marsupial. Manaaki Whenua Press, Lincoln, New Zealand.

Ward, D.F.; Lariviere, M.C. 2004: Terrestrial invertebrate surveys and rapid biodiversity assessment in New Zealand: lessons from Australia. *New Zealand Journal of Ecology 28*: 151–159.

Wardle, D.A.; Barker, G.M.; Yeates, G.W.; Bonner, K.I. Ghani, A. 2001: Introduced browsing mammals in natural New Zealand forests: aboveground and below ground consequences. *Ecological Monographs 71*: 587 - 614.

Wardle, J.; Guest, R. 1977: Forests of the Waitaki and Lake Hawea catchment. *New Zealand Journal of Forestry Science 7*: 44–67.

Watson, I.; Novelly, P. 2004: Making the biodiversity monitoring system sustainable: design issues for large-scale monitoring systems. *Austral Ecology* 29: 16–30.

Wellington City Council Plan: Wellington City Council Plan 2003. Council Plan 2003/04. Wellington, Wellington City Council.

White, P.S.; Walker, J.L. 1997: Approximating nature's variation: selecting and using reference sites and reference information in restoration ecology. *Restoration Ecology 5*: 338–249.

Williams, C.K.; Ives, A.R.; Applegate, R.D. 2003: Population dynamics across geographical ranges: time-series analyses of three small game species. *Ecology 84*: 2654–2667.

Williams, G.R. 1973: Birds. Pp. 304–333 in Williams, G.R. (Ed.): The natural history of New Zealand: an ecological survey. Reed, Wellington, New Zealand.

Williamson, M. 1996: Biological invasions, Chapman & Hall, London.

Wilson, E.O. 1999: The diversity of life. WW Norton, New York.

Wilson, E.O. 2000: On the future of conservation biology. *Conservation Biology 14*: 1–3.

Wilson, E.O. 2003: The encyclopaedia of life. *Trends in Ecology and Evolution 18*: 77–80.

Win, A.; Hickling, G. 2001: Seasonal grazing by Canada geese (*Branta Canadensis*) on South Island high-country pasture. Pp. 292–296 in Proceedings of the 12th Australasian Vertebrate Pest Conference, Melbourne. Department of Natural Resources and Environment, Melbourne, Australia.

Winter, M. 2000: Strong policy or weak policy? The environmental impact of the 1992 reforms to the CAP arable regime in Britain. *Journal of Rural Studies 16*: 47–59.

Wiser, S.K.; Rose, A.B. 1997: Two permanent plot methods for monitoring changes in grasslands: a field manual. Manaaki Whenua – Landcare Research, Christchurch, New Zealand.

Wiser, S.K.; Bellingham, P.; Burrows, L. 2001: Managing biodiversity information: development of New Zealand's National Vegetation Survey databank. *New Zealand Journal of Ecology 25*: 1–17.

World Bank 2004. The Little Green Data Book: from World Development Indicators. Washington, The World Bank.

Wodzicki, K.A. 1950: Introduced mammals of New Zealand. *DSIR Bulletin 98.*

Woinarski, I., Wildlife Commission of Northern Territory 2001: Developing an analytical framework for monitoring biodiversity in Australia's rangeland. Report by the Tropical Savannas CRC for the National Land and Water Resources Audits, Canberra. Tropical Savannas Cooperative Research Centre, Darwin, Australia.

Wraight, M.J. 1962: Methods of measurement of alpine grassland. Pp. 15–23 in Methods of measuring plant communities. New Zealand Institute of Agricultural Science, Wellington, New Zealand.

Wright, P.; Alward, G.; Hoekstra, T.; Tegler, B.; Turner, M. 2002: Monitoring for forest management unit scale sustainability: The Local Unit Criteria and Indicators Development (LUCID) test. USDA Forest Service, Fort Collins.

Wynberg, R**.** 2002: A decade of biodiversity conservation and use in South Africa: tracking progress from the Rio Earth Summit to the Johannesburg World Summit on Sustainable Development. *South African Journal of Science* 98: 233–243.

Wynn, G. 2002: Destruction under the guise of improvement? The forest, 1840–1920. Pp. 100–135 in Pawson, E.; Brooking, T. (Eds): Environmental histories of New Zealand. Oxford University Press, Auckland, New Zealand.

Appendix 1 International biodiversity reporting and suggested indicators

Australia

Figure A1. Australian State of the Environment reporting model.
Table A1. ANZECC-recommended core indicators for biodiversity.
Table A2. ANZECC-recommended core indicators for inland waters.

Canada

Table A3. Criteria and indicators of sustainable forest management in Canada.

United States of America

Table A4. Draft ecological indicators for US EPA State of the Environment Report.

European Union

Figure A2. Organisation of biodiversity reporting responsibilities in the European Union.

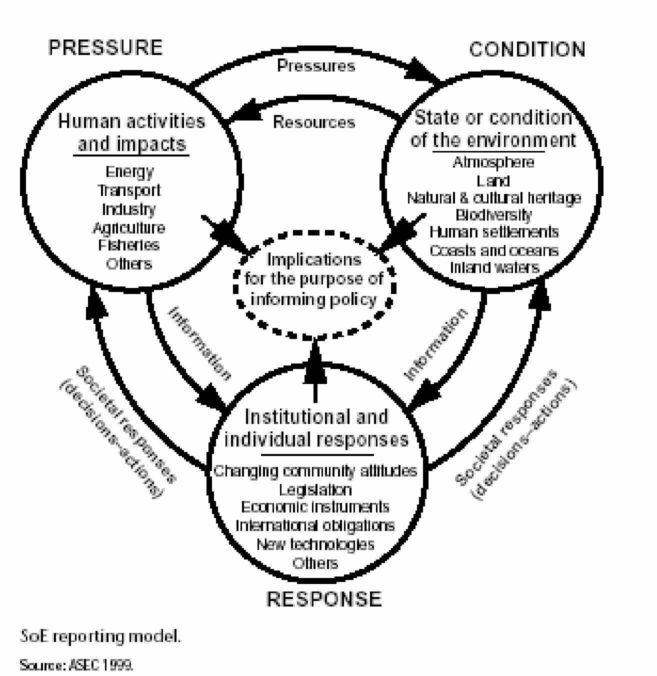

Figure A1. Australian State of the Environment reporting model.

Table A1. ANZECC-Recommended core indicators for biodiversity.

Issue	Indicator	Description
Threatening processes	Native Vegetation Clearing	Rate of clearing, in hectares per annum, of terrestrial native vegetation types, by clearing activity.
	Aquatic Habitat Destruction	Rate of destruction, in hectares per annum, of freshwater and marine habitats, by the types of disturbing activities (e.g. trawling through seagrass beds). Marine habitat types include algal beds, beaches and dunes, coral reefs, intertidal reefs, intertidal sand/mudflats, mangroves, saltmarshes, and seagrass. Freshwater habitat types include those found in streams, rivers, lakes and impoundments.
	Fire Regimes	Area of vegetation burnt, by frequency and intensity of burning and type of vegetation.
	Introduced Species	The distribution (and abundance where possible) of non-indigenous terrestrial, marine and freshwater species (plants, vertebrates, invertebrates, and pathogens) identified as pests. This indicator also includes displaced/translocated native species. The identified species will vary with place and time.
	Species Outbreaks	The number (and identity) of native species outbreaks and the location and area affected.
Loss of biodiversity	Extinct, Endangered, and Vulnerable Species & Communities	Number of species and ecological communities presumed extinct, endangered or vulnerable. This indicator should be reported by major group, together with the estimated number of endemic species per major group. Applies to animals and plants, both terrestrial and aquatic.
	Extent and Condition of Native Vegetation	The area and condition of native vegetation by type. In the absence of other measures, vegetation assemblages are used as surrogates for ecological communities and ecosystem diversity.
	Extent and Condition of Aquatic Habitats	The area and condition of marine, coastal, estuarine and freshwater habitats, by type. Marine and estuarine habitat types include algal beds, beaches and dunes, coral reefs, intertidal reefs, intertidal sand/mudflats, mangroves, saltmarshes, seagrass, and seamounts. Freshwater habitats include riverine areas and wetlands.
	Populations of Selected Species	Estimated populations of selected species, including declining species, are an important measure for assessing the conservation status of species. They are also potential surrogates for assessing changes in genetic diversity.
Biodiversity conservation and management	Terrestrial Protected Areas	Area by vegetation type in protected area categories as defined by IUCN, in hectares and as a percentage of the pre-1750 area, by IBRA region.
	Marine and Estuarine Protected Areas	The number, extent and classification of marine and estuarine protected areas (classification based on IUCN World Conservation Union criteria). Also, area as a percentage of each IMCRA region.
	Recovery Plans	Recovery plans for threatened species and ecological communities as required under legislation.
	Area Revegetated	The area revegetated by species or genus, in hectares per annum, disaggregated into areas revegetated using local vegetation or other vegetation, and the purpose of the revegetation.

Table A2. ANZECC-Recommended core indicators for inland waters.

Issue	Indicator	Description
Groundwater	Groundwater Extraction Versus Availability	Aquifers with falling water levels or bore pressures.
	Exceedences of Groundwater Quality Guidelines	Salinity and nitrate levels in groundwater.
Surface water	Extent of Deep-rooted Vegetation Cover by Catchment	Proportion of each catchment under deep-rooted vegetation.
	Surface Water Extraction versus Availability	Ratio of water use compared to catchment yield. Water extraction to be disaggregated by use and source.
	Environmental Flows Objectives	Number of waterways for which environmental flow provisions have been established, and the number where provisions are being met.
	Discharges from Point Sources	Location and number of point-source discharges into inland waters, including the type and load of materials discharged.
	Surface Water Salinity	Salinity levels in surface waters.
	Exceedences of Surface Water Quality Guidelines	Percentage exceedences of ANZECC water quality guidelines for a suite of microbiological, bacterial and chemical water quality parameters relating to: • protection of aquatic ecosystems • primary contact recreation • irrigation • stock watering.
	Freshwater Algal Blooms	Incidence of freshwater algal blooms.
	Wastewater Treatment	Number of wastewater treatment plants, together with the volume of wastewater released to inland waters, disaggregated according to the level of treatment or filtration used.
	Wastewater Reuse	Wastewater reuse, expressed as a percentage of total wastewater discharged
Aquatic habitats	Vegetated Streamlength	Percentage of total streamlength with riparian vegetation per drainage division. The width of the riparian zone and the quality of the riparian vegetation should also be reported.
	River Health (AUSRIVAS)	Assemblages of macroinvertebrates in rivers as assessed by AUSRIVAS (AUStralian RIVer Assessment Scheme) sampling protocols and computer models.
	Extent and Condition of Wetlands	Extent and condition of wetlands in each drainage division.
	Estimated Freshwater Fish Stocks	Expert assessments of the status of freshwater fish and crustacean stocks.

Canada

Table A3. Criteria and indicators of sustainable forest management in Canada.

Criterion 1:	**Conservation of biological diversity**		
Element 1.1	**Ecosystem diversity**;		
	Indicator 1.l.1	*Percentage and extent of area in forest types relative to historical condition*	
	Indicator 1.1.2	*Percentage and extent of area by forest type and age class*	
	Indicator 1.1.3	*Area, percentage and representativeness of forest types in protected areas*	
Element 1.2	**Species diversity**		
	Indicator 1.2.1	*Number of known forest-dependent species classified as extinct, threatened, endangered, rare or vulnerable relative to total number of known forest-dependent species*	
	Indicator 1.2.2	*Population levels and changes over time of selected species and species guilds*	
	Indicator 1.2.3	*Number of known forest-dependent species that occupy only a small portion of their former range*	
Criterion 2:	**Maintenance and enhancement of forest ecosystem condition and productivity**		
Element 2.1	**Incidence of disturbance and stress**		
	Indicator 2.1.1	*Area and severity of insect attack*	
	Indicator 2.1.3	*Area and severity of fire damage*	
	Indicator 2.1.4	*Rates of pollutant deposition*	
	Indicator 2.1.5	*Ozone concentrations in forested regions*	
	Indicator 2.1.8	*Climate change as measured by temperature sums*	
Element 2.2	**Ecosystem resilience**		
	Indicator 2.2.2	*Percentage of area successfully naturally regenerated and artificially regenerated*	
Element 2.3	**Extant biomass**		
	Indicator 2.3.1	*Mean annual increment by forest type and age class*	
Criterion 3:	**Conservation of soil and water resources**		
Element 3.2	**Policy and protection forest factors**		
	Indicator 3.2.1	*Percentage of forest managed primarily for soil and water protection*	
	Indicator 3.2.2	*Percentage of forest area having road construction and stream crossing guidelines in place*	
Criterion 4:	**Forest Ecosystem contributions to global ecological cycles.**		
Element 4.1	**Contributions to global carbon budget**		
	Indicator 4.1.1	*Tree biomass volumes*	
	Indicator 4.1.2	*Vegetation (non-tree) biomass estimates*	
	Indicator 4.1.3	*Percentage of canopy cover*	
	Indicator 4.1.4	*Percentage of biomass volume by general forest type*	
	Indicator 4.1.5	*Soil carbon pools*	
	Indicator 4.1.6	*Soil carbon pool decay rates*	
	Indicator 4.1.7	*Area of forest depletion*	

	Indicator 4.1.8	*Forest wood product life cycles*
	Indicator 4.1.9	*Forest sector CO_2 emissions*
	Indicator 4.3.2	*Forest sector carbon products emissions*
	Indicator 4.4.1	*Recycling rate of forest wood products manufactured and used in Canada*
Element 4.2	**Forestland conversion**	
	Indicator 4.2.1	*Areas of forest permanently converted to non-forest land use (e.g. urbanisation)*
	Indicator 4.2.2	*Semi-permanent or temporary loss or gain of forest ecosystems (e.g. grasslands, agriculture)*
	Indicator 3.1.2	*Area of forest converted to non-forest land use (e.g. urbanisation)*
Element 4.5	**Contributions to hydrological cycles**	
	Indicator 4.5.1	*Surface area of water within forested areas*

USA

Table A4. Draft (ecological) indicators for US EPA State of the Environment Report.

Type I Indicators: Adequate data are available on a national basis, the underlying monitoring or sampling design permits making inferences and the data can be used to support the development of the indicator. These data are generated by ongoing, systematic monitoring or data collection efforts.

Type II Indicators: Full or partial data are available, but either a complete cycle has not been collected, these data are not available at a national scale, the underlying monitoring design does not permit making inferences, or a quantitative estimate of condition cannot be made.

Type III Indicators: No ongoing monitoring and/or data collection is in place to provide data for these indicators. At the present time, these indicators are considered conceptual or are in a research phase. Type III indicators are useful in revealing gaps that may need to be filled in order to provide quantitative information.

THEME: ECOLOGICAL CONDITION

What is the overall ecological condition of the United States?
- Land Cover and Land Use (NRC) III
- Total Species Diversity (NRC) III
- Native Species Diversity (NRC) III
- Productivity (NRC) III
- Bird Community Index II

What is the extent and condition of ecosystems in the United States?
- What is the condition of Estuaries?
  - Submerged Aquatic Vegetation II
  - Benthic Index of Biotic Integrity II
- What is the condition of Fresh Waters?
  - Fish Index of Biotic Integrity II
  - Benthic Index of Biotic Integrity II
  - Periphyton Index of Biotic Integrity II
- What is the condition of Forests?
  - Lichen Community Index II
  - Crown Condition II
  - Tree Species Richness II
  - Forest Pattern and Fragmentation (Heinz) III
- What is the condition of Grasslands/Shrublands?
  - Area and Size of Grasslands/Shrublands Patches III
- What is the condition of Agroecosystems?
  - No indicators recommended
- What is the condition of Urban Ecosystems?
  - Patches of Forest, Grassland/Shrublands and Wetlands III
- What are pressures on Ecological Condition?
  - Specific pressures, pollutants and stressors that may affect ecological condition are further discussed in subsequent chapters.

THEME: AIR

Outdoor Air Quality in the United States
- What is the quality of the outdoor air in the United States?
  - Number of People Living in Areas with Air Quality Levels above the NAAQS I
  - Ambient Concentrations of Particulate Matter (PM 2.5) I
  - Ambient Concentrations of Particulate Matter (PM 10) I
  - Ozone: Number of People Living in Areas with Air Quality Levels above the NAAQS I
  - Ambient Concentrations of Ozone 8-hour I
  - Ambient Concentrations of Ozone 1-hour I
  - Ambient Concentrations of Lead I
  - Ambient Concentrations of Selected Air Toxics II
  - Visibility II
- What are the contributors to pollutants in air?
  - Particulate Matter Emissions (PM 2.5) II
  - Particulate Matter Emissions (PM 10) II
  - Sulfur Dioxide Emissions II
  - Nitrogen Dioxide Emissions II
  - Lead Emissions II
  - Volatile Organic Compound Emissions II
  - Air Toxic Emissions II
- What are the health effects associated with poor air quality?
  - Health effects associated with poor air quality are discussed further in the Health chapter.
- What are the ecological effects associated with air pollution?
  - Ecological effects associated with air pollution are further discussed in the Ecological Condition chapter

Stratospheric Ozone
- What is the extent and change to the earth's ozone layer?
  - Ozone Levels over North America I
  - UV Levels over North America II
- What are the changes to production and concentration of ozone depleting substances?
  - Production of ODS II
  - Concentrations of ODS over Time II
- What are human health effects associated with depleted ozone levels and what are the trends?
  - Skin Cancers II
  - Cataracts II
  - Human Health effects associated with depleted ozone levels are further discussed in the Human Health chapter

Acid Rain
- What are the deposition rates of pollutants that cause acid rain?
  - Wet Acid Deposition II
  - Dry Acid Deposition II
- What are the emissions of pollutants that form acid rain?
  - Sulfur Dioxide Emissions from Utilities II
  - No Emissions from Electric Power Generation and Large Boilers II
- What are the ecological impacts associated with acid deposition?

Climate Change
- Is the climate of the Earth changing?
  - Combined Annual Land-surface, Air, and Sea Surface Temperature Anomalies I
- What are the contributors to climate change?
  - Greenhouse Gas Emissions and Sinks I
  - Concentrations of CH4 (1000 yrs) I
  - Concentrations of CO2 (1000 yrs) I
  - Concentrations of N02 (1000 yrs) I

THEME: WATER

Water and Watersheds

- What is the condition of waters and watersheds in the United States?
  - Miles/Acres of Rivers and Lakes Meeting State
  - Water Quality Standards for Designated Uses II
  - Water Withdrawals (Heinz) II
  - Altered Freshwater Ecosystems (Heinz) II
  - Trophic Status (NRC) II
  - Harmful Algal Blooms (Heinz) II
- What are the pressures to water quality?
  - Percent Urban Land Cover in Riparian Areas II
  - Atmospheric Deposition of Nitrogen II
  - Atmospheric Deposition of Mercury II
  - Sediment Runoff I
  - Pesticide Runoff II
  - Contaminated Sediment II
  - Water Withdrawal (Heinz) I
  - Toxic Releases to Water (TRI) II
  - Nutrient Runoff (NRC) II

Wetlands

- What is the extent and condition of wetlands?
  - Freshwater Wetland Extent and Change II
  - Coastal Wetland Extent and Change II

Coastal Waters

- What is the condition of coastal waters?
  - Water Clarity I
  - Dissolved Oxygen I
  - Sea Surface Temperature (Heinz) II
- What are the pressures to estuarine waters?
  - Atmospheric Deposition of Nitrogen I
  - Nitrogen Runoff I
  - Contaminated Sediment II
  - Toxic Releases (TRI) II
  - Coastal Eutrophication II
  - Watershed Export of Nitrogen II

THEME: LAND

Land Use and Land Use Change

- How is land used and how is it changing?
  - Change in Developed Lands I
  - Coastal Development II
  - Road Density II
  - Loss of Farmland I
  - Agric. and Urban in Riparian II
- What is the effect of various land uses?
  - Soil Biological Condition (Heinz) II
  - Wetland Loss/change III
  - Soil Erosion for Agriculture I

Pesticides and Fertilisers

- What is the volume, distribution and extent of pesticide and fertiliser use?
  - Agricultural Pesticide Use I
  - Fertiliser Use II
- What is the potential disposition of pesticides and fertiliser use on land?
  - Pesticide Runoff from Farm Fields II
  - Watershed Nitrogen and Phosphorus Export II
  - Nitrate in Farmland Streams and Groundwater (Heinz) I
  - Phosphorus in Farmland Streams (Heinz) I
  - Pesticides in Farmland Streams and Groundwater (Heinz) II

What are the ecological effects of pesticide and fertiliser use on land?
Ecological effects associated with pesticide and fertiliser use on lands will be further discussed in the Ecological Condition chapter.

Waste
How much and what types of waste are generated and how has this changed over time?
Municipal Solid Waste Characterisation III
Radioactive Wastes II
RCRA Info II
What is the quantity and types of toxic releases?
TRI Waste Production II
How much land is contaminated and how has this changed over time?
Hazardous Waste II
Superfund National Priority Sites II
Number and Locations of Leaking Underground Tanks II
Oil, Chemical and Waste Spills III
How much waste is being recycled and minimised?
TRI Waste Recycling II
MSW Recycling II
What are the human health effects associated with waste and contaminated land?
Human health effects associated with waste and contaminated land will be further discussed in the Human Health chapter.

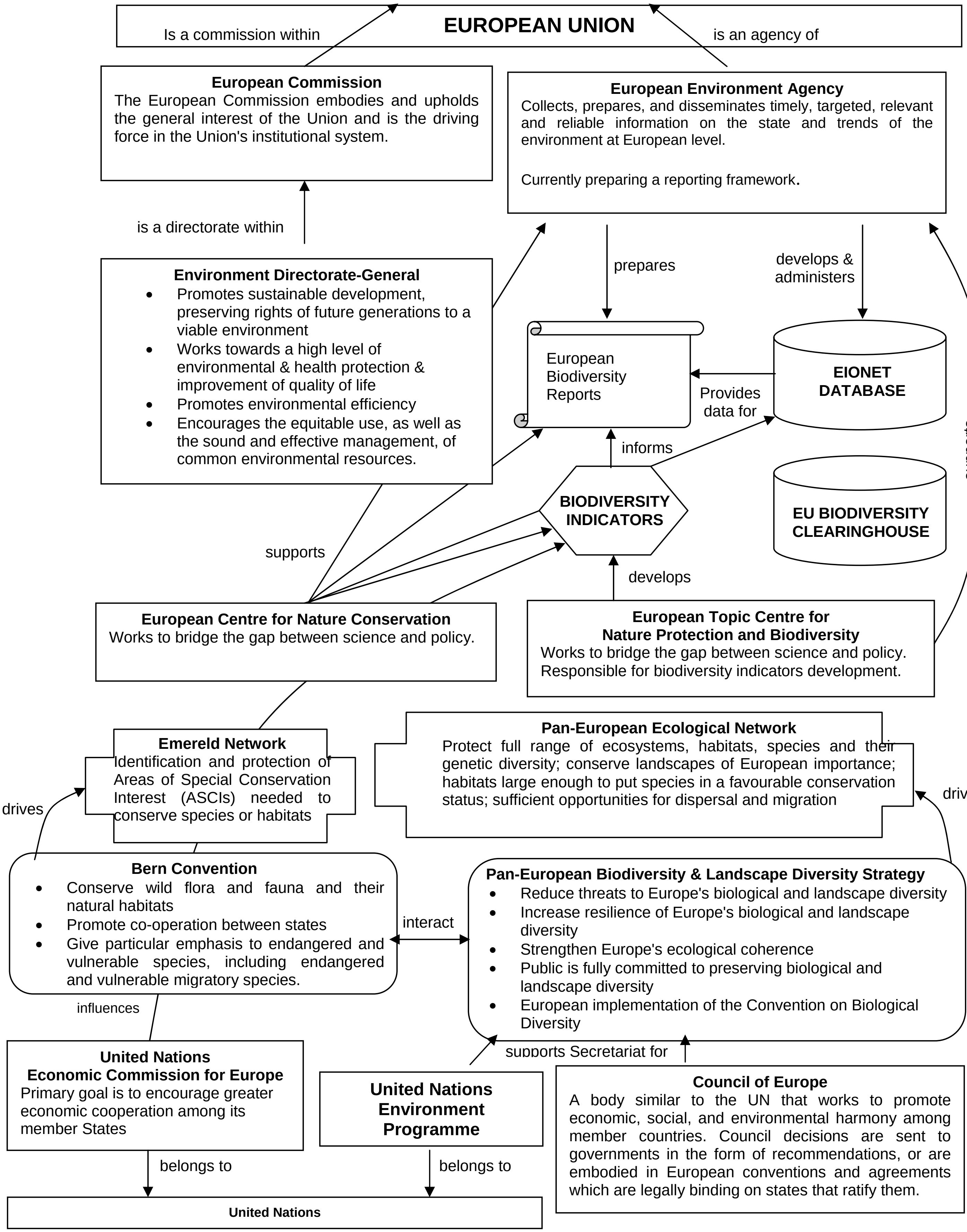

Figure A2. Organisation of biodiversity reporting responsibilities in the European Union.

Appendix 2. Assessment tables for indicators and measures

Outcome Objective 1: Maintaining ecosystem processes

Indicator 1.1 Soil Status

Measure: 1.1.1. Soil carbon status	
Policy relevance & suitability	General and low, because does not relate to specific threat. Will be of use in interpreting other biodiversity changes.
Justification	Soil carbon status is a key component of soil health for productive ecosystems.
Interpretability	Moderate, due to complex character of carbon pools
International compatibility	Widely measured and reported.
Conceptual basis	A useful indicator that summarises the net condition of a soil; a powerful determinant of the rate of ecosystem recovery after disturbance and indicator of depleted soils.
Statistical properties	Difficult to measure accurately, highly variable across the landscape, and thus difficult to model.
Robustness & Reliability	Measurement techniques well understood and robust. Technological change is likely to make analysis faster and cheaper.
Compatibility	Compatible with past work.
Flexibility	Standard techniques means can be routinely collected by various agencies. A change slowly, so is suited to inventory techniques rather than time-sensitive ones.
Cost effectiveness	At cheap end.

Indicator 1.2 Ecosystem productivity

Measure: 1.2.1 Net primary productivity (NPP) of natural terrestrial vegetation	
Policy relevance & suitability	General and moderate. Does not relate to specific threat. Only of specific use when identifiable ecosystem change prompts alert
Justification	A standard measure of total ecosystem performance. Probably capable of providing early warning of major ecosystem change
Interpretability	Low
International compatibility	Used very widely from local to global scales
Conceptual basis	There is a great deal of scientific work at all scales underpinning this measure
Statistical properties	Tractable because of the very large number of individual elements that make up the measure
Robustness & reliability	Techniques well understood and rapidly developing. Technological change is likely to alter the basis on which the measure is done, and backwards compatibility is an issue
Compatibility	Has been used successfully in context of ground-based measures. No long historical record in New Zealand
Flexibility	Highly specialised; dedicated, well-supported teams needed
Cost effectiveness	Remote sensing is not cheap, but value for money

Measure: 1.2.2 Mast flowering and fruit production	
Policy relevance & suitability	Very high; a key indicator for action. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (c)
Justification	Seed and fruit availability in certain ecosystems has been shown to be a key driver of pest abundance and also breeding success of some birds
Interpretability	High
International compatibility	Not used
Conceptual basis	Although complex, the interactions between fruiting, predator abundance cycles and impacts on indigenous vertebrates on one hand, and control of fruiting by climate fluctuations, are becoming clear
Statistical properties	Complex, but manageable
Robustness & reliability	Long data sets available now from some locations and robustness of conclusions that could be drawn from them have been demonstrated
Compatibility	Past data sets can be used to background this measure
Flexibility	Basic data could be collected by many agencies
Cost effectiveness	Moderately expensive; needs regular seed fall monitoring, often in remote locations

Indicator 1.3 Water quality and yield

Measure 1.3.1 Catchment water yield	
Policy relevance & suitability	High. Key policy issue for community relationships. DOC draft General Policy Conservation Act and Related Legislation: 4.2 (a)
Justification	Water yield is one of the key ecosystem services provided by the DOC estate, and is indirectly a measure of ecosystem status. Of key concern in drier regions
Interpretability	Reasonable
International compatibility	Widely used
Conceptual basis	Well understood; increasingly well modelled
Statistical properties	Very long history of statistical work in this area
Robustness & reliability	Long records give confidence in accuracy and context of measures. Changing technology should make this cheaper and more reliable in the intermediate future
Compatibility	Linked with general climate statistics
Flexibility	Specialised work to establish measuring stations, but can be operated on a contract basis
Cost effectiveness	High set-up costs, but a comprehensive network already in place

Measure: 1.3.2 Water chemistry	
Policy relevance & suitability	Good. DOC draft General Policy Conservation Act and Related Legislation: 4.2 (a, b)
Justification	Water chemistry gives a good basic understanding of water quality
Interpretability	Effective systems have been developed to convey message of water quality through ranking
International compatibility	Widely used
Conceptual basis	Sound
Statistical properties	Well understood
Robustness & Reliability	Long standing technology; causal factors well understood. Consistent. Long data series in New Zealand give confidence in this measure
Compatibility	Best used alongside biotic indices for the same waterways
Flexibility	Can be done routinely by contracting laboratories
Cost effectiveness	Moderate

Measure: 1.3.3 Stream invertebrate index	
Policy relevance & suitability	High. Should be policy sensitive. DOC draft General Policy Conservation Act and Related Legislation: 4.2 (a, b)
Justification	The abundance and type of stream invertebrates can be a sensitive indicator of overall waterway integrity
Interpretability	When presented well, should be intuitively easy to understand
International compatibility	Very widely used
Conceptual basis	Much international literature on this. Well worked out indices
Statistical properties	Large literature on statistical basis
Robustness & reliability	Methodology well established. Has been used for some time in New Zealand to good effect. Likely to be consistent over time. Some uncertainty about causes for change, so needs other measures as well
Compatibility	Consistent with chemical indices
Flexibility	Standard techniques can be applied routinely
Cost effectiveness	Moderately expensive as requires sampling and field time

Indicator 1.4 Ecosystem disruption

Measure: 1.4.1 Number, extent and control of fires	
Policy relevance & suitability	High
Justification	The extent of natural areas burnt is an important indicator of serious ecosystem disruption, particularly biomass, nutrient, and biodiversity loss
Interpretability	High
International compatibility	Widely used
Conceptual basis	Much international literature on this. Well worked out indices
Statistical properties	NA
Robustness & reliability	Should be robust when using a standard methodology. Reliable
Compatibility	No long-erm data but would be widely used
Flexibility	Standard techniques can be applied routinely
Cost effectiveness	Relatively inexpensive

Measure: 1.4.2 Disease outbreaks	
Policy relevance & suitability	High
Justification	Biosecurity, threatened species and public awareness
Interpretability	High
International compatibility	Regularly used in highly managed agri-systems, and increasingly in natural ecosystems
Conceptual basis	Much international literature on measuring disease impacts with usable indices
Statistical properties	Standard
Robustness & reliability	Should be robust when using a standard methodology. Reliable
Compatibility	No long-term data but would be widely used
Flexibility	Standard techniques can be applied routinely
Cost effectiveness	Relatively expensive

Measure: 1.4.3 Hydrological change	
Policy relevance & suitability	Highly relevant with regard to policy in relation to water abstraction in sensitive regions
Justification	Certain forests and most wetlands are vulnerable to water table change and subsequent fire and weed risk
Interpretability	Needs extra data from sites at risk
International compatibility	Hydrological measures are very widely used in the United States, Canada, Australia and also near urban areas
Conceptual basis	Hydrological relationships, while complex, have been intensively studied and there is a large body of literature
Statistical properties	Well understood
Robustness & reliability	Standard, well-thought out techniques available
Compatibility	Excellent compatibility with climate statistics; more complex relationships with wetland status measures
Flexibility	Routine
Cost effectiveness	Once capital costs met, should be relatively high

Measure: 1.4.4 Mass erosion	
Policy relevance & suitability	Of importance to management of vulnerable areas
Justification	Mass erosion can have a number of flow-on effects on weed and pest invasion, future stability, downstream effects and intactness of vegetation cover
Interpretability	Moderate, and area specific
International compatibility	More common in agricultural and rangeland measures
Conceptual basis	Sound. A great deal of work has gone into erosion on NZ steeplands
Statistical properties	Remote sensing should yield accurate, replicable results
Robustness & reliability	Satellite remote sensing is stable and reliable
Compatibility	Will work in well with plot-based systems, especially for vegetation cover. Highly susceptible areas may need an augmented ground-based plot network
Flexibility	Remote sensing images need specialised attention
Cost effectiveness	Moderate if confined to high-risk areas

Indicator 1.5 Land cover

Measure: 1.5.1 Land under indigenous vegetation	
Policy relevance & suitability	High
Justification	Fundamental biodiversity layer
Interpretability	High
International compatibility	Almost universally used for reporting
Conceptual basis	Sound; a great deal of work has gone into how to measure vegetation cover
Statistical properties	Excellent
Robustness & reliability	Main issue is how to keep attribution of various vegetation types consistent over time
Compatibility	Base layer for many indicators
Flexibility	Can potentially be carried out by a range of agencies
Cost effectiveness	Expensive if done properly. Long-term commitment needed

Measure: 1.5.2 Area under intensive land use	
Policy relevance & suitability	High
Justification	Measure of irreversible to long-term destruction of indigenous biodiversity
Interpretability	High
International compatibility	Similar measures universally reported
Conceptual basis	Well discussed in urban and rural planning literature
Statistical properties	Good
Robustness & reliability	Clear categories should be stable over time and with changes in collection technology
Compatibility	Compatible with and fundamental to a range of other indicators
Flexibility	Can be contracted out to a range of agencies. Needs specialist analysis however
Cost effectiveness	Moderate

Outcome Objective 2: Reducing exotic spread and dominance

Indicator 2.1 Naturalisation of new weed and pest species

Measure: 2.1.1 Occurrence of self-maintaining populations of new potential environmental weeds and animal pests	
Policy relevance & suitability	Very high. Needs careful interpretation to avoid inappropriate responses. DOC draft General Policy Conservation Act and Related Legislation: 4.3.2 (a, b)
Justification	Rate at which new potential threats enter New Zealand, or make the transition to self-maintaining status are essential basic data
Interpretability	Very high
International compatibility	A widely reported measure
Conceptual basis	Widely accepted measure
Statistical properties	NA
Robustness & reliability	Very long records available for arrival and naturalisation. Depends critically on alert specialist surveillance
Compatibility	NA
Flexibility	Needs well-trained observers
Cost effectiveness	Expensive if dedicated monitoring envisaged. Otherwise, less effective but cheap

Indicator 2.2 Exotic weed and pest dominance

Measure: 2.2.1 Distribution and abundance of exotic weeds and pests considered a threat	
Policy relevance & suitability	Very high, if the pests are updated and assessed regularly. DOC draft General Policy Conservation Act and Related Legislation: 4.3.2 (a, b)
Justification	A number of pests and weeds are considered to constitute a clear danger to ecological integrity, and need to be under surveillance monitoring
Interpretability	High
International compatibility	Very widely used
Conceptual basis	There is a great deal of evidence that early reaction to infestations is the only secure way of preventing spread
Statistical properties	Surveillance programme needs to be informed by a good surveillance strategy and supported by population modelling
Robustness & reliability	Surveillance techniques have been applied with considerable success in New Zealand against invertebrate pests and some vertebrate incursions. Have been far less successful against plants
Compatibility	There is a large amount of existing compatible data
Flexibility	Trained staff needed, but could be done by a range of agencies
Cost effectiveness	Expensive

Measure: 2.2.2 Indigenous systems released from exotic pests	
Policy relevance & suitability	High
Justification	Emerging focus for conservation of vulnerable wildlife
Interpretability	High
International compatibility	Have not seen it reported
Conceptual basis	Sound
Statistical properties	Standard
Robustness & reliability	Will need some assurance measures if private landholder schemes are included, and regular rechecks
Compatibility	Not closely tied to any other indicators, but there is a long data history for these areas
Flexibility	Needs specialised assessment
Cost effectiveness	Moderate

Outcome Objective 3: Environmental pollutants

Indicator 3.1 Ecosystem levels of persistent toxins

Measure: 3.1.1 Accidental release and chronic contamination by chemicals	
Policy relevance & suitability	Moderate. Could lead to promulgation of more effective safeguards. DOC draft General Policy Conservation Act and Related Legislation: 4.2. (a)
Justification	DOC land is traversed by major highways, and poisoning campaigns regularly take place. The risk of spills of oils and environmental poisons and chronic contamination from old dumps and mining activity is always present. Not a major risk, but a constant one
Interpretability	Moderate. Needs to be carefully put in context
International compatibility	Statistics on this measure are routinely collected
Conceptual basis	Causal factors well understood
Statistical properties	Unsure. High stochasticity
Robustness & reliability	Unsure
Compatibility	Records of major incidents will be readily available; Potential contaminated sites on DOC land would need to be mapped and assessed to establish baseline information
Flexibility	Many agencies could record these data
Cost effectiveness	Cheapish

Measure: 3.1.2 Toxins in tissues of wildlife and native species for which poisoning is suspected	
Policy relevance & suitability	High. DOC draft General Policy Conservation Act and Related Legislation: 4.2. (a)
Justification	There is widespread disquiet about persistent toxins in indigenous ecosystems, and little is known about their effects
Interpretability	Low
International compatibility	Similar measures are regularly made
Conceptual basis	Effects of some toxins are well known, and suspected in others
Statistical properties	Complex. Determining the error and correct limits to apply will need specialist input
Robustness & reliability	Techniques and sampling strategies are well understood, and a considerable literature exists
Compatibility	Records available
Flexibility	Specialists laboratories needed
Cost effectiveness	Expensive. Labour and analytical costs high for comprehensive surveys

Outcome Objective 4: Preventing declines and extinctions

Indicator 4.1 Extinct taxa

Measure: 4.1.1 Number of indigenous taxa presumed extinct	
Policy relevance & suitability	Yes. But care has to be taken to present in context. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (b)
Justification	A fundamental category that is reported universally
Interpretability	One of the best. However, multiple causes of extinction mean there are no simple relationships with underlying causes of decline. Taxa may be functionally extinct long before they satisfy the Molloy et al. (2002) criteria for extinction. Reporting should include an assessment of species likely to be extinct but not yet meeting Molloy et al. criteria.
International compatibility	Standard international measure
Conceptual basis	Sound
Statistical properties	NA
Robustness & reliability	Well documented and reliable. But could be extinct for many years before meeting the criteria – see above
Compatibility	Yes
Flexibility	Specialised assessors needed
Cost effectiveness	High

Indicator 4.2 Status of acutely threatened taxa

Measure: 4.2.1 Number of acutely threatened indigenous taxa	
Policy relevance & suitability	High; but problems with conceptual basis have to be borne in mind. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (d)
Justification	Major indicator concerning need for conservation effort
Interpretability	Excellent. Threat categories are relatively broad so movements between them will be uncommon. The measure is coarse but should present a clear message. However, multiple causes of decline involved and factors influencing this indicator are not well understood. Interpretability will be influenced by the baseline used for comparison. The measure should use Molloy et al. (2002) and Hitchmough (2002) as the baseline, with changes in number of taxa in each category being reported relative to the number identified in 2002. Changes in the lists resulting from changed knowledge of data-deficient species need to be clearly accounted for
International compatibility	Widely used
Conceptual basis	Controversial. There are problems with rare and endangered lists that should always be borne in mind, involving difficulties in assessing actual risk, lack of knowledge, and the procedures by which taxa enter and leave them
Statistical properties	NA
Robustness & reliability	Human judgement plays a large role. Has to be assessed by experts; probably not very stable with time, but this may be improving
Compatibility	Methodologies and classifications have changed in the recent past. Possibly could be used with other pressure indicators
Flexibility	Specialist assessment needed
Cost effectiveness	High

Measure: 4.2.2 Number of acutely threatened taxa under active management	
Policy relevance & suitability	Indicator gives an idea of the size of the task and how it is changing with time
Justification	This indicator identifies the amount of effort being put into restoration of acutely threatened species and changes in our understanding of the size of the threatened species problem. Need to report on management effort at both population and taxon level, including indicating what proportion of the taxon is under management
Interpretability	Good indicator of change in effort over time, but does not report on the efficacy of that effort
International compatibility	In line with general measures elsewhere
Conceptual basis	Based on expert judgement of which species need management effort first
Statistical properties	NA
Robustness	Will be influenced strongly by changing knowledge of perceived urgency of management and by the availability of resources over time
Reliability	Unproven. Change in effort depends on variability in understanding of size of problem, perceived urgency, improvements in efficiency of business planning, variability in resource availability, and political influence on resource allocation
Compatibility	Yes
Flexibility	Specialised assessors needed
Cost effectiveness	High

Measure: 4.2.3 Security of acutely threatened taxa under active management	
Policy relevance & suitability	Indicator gives an idea of the size of the task and how it is changing with time. If presented well, will size potential exposure to additional expenditure. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (d)
Justification	This indicator identifies population trends but not the causes of these trends
Interpretability	Should be high for robust individual indices. However, the extent to which trends from subpopulations can be extrapolated to a taxon as a whole is uncertain for widespread threatened species. Work to determine this will need to be undertaken
International compatibility	In line with general measures elsewhere
Conceptual basis	Based on expert judgment on high-risk categories
Statistical properties	Standard
Robustness	Will be influenced strongly by changing knowledge as to risks and trajectories of populations
Reliability	Unproven. Dependent on quality, geographic spread and rigor of monitoring. Monitoring effort is very patchy in terms of taxa with wide geographic ranges and generally limited to relatively short time series
Compatibility	There is a wealth of observational data compatible with this measure
Flexibility	Routine monitoring of some taxa could be done by contractors, but a large number of programmes will always need specialised staff
Cost effectiveness	Very expensive monitoring effort. Not within current staff capability or Departmental resources to undertake this for all acutely threatened taxa and an appropriate range of populations even if restricted to monitoring only some populations

Measure: 4.2.4 Demographic response to management at population level for selected taxa under active management	
Policy relevance & suitability	Very high. Suitable for measuring status and for audit if provisos about external factors not related to the conservation effort are taken into account. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (d)
Justification	Population demography is an essential outcome measure and can be related to key known pressure factors in many cases. Are essential data for understanding processes leading to extinction. Perhaps best expressed as simple change categories (increasing, stable, decreasing) for actively managed species (although based on a rigorous understanding of trends). Need to report on the effect of management at both population and taxon level, including indicating what proportion of the taxon is under management
Interpretability	High. Would be strengthened if trends are shown for populations *without* management compared with predicted trend *with* management so that the size of the problem can be illustrated effectively (and potentially costed)
International compatibility	Widely used
Conceptual basis.	Large literature and practical experience provides a sound basis. Based on knowledge of the factors influencing long-term population viability and the application of rigorous modelling techniques
Statistical properties	NA
Robustness	Well-understood techniques available for measuring demography change
Reliability	Monitoring effort is very patchy in terms of taxa, geographic coverage and time series. Long records available for only a few species
Compatibility	High. Often linked with other indicators in intensively managed areas
Flexibility	Specialised monitoring needed in most cases
Cost effective	Expensive. Would require additional staff capability and Departmental resources to undertake this for all acutely threatened taxa under active management

Indicator 4.3 Status of chronically threatened taxa

Measure: 4.3.1 Number of indigenous chronically threatened taxa	
Policy relevance & suitability	Very suitable. Arguably one of the most pressing policy issues is how much time and effort to invest in pre-critical species. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (d)
Justification	This is a critical measure, as it deals with species that can be relatively widespread and abundant, but are likely to move to a more critical status in the absence of intervention
Interpretability	Threat categories are relatively broad so movements between them will be uncommon. The measure is coarse but should present a clear message
International compatibility	Similar measures are widely used at both national and regional levels
Conceptual basis	As with most of the measures for acutely threatened species, complicated by the need for expert judgement and variable criteria
Statistical properties	NA
Robustness & reliability	Based on expert judgement and reliant on intensive inventory, and therefore likely to be inconsistent for many taxa over the short term. Present long-term data probably insufficient to demonstrate how reliable current measures are. With time should be more stable. Science of rareness under active development worldwide
Compatibility	Can make use of previous records
Flexibility	Needs specialist input
Cost effectiveness	Data already collected on a routine basis, so relatively cheap

Measure: 4.3.2 Number of chronically threatened taxa under active management	
Policy relevance & suitability	Indicator gives an idea of the size of the task and how it is changing with time
Justification	This indicator identifies the amount effort being put into restoration of chronically threatened species and changes in our understanding of the size of the problem. Need to report on management effort at both population and taxon level, including indicating what proportion of the taxon is under management
Interpretability	Good indicator of change in effort over time, but does not report on the efficacy of that effort
International compatibility	In line with general measures elsewhere
Conceptual basis	Based on expert judgement of which species need management effort first
Statistical properties	NA
Robustness	Will be influenced strongly by changing knowledge of perceived urgency of management and by the availability of resources over time
Reliability	Unproven. Change in effort depends on variability in understanding of size of problem, perceived urgency, improvements in efficiency of business planning, variability in resource availability, and political influence on resource allocation
Compatibility	Yes
Flexibility	Specialised assessors needed
Cost effectiveness	High

Measure 4.3.3 Security of chronically threatened taxa under active management	
Policy relevance & suitability	Very high. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (d)
Justification	Critical to early intervention when there is still hope of success
Interpretability	If well presented, and accepting rigorous monitoring techniques, should be interpretable
International compatibility	Have not seen it used
Conceptual basis	Will need careful design to assess a range of very different organisms
Statistical properties	Requires well-thought-out sampling strategy to be useful
Robustness & reliability	Sufficient historical data on long-term monitoring exists now to give guidelines of how to gather data for this measure. Multiplicity of confounding factors makes it essential that a long-term view is taken, and this is not done simply as short-term response measure
Compatibility	Yes
Flexibility	Data must be collected as part of a well-planned management strategy, and so is probably not well suited to casual contractors
Cost effectiveness	Expensive, but should be a mandatory part of any pest control intervention

Measure 4.3.4 Response to management of chronically threatened taxa.	
Policy relevance & suitability	Very high. Will appropriately focus attention on problems where, possibly, extra effort will make a large difference. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (d)
Justification	Other measures are insufficient of themselves to demonstrate the wider spatial consequences of contraction of once-common species. This measure complements it by mapping those species important components in the recent past of widespread ecosystems
Interpretability	The mapped data, once historical time series are collated, will be easily interpreted. Species must have suffered substantial range contraction for recolonisation to be readily mappable
International compatibility	Similar measures widely used
Conceptual basis	Mapping only captures part of the dynamics of taxon change, but abundance is too difficult to measure on a wide spatial scale. Will have to be supplemented by specialist studies
Statistical properties	Recording sparse distributions poses many problems. How and how often the mapping exercises are done, and the quality of the underlying data, will need close attention. Too sparse a network, and too short a time series, could make it excessively vulnerable to accepting a no-change hypothesis when significant change has occurred (Type II error)
Robustness	A great deal of effort has gone into understanding how to record distributions. It is possible that models will be necessary to get an acceptable overview of the distributions of some taxa.
Reliability	Historical data are likely to be weak for many taxa, and previous attempts to demonstrate changing ranges have been relatively coarse. However, the scientific basis appears sound
International compatibility	Yes
Flexibility	Will need a centrally co-ordinated surveillance monitoring effort, but should be able to be carried out by non-specialist teams
Cost effectiveness	Will be relatively costly

Indicator 4.4 Genetic change in critically reduced species

Measure: 4.4.1 Changes in quantitative genetic characters	
Policy relevance & suitability	High
Justification	Good indicator of long-term prospects for near-extinct organisms
Interpretability	Not high at present
International compatibility	Used elsewhere in critical-species recovery programmes
Conceptual basis	Genetic change is likely to dramatically affect long-term viability
Statistical properties	Complex
Robustness & reliability	Really still at investigation phase
Compatibility	Should be supported by existing long data series
Flexibility	Highly specialised teams needed
Cost effectiveness	Very expensive

Outcome Objective 5: Ecosystem composition

Indicator 5.1 Composition

Measure: 5.1.1 Size-class structure of canopy dominants	
Policy relevance & suitability	High. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (c.) Not much public awareness of all but a few canopy trees
Justification	Dominant primary producers on the landscape and thus key to basic ecosystem processes. Early warning of major change can be obtained from this measure
Interpretability	Low
International compatibility	Used in all nations with a functioning forest plot network
Conceptual basis	Strong: there is a very large scientific literature on this measure
Statistical properties	Excellent. A sound status and trend monitoring system of fixed remeasured plots deployed for maximum statistical power has been constructed (Carbon Monitoring System) and this should provide a good basis for analysis
Robustness & reliability	Well-understood approach and technology. Interpretation of changes, however, can be difficult because of multiple influences. Changes in technology will enhance speed and reliability. Long data sets have demonstrated reliability of this measure
Compatibility	Fundamental base data for other measures done on plot-based systems
Flexibility	Good training and supervision needed, but no highly specialised skills
Cost effectiveness	Expensive

Measure: 5.1.2 Demography of widespread animal species	
Policy relevance & suitability	Very suitable as general indicator of broad interest to the public, and likely to gain local government support. Birds are well known but lizards and large invertebrates currently have limited profile
Justification	The gradual loss of widespread and common species provides early warning of change in threat impacts, and a useful approach to gaining public support for preventing extinctions at a regional scale. Strong links to people's perceptions of declining biodiversity
Interpretability	Will vary, but could be best understood at a national level
International compatibility	Used in nations with strong amateur naturalist societies
Conceptual basis	Strong: there is a very large scientific literature on this measure.
Statistical properties	Excellent. A sound status and trend monitoring system of fixed observations on animal abundances should provide a good basis for analysis
Robustness & reliability	Well-understood approach and technology. Interpretation of changes, however, can be difficult because of multiple influences. Changes in technology will enhance speed and reliability. Long data sets have demonstrated reliability of this measure
Compatibility	Would link with range of environmental databases, as well as comprehensive plot-based systems
Flexibility	Good training and supervision needed, but no highly specialised skills
Cost effectiveness	Expensive

Measure: 5.1.3 Representation of plant functional types.	
Policy relevance & suitability	Fairly high. Should be capable of guiding preventative action. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (c.)
Justification	Needed to capture broad, general changes which may be transforming our ecosystems but are lost in the detail of species by species change
Interpretability	Could be high. Functional groups more intelligible than individual species
International compatibility	Not often used quite in this fashion, although broad organism groupings are, but is likely to become more common
Conceptual basis	Linking organisms into functional groups that perform in a similar fashion has become the focus of much research and the basis on which many ecosystem models now work
Statistical properties	Should be sound if underlying data layers are properly connected
Robustness & reliability	Basic data layers are not a problem. Needs sophisticated analysis and models to extract meaningful trends and maps. Long historical records (NVS) exist to test this measure on
Compatibility	Has a wide range of plot-based measures to compare with
Flexibility	Basic data layers collected by status and trend monitoring teams. Needs specialised analysis
Cost effectiveness	Cheap after basic data have been collected

Measure: 5.1.4 Representation of animal guilds	
Policy relevance & suitability	High. Should be capable of guiding preventative action. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (c.)
Justification	Needed to capture broad, general changes, which may be transforming our ecosystems but are lost in the detail of species by species change
Interpretability	Could be high. Functional groups more intelligible than individual species, although limited representation of some functional groups nowadays
International compatibility	Not often used quite in this fashion, although broad organism groupings are, but is likely to become more common
Conceptual basis	Linking organisms into functional groups that perform in a similar fashion has become the focus of much research and the basis on which many ecosystem models now work
Statistical properties	Could be challenging when different species/densities involved, but potentially achievable
Robustness & reliability	Needs sophisticated analysis and models to extract meaningful trends
Compatibility	Disparate measurements available
Flexibility	Could be based on amalgamated data layers for individual species, but would need specialised analysis
Cost effectiveness	Moderate costs but essential data

Indicator 5.2 Occupancy of environmental range

Measure: 5.2.1 Extent potential range occupied by focal indigenous species	
Policy relevance & suitability	Strong. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (a, b)
Justification	Certain species perform critical roles in maintaining the natural character and function of an area (kereru, fuchsia, mountain totara). A measure of their occupancy of their natural range gives early warning of ecosystem degradation or changing integrity
Interpretability	Potentially high
International compatibility	Changing ranges of key taxa are often used as indicators
Conceptual basis	Complex. The concept of 'ecosystem engineers' and 'canaries' is well established in the literature, but so is the idea of extensive redundancy in species assemblages. A precautionary attitude would ask for an indicator addressing the problem, nevertheless
Statistical properties	As long as adequate base data collected according to a sound statistically based scheme, should be excellent
Robustness & reliability	Base data collected by well-understood techniques so should be robust. Many of the key species have long archival records, so reliability could be assessed
Compatibility	Will be collected as part of a suite of other ecosystem data
Flexibility	Simple data collection techniques should make this quite flexible for many groups
Cost effectiveness	Moderate

Indicator 5.3 Patch size/fragmentation of wooded ecosystems

Measure: 5.3.1 Degree of connectivity in transformed landscapes	
Policy relevance & suitability	Could be high. If areas well chosen, should not distort. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (a, b, c.)
Justification	There is widespread concern over canopy collapse over wide areas of native forest. There is also interest and concern as to how fast ecosystems will recover after major land-use change, or vulnerability of small remnants in transformed landscapes. Remotely sensed indices provide a way of getting overviews of the rate of change in such areas
Interpretability	If presented well, high
International compatibility	Connectivity indices have been widely used, because they are easy to generate
Conceptual basis	Still uncertain. Connectivity in natural intact landscapes are a waste of time, and therefore should only be used in areas of concern in core DOC estate. As a general indicator of potential problems in transformed landscapes, they may have a subsidiary role
Statistical properties	There are problems in devising robust ways of analysing the data to obtain meaningful indices
Robustness & reliability	Basic methodology is standard; applications not so clear. Yet to be properly tested in New Zealand
Compatibility	Should work well with other ground-based measures of ecological integrity and pressure
Flexibility	Needs specialised input
Cost effectiveness	Very cheap – why do you think it is reported so often?

Outcome Objective 6: Ecosystem representation

Indicator 6.1 Environmental representation and protected status

Measure: 6.1.1 Proportion of environmental unit under indigenous cover	
Policy relevance & suitability	High. Good basic data to guide judgements as to value of certain ecosystems. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (a, b)
Justification	Fundamental data on extent of natural estate, according to abiotic environments. Basic analysis of distortion of natural ecosystem by human activity
Interpretability	High. Already well used in form of statistics on extent of lowland forests
International compatibility	Widely used in some form or another
Conceptual basis	LENZ classification of basic abiotic environments provides a good basis for degree of occupancy by indigenous elements. However, some indigenous ecosystems (i.e. montane and lowland grasslands) are themselves highly modified, and some investigation will be needed into how to represent this
Statistical properties	If base data reliable, should be excellent
Robustness	LENZ provides a quantitative basis for analysis at this scale
Reliability	Uncertain
Compatibility	LENZ layers, and land cover databases will provide basic data
Flexibility	Specialised data analysis needed
Cost effectiveness	Relatively cheap as relies on other data that will be routinely collected or is already archived

Measure: 6.1.2 Proportion of environmental unit under indigenous cover and protected	
Policy relevance & suitability	High. Should be useful in guiding conservation decisions. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (a, b)
Justification	A key criterion for conservation value is the proportion of a given environment with protected status
Interpretability	High
International compatibility	Often reported, but not usually systematically as suggested here
Conceptual basis	Basic conservation theory holds that quality is more important than area per se
Statistical properties	NA
Robustness	Information available. Threat factors understood. Can be consistently applied
Compatibility	Easily matched with other factors and indices
Flexibility	Specialised but should not be too demanding
Cost effectiveness	Cheap

Measure: 6.1.3. National change in extent and integrity of threatened naturally uncommon and significantly reduced habitats.	
Policy relevance & suitability	Very high. Will not distort effort if habitat well defined and characterised. DOC draft General Policy Conservation Act and Related Legislation: 4.3.1 (a, b, c)
Justification	There is a disproportionate number of rare and endangered species in certain specialised habitats. Many of these habitats (i.e. dry lowland forest) were once among the most abundant in the country
Interpretability	Very high
International compatibility	Widely used
Conceptual basis	Link between special habitats and special species is well established
Statistical properties	Sampling pattern must be carefully designed for habitats often fragmented and dispersed
Robustness	Consistency of definition will be a problem, as these have tended to vary widely from survey to survey. Factors underpinning decline of specialised habitats are well understood
Reliability	Past surveys of variable quality. However, international experience is developing fast in this area
Compatibility	Can use past data to a certain extent
Flexibility	Much of the monitoring/inventory will rely on high-resolution satellite and aerial photography interpretation. Specialised interpretation is needed to maintain consistency
Cost effectiveness	Remote sensing will lower the price per survey, although need for comprehensiveness will keep overall costs high

Measure: 6.1.4 Proportion of threatened naturally uncommon and significantly reduced habitats protected	
Policy relevance & suitability	High
Justification	Gives indication of degree to which these habitats are secure from transforming human activity
Interpretability	High
International compatibility	Common measure
Conceptual basis	Sound
Statistical properties	NA
Robustness	Should be stable with good documentation
Reliability	Depends on quality of initial habitat delimination
Compatibility	Works in well with a number of other indicators. For some habitats there is a long history of documentation (wetlands); for others (outcrops) virtually none
Flexibility	Not highly specialised
Cost effectiveness	Cheap

Outcome Objective 7: Climate change and variability

Indicator 7.1 Basic climate series

Measure: 7.1.1 Climate averages indices and extreme events	
Policy relevance & suitability	Moderate, but long term
Justification	Climate is a basic driver of ecosystem processes, and annual and seasonal fluctuations have been shown to have substantial effects on viability of vulnerable indigenous taxa. The probability of continued climate change is an additional factor
Interpretability	Moderate. Climate trends can be noisy and confusing
International compatibility	Universally used
Conceptual basis	There is a huge scientific literature on climate and climate change, and the basics are understood better than any natural ecosystem process
Statistical properties	Well worked out and reliable
Robustness & reliability	As good as it gets
Compatibility	Very long data sets available
Flexibility	Basic data can be routinely measured by a variety of agencies
Cost effectiveness	Moderate. Base data is low cost. However, New Zealand climate network is expensive, and additional stations for DOC purposes could be likewise

Indicator 7.2 Biological responses to climate change

Measure: 7.2.1 Extreme events and biological response	
Policy relevance & suitability	Moderate; meets long-term information needs for policy development
Justification	Many limits to plant distributions are set by extreme climatic events at a regional scale, and these need to be monitored as they provide essential background information for interpreting temporal patterns and trends
Interpretability	High
International compatibility	Variable use
Conceptual basis	Links between climate and species responses reasonably well understood
Statistical properties	Ad hoc data and hard to handle unless part of a series
Robustness & reliability	Variable use but reliable if context understood
Compatibility	NA
Flexibility	Should be part of regional climate monitoring
Cost effectiveness	Relatively cheap

Indicator 7.2 Biological responses to climate change

Measure: 7.2.2 Changing natural distributions of indigenous taxa	
Policy relevance & suitability	Moderate. More background information than anything else at moment. This could change if rapid climate change begins to occur
Justification	At present there is little predictive ability in New Zealand as to the possible effects of climate change on indigenous ecosystems. It is essential to differentiate changes that are promoted by climate and those occurring as a result of other factors
Interpretability	Moderate
International compatibility	Very widely reported
Conceptual basis	In New Zealand remains weak. Changes have occurred in the past but how and why remain obscure. Current attempts to match changing range limits with climate are equivocal. Modelling results remain untested
Statistical properties	Not robust. Noisy climate series are combined with equivocal natural changes
Robustness & reliability	Climate data are inadequate in upland areas. Few reliable measures have been made to date. If good range data can be collected and new climate records established in upland or crucial areas, results will be reliable
Compatibility	There is a large amount of pre-existing data
Flexibility	Basic elements can be collected by a variety of agencies. Analysis needs specialists
Cost effectiveness	Moderately expensive. May need new climate stations and dedicated survey

Measure: 7.2.3 Southern expansion of subtropical exotics	
Policy relevance & suitability	Moderate. DOC draft General Policy Conservation Act and Related Legislation: 4.3.2 (a, b)
Justification	Some weeds and invertebrate pests are currently limited by temperature. It is essential to get some idea of how their ranges might react to changing temperatures, in particular extremes
Interpretability	High
International compatibility	Often reported as part of generalised monitoring of climate and species ranges
Conceptual basis	Relatively strong, in particular with C4 plant weeds and invertebrates. Environmental modelling of exotic species is well advanced in New Zealand, and this will give an opportunity to test its reliability
Statistical properties	Sound
Robustness & reliability	Cause and effect fairly well established in many cases. Should produce clear interpretable results, especially in association with modelling
Compatibility	Climate data base excellent; long history of weed and pest surveillance should yield useful records
Flexibility	Initial surveillance can be done by many agencies. Modelling and analysis needs specialists
Cost effectiveness	Cheap if base data collection funded by other programmes

Outcome Objective 8: Sustainable use

Indicator 8.1 Recreational use of DOC land and its impacts

Measure: 8.1.1 Numbers and distribution of visitors in defined categories	
Policy relevance & suitability	High. DOC draft General Policy Conservation Act and Related Legislation: 4.2. (b); 9.1
Justification	Basic measure of potential impact and degree to which conservation ecosystem services are being supplied
Interpretability	Very high
International compatibility	This information is collected within most National Park systems and some public forests
Conceptual basis	Link between visitor numbers and impact should be examined, including revenue generated and expenditure on asset maintenance
Statistical properties	Good
Robustness & reliability	How to collect adequate visitor number data is well treated in the literature. Good New Zealand experience available
Compatibility	Not sure
Flexibility	Best collected by landholding agency
Cost effectiveness	Moderate

Measure: 8.1.2 Amount and standard of huts, tracking and roading	
Policy relevance & suitability	High. DOC draft General Policy Conservation Act and Related Legislation: 4.2. (b)
Justification	The vulnerability of natural areas is increased by the density and intensity of use of the vehicle and track system
Interpretability	High
International compatibility	Widely collected, especially in national parks and forests
Conceptual basis	Very good evidence for link of weed and pest invasion, vandalism and fire, and degree of roading
Statistical properties	Good
Robustness & reliability	Sound
Compatibility	Inventories of the network available
Flexibility	Collected by landholding agency
Cost effectiveness	Cheap

Measure: 8.1.3 Impacts on ecological integrity of land used for recreation	
Policy relevance & suitability	Moderate. Probably useful as background information on usage. DOC draft General Policy Conservation Act and Related Legislation: 4.2. (b); 9.1
Justification	Measure of recreational activity in DOC land, and its impact. Debates over recreational access and provision for public are likely to intensify in the future
Interpretability	Moderate
International compatibility	Possible analogues in Australia
Conceptual basis	Balance between public activity and conservation demands is always fraught, and commercial and community interests need sound data on impact of activities
Statistical properties	Complex, as recreational activities often have localised effects
Robustness & reliability	Some investigations on recreational impact have been carried out, and suggest that a reliable methodology could be developed
Compatibility	Little existing data that could be used
Flexibility	Routine surveys of impact could be carried out by a variety of agencies or contractors
Cost effectiveness	Expensive

Measures 8.1.4 Recreational hunting and fishing effort	
Policy relevance suitability	Highly relevant, as impact is disputed
Justification	Consistent, widely accepted policies regarding recreational hunters are needed
Interpretability	At the moment low because of poor collection and analysis of returns. But could be put on a sound basis with high interpretability
International compatibility	Hunting effort is an important consideration in most forested areas internationally, as game hunting has been a primary management goal
Conceptual basis	Social issues around self-reporting and consistency have to be worked out
Statistical properties	Long series should be amenable
Robustness & reliability	Uncertain, as a very large amount of public cooperation will be needed
Compatibility	Should run alongside other indicators well
Flexibility	Probably best kept within land management agency
Cost effectiveness	Uncertain. Depends on degree of compliance

Indicator 8.2 Economic use of DOC land and its impacts

Measure: 8.2.1 Number of concessions in defined categories, economic benefit and level of activity	
Policy relevance & suitability	Relevant to overview of socio-economic impact of the DOC estate
Justification	Consistent, verifiable statistics are needed in this complex area
Interpretability	The very different nature of the activities involved and their very different potential impacts makes this a challenge to interpret
International compatibility	Many international conservation areas are run with a wide range of permitted socio-economic activities, and statistics are widely collected in this area
Conceptual basis	Will need careful development
Statistical properties	Uncertain
Robustness & reliability	Good, as permitting system allows basic information collation
Compatibility	Will be difficult to link with other biodiversity indictors
Flexibility	DOC collection only
Cost effectiveness	Cheap

Measure: 8.2.2 Volume of harvested material	
Policy relevance & suitability	High. DOC draft General Policy Conservation Act and Related Legislation: 4.2. (a, b, c).
Justification	Indigenous timber, some forest products (e.g sphagnum moss, pingao, kiekie), and native fish are taken from the natural estate. Volume of this take will document trend and therefore sustainability
Interpretability	Moderate. Would need careful explanation
International compatibility	Very widely used measure, especially for mammals and timber
Conceptual basis	Linkage between sustainability and take often vague, and will need separate investigation
Statistical properties	Good experience available
Robustness & reliability	Long time series available for some measures. Concealment of volume by operators may be a problem for non-timber operations
Compatibility	Matches existing data sets
Flexibility	Statutory agency collection only
Cost effectiveness	Uncertain: depends on effectiveness of current data collection

Measure: 8.2.3 Impacts on ecological integrity of permitted activity	
Policy relevance & suitability	Moderate. Probably useful as background information on usage. DOC draft General Policy Conservation Act and Related Legislation: 4.2. (b); 9.1
Justification	Measure of permitted recreational activity in DOC land, and its impact. Debates over guided recreational access and provision for public are likely to intensify in the future
Interpretability	Moderate
International compatibility	Possible analogues in Australia
Conceptual basis	Balance between public activity and conservation demands is always fraught, and commercial and community interests need sound data on impact of activities
Statistical properties	Complex, as recreational activities often have localised effects
Robustness & reliability	Some investigations on recreational impact have been carried out, and suggest that a reliable methodology could be developed
Compatibility	Little existing data that could be used
Flexibility	Routine surveys of impact could be carried out by a variety of agencies or contractors
Cost effectiveness	Expensive

Measure 8.2.4 Conservation benefits derived from concession activities	
Policy relevance & suitability	Moderate. Probably useful as background information on usage. DOC draft General Policy Conservation Act and Related Legislation: 4.2. (b); 9.1
Justification	Debates over recreational access and provision for public are likely to intensify in the future. Measures of relative conservation benefits from concessions on DOC land need to be established
Interpretability	Moderate
International compatibility	Possible analogues in Australia
Conceptual basis	Balance between public activity and conservation demands is always fraught, and commercial and community interests need sound data on impact of activities
Statistical properties	Potentially complex
Robustness & reliability	Some investigations on conservation benefits have been carried out, and suggest that a reliable methodology could be developed
Compatibility	Little existing data that could be used
Flexibility	Routine surveys of impact could be carried out by a variety of agencies or contractors
Cost effectiveness	Expensive

Outcome Objective 9: Community in conservation

Indicator 9.1 Community involvement

Measure: 9.1.1 Community consultations	
Policy relevance & suitability	High. DOC draft General Policy Conservation Act and Related Legislation: 3.0
Justification	Measure of involvement of communities and DOC activity to meet community needs
Interpretability	Moderate. Needs context
International compatibility	Similar measures have been proposed for the LUCID (US Forest Service)
Conceptual basis	Should be a sound measure, although will be affected by high interest episodes such as protests or opposition to certain DOC activities
Statistical properties	Good
Robustness & reliability	Not sure. But should be routine
Compatibility	Uncertain if these records have been kept
Flexibility	DOC to collect
Cost effectiveness	Cheap

Measure: 9.1.2 Participation in conservation	
Policy relevance & suitability	High
Justification	An important way of increasing effort in biodiversity conservation, and a direct measure of public interest and support
Interpretability	Good
International compatibility	Unaware of formal reporting on this, but is certainly part of the conservation scene elsewhere and therefore likely to be reported widely
Conceptual basis	Straightforward
Statistical properties	NA
Robustness & reliability	Good, direct measure
Compatibility	Will complement public awareness indicators
Flexibility	DOC collation
Cost effectiveness	Cheap

Measure: 9.1.3 Number and value of corporate sponsorships in conservation	
Policy relevance & suitability	High
Justification	Increasingly important source of funding for biodiversity conservation
Interpretability	High
International compatibility	Likely to be a standard report item by most conservation organisations
Conceptual basis	Sound
Statistical properties	NA
Robustness & reliability	Excellent
Compatibility	Links well with public awareness indicators
Flexibility	DOC collects
Cost effectiveness	Cheap

Indicator 9.2 Iwi partnerships

Measure: 9.2.1 Cultural partnership projects	
Policy relevance & suitability	High
Justification	Given Treaty issues, this is an important facet of conservation
Interpretability	Difficult to say at present, but basic statistics needed in any case
International compatibility	Not seen; but likely to be an issue in Australia, Canada, United States
Conceptual basis	Sound
Statistical properties	NA
Robustness & reliability	Should be good
Compatibility	Should complement basic diversity and public awareness indicators in some cases
Flexibility	DOC to collect
Cost effectiveness	Cheap

Measure: 9.2.2 Cultural protection mechanisms	
Policy relevance & suitability	High
Justification	A under-utilised approach to biodiversity management
Interpretability	Uncertain
International compatibility	Not aware of similar measures elsewhere
Conceptual basis	Good
Statistical properties	NA
Robustness & reliability	This will need to be demonstrated in practice
Compatibility	Should combine well with basic indicators
Flexibility	DOC to collect
Cost effectiveness	Cheap

Measure: 9.2.3 Access to cultural materials	
Policy relevance & suitability	High
Justification	Although likely to be of low overall impact, it is likely to have impacts in limited areas and have a high profile
Interpretability	Complex
International compatibility	Increasingly part of conservation arrangements with indigenous peoples internationally, and New Zealand is likely to be asked for indicators
Conceptual basis	Yet to be well thought through because of the social ramifications
Statistical properties	NA
Robustness & reliability	Uncertain
Compatibility	Should be possible to link in with other indicator networks
Flexibility	DOC collection
Cost effectiveness	Moderate to expensive, depending on degree of actual impact monitoring

Indicator 9.3 Eco-vandalism

Measure: 9.3.1 Degree of illegal activity	
Policy relevance & suitability	Moderate. Complex factor, but needed as background. DOC draft General Policy Conservation Act and Related Legislation: 4.2. (b)
Justification	Detection of illegal depredations on conservation land are a measure of (1) public acceptance of conservation ethics; (2) surveillance efficiency
Interpretability	Not high
International compatibility	Statistics collected elsewhere
Conceptual basis	Complex interaction between detecting illegal activity and simply measuring surveillance input will have to be thought through before this could be confidently used as a measure
Statistical properties	Not relevant
Robustness & reliability	Legal proceedings are always recorded, so reliable
Compatibility	Long records available
Flexibility	Collected by statutory authorities only
Cost effectiveness	Cheap

Measure: 9.3.2 Number of deliberate pest releases	
Policy relevance & suitability	High. DOC draft General Policy Conservation Act and Related Legislation: 3.0; 4.3.2 (b, g)
Justification	A measure of the pressure to extend the range of game animals, and hence the ability to convince the hunting and fishing public of the primacy of conservation values
Interpretability	Low
International compatibility	Unsure
Conceptual basis	As probably only a few individuals indulge in illegal release programmes, this is probably not a highly sensitive measure
Statistical properties	Good
Robustness & reliability	Will depend on intensity of surveillance
Compatibility	Records are available for some illegal releases
Flexibility	A multi-agency effort is needed
Cost effectiveness	Will be expensive if dedicated monitoring is necessary; but cheap if information obtained during the course of other programmes

Indicator 9.4 Conservation profile

Measure: 9.4.1 Conservation and indigenous biodiversity in the written media	
Policy relevance & suitability	Moderate
Justification	Indicator of conservation effectiveness in raising interest in biodiversity matters
Interpretability	Not necessarily high. Confounding factors will have to be taken into account
International compatibility	Not aware of its use
Conceptual basis	Will need to be carefully worked through
Statistical properties	Probably difficult to get sound indicators
Robustness & reliability	NA
Compatibility	Should be supported by other public awareness indicators
Flexibility	Best collected by external agencies
Cost effectiveness	Cheap

Measure: 9.4.2 Television and radio time devoted to indigenous biodiversity	
Policy relevance & suitability	Of itself, not high. But in combination with other indicators, probably a worthwhile addition
Justification	A measure of exposure of New Zealand public to information regarding biodiversity
Interpretability	Will need support through surveys to be most useful
International compatibility	Not aware of similar measures being used
Conceptual basis	There is a very large literature on impact of electronic media
Statistical properties	Uncertain
Robustness & reliability	Uncertain
Compatibility	Will fit in with the full suite of awareness/support indicators
Flexibility	Can be contracted to other agencies
Cost effectiveness	Moderate

Measure: 9.4.3 Web site usage	
Policy relevance & suitability	Moderate
Justification	Accounts for this important investment in public information
Interpretability	Moderate
International compatibility	Almost certainly used in organisation-specific measures
Conceptual basis	Straightforward if nature of Web usage is understood
Statistical properties	High volume of information should make it sound
Robustness & reliability	Sophisticated tools available. But for long-time-series compatibility, a number of adjustments will have to made to the base rates
Compatibility	Part of a suite of public awareness/information indicators
Flexibility	Standard part of web site design
Cost effectiveness	Cheap

Measure: 9.4.4 Awareness and events	
Policy relevance & suitability	Moderate
Justification	Indicator of conservation effectiveness in raising interest and increasing understanding conservation matters
Interpretability	Not necessarily high. Confounding factors will have to be taken into account
International compatibility	Not aware of its use
Conceptual basis	Will need to be carefully worked through
Statistical properties	Probably difficult to get sound indicators; Surveys
Robustness & reliability	NA
Compatibility	Should be supported by other public awareness indicators
Flexibility	Best collected by external agencies
Cost effectiveness	Cheap