BIODIVERSITY ASSESSMENT AND MONITORING

Guidance for practitioners

UNEP WCMC

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The UNEP World Conservation Monitoring Centre is the biodiversity assessment and policy implementation arm of the United Nations Environment Programme (UNEP), the world's foremost intergovernmental environmental organisation. UNEP-WCMC aims to help decision-makers recognise the value of biodiversity to people everywhere, and to apply this knowledge in all that they do. The Centre's challenge is to transform complex data into policy-relevant information, to build tools and systems for analysis and integration, and to support the needs of nations and the international community as they engage in joint programmes of action.

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CONTENTS

EXECUTIVE SUMMARY

Biodiversity assessments are increasingly being carried out at a variety of scales by direct users and managers of biological resources, government departments, non-governmental organisations, research organisations, international bodies and the private sector. The need for biodiversity assessment and monitoring is explicitly recognised by policy processes such as Convention on Biological Diversity (CBD) and Agenda 21. However, as biodiversity is a highly complex concept, uncertainty exists among practitioners regarding how biodiversity can be assessed in practice, including issues such as the selection of variables for measurement, definition of appropriate measurement techniques, approaches for sampling and data analysis, and the selection and use of indicators.

This report aims to provide guidance to practitioners involved in biodiversity assessment and monitoring. The process of undertaking a biodiversity assessment can be conceived as a series of stages:

- Identification of information needs
- Identification of different biodiversity values
- Assessment of existing information, and identification of information gaps
- Definition of what to measure, and how to measure it
- Development and implementation of a sampling programme
- Analysis and presentation of results

Guidance is provided for each of these stages, including identification of key sources of information, and the relative merits of different approaches are considered. Particular emphasis is given to how the values that underpin any biodiversity assessment may be identified. In particular, many of the current approaches to biodiversity assessment emphasise global over local values, a bias that is seldom made explicit and is often not intended. Attention is therefore given here to how "local values", held by the direct users of biological diversity, may be assessed using participatory approaches, and integrated with assessments of global values. This report should therefore support practitioners in implementing the Ecosystem Approach of the Convention on Biodiversity (CBD), which specifies the need for pluralist, negotiated, adaptive management based at local levels.

1. INTRODUCTION

Context: unsustainable development

Although humans activities have had a significant impact on the biosphere for at least 400,000 years, evidence suggests that impacts on biodiversity and on the provision of biosphere goods and services have intensified over the past four centuries. The rate of species extinction over this period appears to be between 10 and 100 times higher than the average background rate, as indicated by the fossil record (Groombridge and Jenkins 2002). Humans now use or divert more than one third of net primary production on land, and no other single species approaches humanity in numbers, biomass and extent of distribution (Groombridge and Jenkins 2002). At the same time, many millions of people are subject to poor nutrition, poor health, and social inequality.

An implication of these trends is that current pathways of human development are unsustainable at the global level. In 1992, Chapter 40 of Agenda 21 identified two principal information needs that were considered to constrain progress toward sustainability:

- More data of suitable type, quality and scale were required "indicating the status and trends of the planet's ecosystem, natural resource, pollution and socio-economic variables"
- Relevant information must be made more widely available to support policy development and sound decision-making.

Progress has been made towards addressing these needs during the past decade. For developed countries in particular, many more data have been collated and made available, often using the internet as a means of delivery. Considerable effort has been devoted to the design of information systems, and to building capacity among less developed nations to take advantage of technological advances.

However, the data used to support policy development and decision-making are often inadequate in quantity and quality, or are not presented in an appropriate form. Much of the evidence used to assess the status and change of biodiversity is anecdotal or qualitative, has been gathered retrospectively, and employs terms and measures that are highly case-specific. There is therefore an urgent need to increase the amount of high-quality information relating to biodiversity, particularly through the establishment of appropriately designed monitoring and assessment programmes. There is also a need to improve access to the large amount of information relating to biodiversity that already exists, through development of appropriate delivery tools. Finally, there is a need to provide biodiversity information in a form that is appropriate to user needs.

Scope of the report

Among the general subject areas identified in Agenda 21, particular emphasis is given to biodiversity assessment. **Biodiversity assessment** may be defined as the process of

determining the biodiversity complement or value of particular areas or resources. This may usefully be differentiated from **biodiversity monitoring**, which explicitly addresses changes in the status or value of biodiversity over time. The analysis of trends in biodiversity is particularly challenging, because it must be based on measurements that can be repeated and are comparable over time.

This purpose of this report is to provide guidance for undertaking biodiversity assessment and monitoring at a variety of scales. Given UNEPs mandate, which refers explicitly to the provision of technical and policy advice to national Governments, this report focuses particularly on biodiversity assessment and monitoring at the national scale. However, it is recognised that national assessments will often be based on information collected at the local scale, at which most decisions relating to patterns of land use are actually made. Particular attention is therefore given here to how information may be integrated across a variety of different scales. For example, information on the detailed species composition of a patch of forest within some small sub-national administrative unit is likely to have little relevance to a national assessment of biodiversity. However, if the survey data can be aggregated and mapped to a vegetation class that is valid at a national scale, the information may then be highly relevant for broad environmental assessment purposes. This relationship is reciprocal, because a key purpose of national assessments is to establish the wider context in which local actions are undertaken, and to allow them to be better prioritised.

A note on definitions

The term *biodiversity* may be used to refer to the extent of variation in some biological entity, eg. the differing features of a series of geographical populations of a species, or to the totality of biological variation at a site or in the world overall. Three elements of biodiversity are generally differentiated: diversity within species, between species and of ecosystems (Box 1). Diversity within species refers to phenotypic and genetic variability, including diversity of genes and gene complexes. At the species level, the number of species (species richness) present in an area is often considered to be an important measure of biodiversity, although the number of taxonomically different kinds of species, or the relative abundance of each, also contribute to the range of possible measures. In addition, the endemicity of species present (ie. the extent to which they are restricted to some defined area) is often considered to be highly significant in assessing the biodiversity value of an area.

Ecosystems are composed of interacting species populations and non-living components of the biosphere. In biological terms, and as originally described, an 'ecosystem' is defined by the flow of energy and materials between individuals representing communities of species. In practice, ecosystems have come to be defined by macro-scale physical and climatic features, eg. in terms of the dominant vegetation cover in the case of most terrestrial systems, or depth and seabed characters in the case of marine systems. Strictly, 'habitat' should be defined in relation to the space occupied by some given species, but in practice the term is commonly applied to a landscape-scale portion of any ecosystem complex, and in such usage, the terms 'ecosystem' and 'habitat' are largely interchangeable.

Box 1. Definition of biological diversity (biodiversity) according to the Convention on Biological Diversity (http://www.biodiv.org/):

Biological diversity means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Biological resources includes genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity.

Habitat means the place or type of site where an organism or population naturally occurs.

Protected area means a geographically defined area that is designated or regulated and managed to achieve specific conservation objectives.

Sustainable use means the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

> end of box

Structure of the report

The process of undertaking a biodiversity assessment can be conceived as a series of stages:

- Identification of information needs
- Identification of different biodiversity values
- Assessment of existing information, and identification of information gaps
- Definition of what to measure, and how to measure it
- Development and implementation of a sampling programme
- Analysis and presentation of results

The report is structured according to these different stages.

The identification of biodiversity values is included here, as it is a key component of any assessment, determing what is to be measured, and how. Different interest groups identify and prioritise biodiversity values differently. For example, one contrast is between "global values" – such as environmental services and intrinsic existence values that accrue to all humanity – and "local values" held by the day-to-day managers of biological diversity, whose concerns often prioritise direct use of the goods that biodiversity provides. Assessments are based on such values. Many of the current approaches to biodiversity assessment advocated by governments and advisory bodies emphasise global over local values, a bias that is seldom made explicit and is often not intended. Particular attention is therefore given in this report to participatory methods of biodiversity assessment, which enable local values to be incorporated in the assessment process.

2. WHO NEEDS BIODIVERSITY ASSESSMENT?

The audience for biodiversity assessments is broad, and includes managers, planners, policy-makers, decision-makers, educators and public-awareness builders, and ultimately civil society itself. Such information users may include members of a variety of different institutions, including governments (local and national), the private sector, non-governmental organizations, local communities and intergovernmental organizations. Within this overall structure it may be possible to recognise a wide range of interest groups, some of which may overlap. Some of these groups include providers as well as users of relevant information.

It is important to note that different types of user are likely to have somewhat different information needs. A key element at the outset of any biodiversity assessment or monitoring programme will be the definition of user needs, and an analysis of the uses to which the information will be put. The following section outlines some of the most important categories of users of biodiversity-related information and sets out what their major requirements may comprise.

Biodiversity information needs of different users

Managers

This category includes a range of professionals responsible for natural resource management, including:

- those who manage areas whose main aim is the maintenance of biodiversity;
- those who manage various activities that exploit natural resources, such as forestry, fisheries, game harvest or sport hunting;
- those who manage activities that may have collateral impact on biodiversity, such as mining, farming, maintenance of waterways, outdoor sports including skiing, off-road driving, climbing.

Increasingly, most managers have to deal with many different uses of any given area, and are required to address the needs of a range of stakeholders. Their major information needs are:

- information on the occurrence and frequency of natural resources and ecosystems, and their use, within the area under the purview of the manager;
- contextual information indicating those aspects of the area that may have wider importance eg. presence of nationally or globally threatened species, endemic species, unique ecosystems, wildlife corridors;
- guidelines on best management practice, including evaluation of the limits of sustainable use, and impact assessment.

Planners

At programme planning level, organisations need to be able to identify global, regional and national level priorities for those activities that deal directly with biological diversity. For this they require information on the occurrence and status of globally or regionally important components of biological diversity in their own country, or in the case of organisations with an international mandate, all those countries in which they operate. Such components may include populations of

threatened or endemic species, occurrence of unique ecosystems, wilderness areas, areas of high diversity or of importance for particular groups of species (eg. Ramsar wetland areas). Knowledge of potential impacts of human activity on biodiversity is also needed.

Decision-makers

While in some circumstances, resource managers may have a considerable amount of autonomy, they generally operate within a legislative and policy framework that is established at a national or regional level. Decisions made at these levels can affect biodiversity conservation within a country, and can also have an impact elsewhere, for example though bilateral aid and trade policies. Higher level decision-makers usually have little detailed knowledge of biodiversity. Typically, they depend on technical advisors to provide them with targeted briefing documents summarising major issues, within a national or international context. Technical advisors typically require concise, accurate, synthesised information presented at national level and above.

Educators

There is a worldwide need for information on biodiversity and ecosystems for educational purposes. Under Article 13 of the Convention on Biological Diversity, Parties to the Convention – which comprise the great majority (*c* 180) of the world's countries – are obliged to promote and encourage the understanding of the importance of, and the measures required for, the conservation of biological diversity, as well as the inclusion of these topics in educational programmes.

Information needs in education are very variable. Roughly, they can be divided into requirements at the primary, secondary and tertiary level. Materials may be directly aimed at specific syllabuses or may be more general. In the former case they often need to be country specific, particularly at primary and secondary levels. Information products may be designed differently for use by pupils or by educators. In all cases, considerations of clarity of presentation and simplicity of language are paramount. At tertiary level there is far more scope for more generic products, which can often be detailed and of considerable technical complexity. In all cases, educational materials should ideally be designed to have a relatively long life both materially and in terms of content, as few educational establishments can afford rapid turnover.

Public-awareness builders

There is considerable overlap between education and public-awareness raising. In particular, materials intended primarily for the latter may often be used in a more strictly educational context. However, there are differences in emphasis and approach. Most importantly, raising of public awareness depends strongly on timeliness and initial impact. This particularly applies to information that is mediated through the press, television or radio, where in general "newsworthiness" is a prime consideration. Generally, the media also look for local (that is national or sometimes sub-national) issues to which news items may be linked, unless the wider issue is considered of global importance.

Government departments

Government departments that deal directly with environmental and natural resource issues have the most explicit need for information on ecosystems and other aspects of biodiversity. These departments also generally recognise the need for such information. However, many other sectors of government, including industry, transport, trade and education, also have an impact on environmental issues, and should therefore also be making use of biodiversity information. Often, however, the importance of environmental information is not fully acknowledged within these sectors, and as a result the incorporation of biodiversity information into decision-making may be problematic.

The Global Environment Facility (GEF) and Aid agencies

The GEF is a facility for financing projects, using multilateral sources and operating in conjunction with national stakeholders. All major bilateral and multilateral aid agencies now engage to a greater or lesser degree with environmental issues. Most include projects that directly address these issues as part of their portfolio. The World Bank is the single most important multilateral aid agency.

Information needs of such organisations are quite complex, reflecting the several dimensions in which they operate. They need to be able to influence policy, both nationally and internationally, and respond to questions put to them by national decision-makers. This is necessary in order to secure funding from national exchequers, and approval for the policies and programmes undertaken. These agencies also need to be able to explain the basis for their policies and programmes to governments in countries in which they operate. They thus require information appropriate to high-level decision-makers, as outlined above. At programme planning level, they need to be able to identify global, regional and national level priorities for those activities that deal directly with biological diversity. For those agencies that implement projects on the ground, they also require specific management-level information.

Non-governmental organisations (NGOs)

NGOs form an extremely heterogeneous group, with a wide range of constituencies and aims, operating at all levels from the local the global. Their roles variously include advocacy, education and raising of public-awareness, capacity-building and implementation of field programmes and projects. Virtually all also have to engage in fund-raising. Globally-operating NGOs that implement field programmes have the most extensive information needs, which are essentially the same as those for aid agencies outlined above. Important NGOs that operate at this level include WWF, WRI, Conservation International, IUCN – the World Conservation Union (which is also an IGO), WCS, FFI and the BirdLife network.

Local communities

Information on biodiversity may be required at very local scales, by the people who depend on natural resources for their livelihoods, or by communities aiming to conserve or sustainably manage biodiversity in areas close to where they live. Such information may be needed to support decision-making, for example to assist the development and implementation of management plans for communally owned lands, or the allocation of areas to different forms of land use. Local communities may also be important sources of information regarding the status, trends, values and uses of

species and habitats with which they are familiar. Approaches to participatory biodiversity assessment, involving the collection and use of biodiversity information by local people, are considered on detail in a later section in this report.

The information needs of intergovernmental agreements and organisations

The major international entities that require information on biodiversity-related issues are the multilateral environmental agreements (MEAs) and a number of the UN agencies and processes, most importantly UNEP, FAO, UNESCO, UNDP, CSD and the UN Forum on Forests (UNFF), and also the World Bank and the GEF (referred to above). As with many of the other organizations discussed here, each of these may fill a variety of roles. In many cases they are not strictly the end-users of information but are responsible for the compilation and synthesis of information for presentation to member governments and civil society (notable exceptions are those that act as implementing agencies for environmental programmes and projects on the ground; in this context, their information requirements are similar to those of aid agencies outlined above). Nevertheless, they all have information requirements which in many cases cannot be met internally and, as discussed further below, may have important procedural constraints on the ways in which information is obtained and presented. Overall, they are undoubtedly among the most significant global-level users of information on biodiversity.

The main global MEAs relating to biodiversity are:
- The Convention on Biological Diversity (CBD)
- The UN Framework Convention on Climate Change (UNFCCC)
- The UN Convention to Combat Desertification (UNCCD)
- The Convention on Wetlands of International Importance (Ramsar Convention)
- The World Heritage Convention
- The Convention on International Trade in Endangered Species (CITES)
- The Convention on Migratory Species (Bonn Convention)

In addition there is a wide range of regional agreements (eg. the UNEP regional seas conventions and their associated protocols, CCAMLR, the Bern Convention on European Habitats) and those dealing with particular aspects of natural resource use (International Tropical Timber Agreement, UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks).

Information requirements of the CBD

Of all the MEAs, the Convention on Biological Diversity has the most explicit mandate to make use of information on all aspects of biodiversity. Under Article 25, its Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) is charged with providing the Conference of the Parties (COP) with scientific and technical assessments of the status of biological diversity, in accordance with guidelines laid down by the COP.

As it has evolved, the CBD has envisaged assessments undertaken within each of the thematic work programmes under the Convention, following the ecosystem approach,

which has been adopted as the fundamental paradigm of the Convention's implementation. The major thematic work programmes cover:

- marine and coastal biological diversity
- inland water biological diversity
- forest biological diversity
- agricultural biological diversity
- dry and sub-humid lands

It is expected that a work programme on mountain ecosystems will be established at the seventh meeting of the Conference of the Parties, probably to be held in 2004.

Each work programme calls for assessments of the state of biodiversity within that ecosystem type to be made (and in the case of agriculture, on the effects of agricultural practices on biodiversity in other ecosystem types). Each is formulated in a somewhat different way. Thus the work programme for agricultural biological diversity calls for country-driven assessments while that for inland water biological diversity indicates that SBSTTA should have primary responsibility for carrying out the assessment. The Secretariat of the Convention is responsible for any assessments of marine and coastal biological diversity. An ad hoc technical expert group has been established on forest biological diversity, which is mandated to carry out an assessment of the status of, and trends in, forest biological diversity. It is generally stated that assessments should make use of existing information and be carried out in cooperation with relevant organisations.

The CBD requested contracted parties to systematically report on Articles 5 to 26 of the Convention, via national reports. This is achieved by answering a series of questions, relating to the implementation of each of the articles of the Convention within each country. Article 7 of the Convention, 'identification and monitoring', is the only article that specifically relates to monitoring. Countries are requested to indicate whether they have ecosystem or species monitoring programmes in place, are developing national biodiversity indicators or are co-operating with other parties to demonstrate assessment and indicator methodologies. The reporting process for this Convention is evolving and becoming more precise, something that is likely to continue, increasing the need for information on status and trends in biodiversity to be collected at the national scale.

The Convention on Migratory Species (CMS) is now following in the steps of the CBD, with the development of clearer information guidelines. Many of the other key global wildlife and biodiversity conventions, such as the Ramsar Convention, World Heritage Convention and Convention on Trade in Endangered Species (CITES) are working together to harmonize their reporting processes, providing clearer direction regarding the information required to show that the obligation is being met. Clearer guidelines and improved information will provide a better opportunity to inform the global community about the state of the world's environment, pressures being placed upon it and responses to reduce or combat such pressures. However, progress has been limited to date.

> Text Box:

Requirements of the CBD relating to biodiversity assessment and monitoring.

Article 7 of the Convention requires that each Contracting Party shall, as far as possible and as appropriate,

(a) Identify components of biological diversity important for its conservation and sustainable use having regard to the indicative list of categories set down in Annex I, namely:

- Ecosystems and habitats: containing high diversity, large numbers of endemic or threatened species, or wilderness; required by migratory species; of social, economic, cultural or scientific importance; or, which are representative, unique or associated with key evolutionary or other biological processes;
- Species and communities which are: threatened; wild relatives of domesticated or cultivated species; of medicinal, agricultural or other economic value; or social, scientific or cultural importance; or importance for research into the conservation and sustainable use of biological diversity, such as indicator species; and
- Described genomes and genes of social, scientific or economic importance.

(b) Monitor, through sampling and other techniques, the components of biological diversity identified pursuant to subparagraph (a) above, paying particular attention to those requiring urgent conservation measures and those which offer the greatest potential for sustainable use;

(c) Identify processes and categories of activities which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity, and monitor their effects through sampling and other techniques; and

(d) Maintain and organize, by any mechanism data, derived from identification and monitoring activities pursuant to subparagraphs (a), (b) and (c) above.

Source: http://www.biodiv.org.

➢ End of text box

Information requirements of other major MEAs

The other MEAs have more specific, and sometimes indirect, information requirements:

The Climate Change Convention's major interest is in carbon sequestration and the role of different ecosystem types, particularly forests, in this process. It too has a subsidiary body charged with providing the Conference of the Parties with scientific advice.

The World Heritage Convention requires contextual information by which to judge submissions of sites for inclusion in the list of World Heritage Sites, specifically in this case with regard to sites of biological importance. It also monitors the status of World Heritage Sites to determine whether they should be included in the list of sites in danger.

CITES requires information on the status of species included in its appendices (and in which international trade is prohibited or monitored) and, periodically, on the status of species proposed for inclusion in the appendices. In particular, it requires information on the impact of harvest for international trade of such species. Theoretically, under Article IV it also requires information on the role of Appendix-II listed species in their respective ecosystems, although this requirement is rarely exercised in practice.

The Bonn Convention requires information on the status of those species listed in its two appendices, and particularly those in Appendix I. This includes information on the status of important sites and migratory routes for those species.

The Ramsar Convention needs information on the status of inland aquatic species and ecosystems, particularly those used to judge whether a given site is of international importance. It also needs more detailed information on the state of Ramsar sites themselves, and on sites proposed for classifying as Ramsar sites. There is considerable overlap between this convention's information needs and those of the inland waters programme under the Convention on Biological Diversity.

The Convention to Combat Desertification needs information on the status of "susceptible drylands", that is, areas of arid or semi-arid land (excluding hyperarid regions) that are susceptible to land degradation. In this respect, there is much overlap between the needs of this convention and of the work programme on dry and sub-humid lands of the Convention on Biological Diversity. However, the focus of the UNCCD is very strongly on sustainable development, so that its information needs are tailored more specifically towards an understanding of the role of land degradation on poverty and human needs in dryland areas.

A strengthened international policy context for biodiversity assessment and monitoring: the 2010 target

The World Summit on Sustainable Development (WSSD), convened in 2002, recognised that despite the progress made since the 1992 Earth Summit, biodiversity is still being lost at a high rate. While the WSSD did not create any new international processes to remedy this, it endorsed existing international commitments such as the UN Millennium Declaration and those arising from the Convention on Biological Diversity, which held its sixth Conference of the Parties in April 2002. At this meeting, through *The Hague Ministerial Declaration* and the *Strategic Plan for the Convention* (Decision VI/26), Parties committed themselves to a target of a significant reduction of the current rate of biodiversity loss at the global, regional and national level by 2010, as a contribution to poverty alleviation and to the benefit of all life on earth. This target was further endorsed at WSSD.

For the first time, therefore, a global consensus has been reached in establishing a major biodiversity target, and in setting a date (2010) by which that target should be met. As the global community will need ascertain whether this target has been met, these policy developments strengthen the need for biodiversity assessment and monitoring. In particular, information will be required on the rates of biodiversity loss at global, regional and national levels, in order to allow assessment of the change in that rate between now and 2010. In addition, it may be necessary to define what should be measured, and how. The current report has been prepared to help address such questions.

3. HOW MAY BIODIVERSITY BE VALUED?

Introduction

Biodiversity is a good example of a resource that is often managed locally, but is also subject to much wider claims as a public good – often a public good valued for the diffuse actual or potential value to all humanity around the world. As public concerns about biodiversity management grow, so there is increasing demand for communication between local and global approaches to valuing, and hence managing, biodiversity.

Evaluating, or assessing, a resource is a fundamental prerequisite for its effective management. Approaches to biodiversity assessment depend ultimately on underlying social values. Sometimes there are stark differences between the values that local people see to accrue locally, and what is valued for the public good.. These differences are reflected in the ways that biological variety is described and evaluated.

Biodiversity assessments are not merely an outcome of different sets of values and different ways of managing ecosystems. They are also a potentially a very useful tool for facilitating communication among these different approaches. In recent decades, there has been a growing awareness that management of natural resources is more efficient, sustainable and equitable when done locally. The primary framework for the implementation of the Convention on Biological Diversity (CBD), is the "ecosystem approach", which endorses principles of negotiated local governance and adaptive management (see later).

Shared, adaptive decision-making over management of ecosystems requires better communication. For biodiversity assessment this means at best, joint evaluation, and at least a mutual understanding and agreement about how the variety of life is measured. This section explores how multiple values attached to biodiversity may be integrated in a biodiversity assessment process.

The primary purpose of biodiversity assessments is to provide the sort of information to decision-makers that facilitates more effective management of biodiversity and associated resources. Perhaps the most important of these decision-makers, in terms of how much they value and how much they influence biodiversity, are the most direct users and managers: farmers and other people whose livelihoods depend immediately on the variation and variability of biological resources. People have been assessing biodiversity for millennia, often in ways that are not documented or accessible by outsiders.

As biological resources became scarcer relative to human populations, claims have been made for biodiversity as a global good. Over the past century, the perception that the benefits of biodiversity accrue globally has given rise to a strong international conservation lobby and a swathe of international processes and agreements that refer to biodiversity. As noted earlier, many of these agreements require signatories to conduct some form of biodiversity assessment. Signatories are national governments, who are subject to both national and international interests. The rising interest in biodiversity assessment has not been confined to governments. The private sector too has had to comply increasingly with environmental criteria that include standards for

biodiversity, and companies have also been able to take advantage of new commercial opportunities for managing and monitoring biodiversity.

For all stakeholders, management of biodiversity is increasingly about interacting with other interest groups, in particular interest groups made up of local residents and resource users. The shift towards acknowledging the authority of local groups to analyse, plan, negotiate and act in the management of biodiversity is borne out by the "ecosystem approach" adopted by the Conference of Parties of the CBD. The operational guidelines of the ecosystem approach are based on 12 principles that explicitly acknowledge the trade-offs between local and global biodiversity values and advocate an inclusive and pragmatic approach to decision-making (Box 2).

International agreements naturally do not guarantee agreement or action at the local scales that matter, but at least in principle a large number of national governments are committed to work towards decentralised and collaborative modes of biodiversity management. Inter-governmental and non-governmental bodies are also responding to this challenge. How then can methods for assessing biodiversity be made useful as tools in exchange of information among stakeholders, or in shared decision-making?

Box 2. Principles of the Ecosystem Approach

The following 12 principles are complementary and interlinked.

Principle 1: *The objectives of management of land, water and living resources are a matter of societal choices.*

Principle 2: *Management should be decentralised to the lowest appropriate level.*

Principle 3: *Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.*

Principle 4: *Recognising potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:*

a) Reduce those market distortions that adversely affect biological diversity;
b) Align incentives to promote biodiversity conservation and sustainable use;
c) Internalise costs and benefits in the given ecosystem to the extent feasible.

Principle 5: *Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the Ecosystem Approach.*

Principle 6: *Ecosystems must be managed within the limits of their functioning.*

Principle 7: *The Ecosystem Approach should be undertaken at the appropriate spatial and temporal scales.*

Principle 8: *Recognising the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.*

Principle 9: *Management must recognise that change is inevitable.*

Principle 10: *The Ecosystem Approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.*

Principle 11: *The Ecosystem Approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.*

Principle 12: *The Ecosystem Approach should involve all relevant sectors of society and scientific disciplines.*

Source: CBD 2002

Biodiversity assessments arise from many different motives, contexts and cultures. But the many approaches to biodiversity assessment have some basic common features, such as frameworks of time and space, and reliance on observation of only a small sub-set of the facets of biological variety and variability. Each of the stages involved in implementing a biodiversity assessment requires a decision, essentially a prioritisation of what matters more and what matters less: a value judgment. Choices must be made about which organisms or processes to measure, and what to measure about them. The complexity of the natural world means that there is no single universal objective measure of biodiversity. Instead, all measurements and assessments of biodiversity are predicated on value judgments about which facets of biodiversity matter more and which matter less.

Values of biodiversity

What is biodiversity good for?

Biodiversity may be considered as a provider of goods and services to people, rather than being simply equivalent to biological resources (Box 6). These goods and services can be grouped into three categories – direct use, indirect use and non-use values (Table 1).

Box 6. Biodiversity values versus biological resource values

The valuation of biodiversity has often been based on the assumption that biological resources are "*the* physical manifestation" of biodiversity. Thus, the value of biodiversity has often been taken as equal to that of the value of biological resources. However, if biodiversity is taken to represent the *diversity* of biological resources rather than the biological resources themselves, the value of one will not necessarily be equivalent to the value of the other. Aylward (1991) argues that valuing biodiversity as biological resources has meant that the role of biodiversity *per se* is actually overlooked in land use decision making. For example, consider two competing land use investment alternatives with the *same* biological resource values *and* the same direct costs. Plan A maintains a high level of diversity and Plan B a low level of diversity. If these two plans are compared on the basis of their biological resource value then there will be no discernible difference between the two plans. The value of diversity therefore needs to be made explicit to make the optimal land use decision in these kinds of cases.

The relationship between biodiversity and the provision of goods and services to people is poorly understood. Empirical evidence linking biodiversity with direct benefits of increased or more stable yields, indirect benefits such as watershed protection or carbon sequestration, or option values of present or yet-to-evolve organisms, is scanty. Much of the challenge is methodological, as experiments on biodiversity are costly and difficult to generalise to other (or more complex) situations. Although it is difficult to quantify the benefits of more biologically diverse compared to less diverse systems, there is a general consensus about the kinds of goods and services that can be provided by biodiversity:

- Direct use values of biodiversity accrue from the benefits of a wider range of raw materials (e.g. foodstuffs, medicines, building materials and fodder for livestock). Often the most valuable aspects of biodiversity as a direct use are associated with supply of food resources during critical periods of time when staples are not available (e.g. dry seasons or droughts).

- Indirect use values of biodiversity are mostly associated with the environmental services that biodiversity sometimes enhances. More diverse ecosystems may be better providers of stable and effective microclimate regulation, protection from erosion, or other services. A perhaps underestimated indirect use value of greater biodiversity is protection from predators, parasites and diseases.

- <u>Non-use values</u> of biodiversity consist primarily of the option to use biological resources in the future (Table 1). More diverse communities of plants and animals offer a greater variety of potential future uses as well as a greater capacity to evolve new forms and processes. Also included as a non-use value is the concept of intrinsic value, which some consider to override all other biodiversity values.

A consideration of the different values of biodiversity provides a framework for appreciating the different meanings of biodiversity to different people and at different times. The various values of biodiversity can augment or compete with each other, and augment or compete with other direct, indirect or non-use values of biological resources. There may also be trade-offs between biodiversity values and the non-biological values associated with alternative land uses. Various stakeholders will rank these sets of competing values differently. Stakeholders' assessments are strengthened as decision-making tools by clear links between what they measure and what they value about biodiversity. Trade-offs in biodiversity values are considered in more detail in the following section.

Table 1. Values of biodiversity according to different authors. (N.B. correspondences are not exact – different authors mean sometimes different things by the same term).

Categories	Description	Koziell 2001	Bass et al. 2001a	Gaston and Spicer 1998	CI 2001	Takacs 1996	Blench 1997
DIRECT USE	These concern the ways in which biodiversity contributes directly to people's livelihoods, for example by improving nutrition, health and income. Direct use values are frequently divided between subsistence (or household use) values and productive (or tradable) values to distinguish goods that do not enter the market from those that do.	Subsistence Tradable	Consumptive Productive	Direct use (subsistence and tradable)	International export Regional market Local market Household use	Economic Social amenity	Economic
INDIRECT USE	These derive from the many services biodiversity provides that support human well-being. These are predominantly environmental services, such as regulation of climate, air quality, water quality and soil formation.	Environmental services Informational / evolutionary	Environmental services	Indirect use (ecological)	Ecological Geopolitical	Ecological	Ecosystem services Protection against pathogens
NON-USE	These include three components: the option to use facets of biodiversity in the future, as uses become apparent (option value); bequest to future generations (bequest value); and the belief that different organisms and ecosystems should be allowed to exist regardless of utility to humans (intrinsic value). Several authors combine these with indirect use values.	Option Intrinsic	Aesthetics and pleasure Option	Option and bequest Intrinsic		Scientific Biophilic Transformative Intrinsic Spiritual Aesthetic	Aesthetic Ethical

Global values and local values: whose count?

Biodiversity is a moving target: its manifold facets, ever dynamic, confer numerous and sometimes competing goods and services. All humans value direct use, indirect use and non-use values of these goods and services in some way, but the specifics of those values are also liable to change over time, and vary considerably among the people that hold them. Different people can be expected not only to have very different understandings of what biodiversity means, but also to prioritise the various facets of diversity differently, and to make different judgments on the trade-offs between biodiversity and non-biodiversity values. The values that people attach to biodiversity will affect the ways in which biodiversity is assessed, and in turn the land use and natural resource management decisions that are based on these assessments.

Management of biodiversity may therefore be subject to competing perceptions, claims and priorities, and the choice of assessment methods may also be subject to disagreement. However, the ways in which biodiversity assessments reflect different sets of values, and the links between these sets of values and management decisions, are often not explicit. One of the root causes of the lack of transparency in the biodiversity debate is the poor empirical understanding of how biodiversity delivers goods and services, noted earlier. Under these circumstances, a sensible management policy is the "precautionary principle" (Myers 1993), suggesting that where there are threats, we should not wait for full scientific knowledge before taking steps to protect the environment. The precautionary principle tends to guide management of biodiversity to the extent that the terms "biodiversity" and "conservation" are almost synonymous, at least at global and national levels. In the absence of understanding which facets of biodiversity maintain which direct and indirect use values, conservation of the broadest range possible of ecosystem and taxonomic diversity is considered the best way to maintain benefits to production, environmental services and options for the future. These benefits accrue ultimately to everyone on earth, and thus can be described as "global values".

For the vast majority of the world's population who are poor and rural, these global values matter, but may not matter as much as more immediate goods and services gained from biodiversity locally, or "local values" (Box 8). This difference in emphasis translates directly into different priorities for management of land and biological resources. For example, given the choice between 100 ha of a globally rare type of forest or 50 ha of that forest and 50 ha of diverse cropland, global values would prioritise the first option and local values the second, even if some measures of biodiversity (such as plant species diversity) were identical.

Box 8. Some features of local biodiversity values, with illustrative examples

- Biodiversity is especially important as a contribution to food security. In the Altiplano Andes of southern Bolivia, each family cultivates 3-4 varieties of quinoa belonging to two main groups: (a) varieties of high productivity in good years and (b) varieties of high resistance to frosts, pests and other environmental pressures, that yield a minimum production even in a bad year (Gari 1999).

- The frontier between wild and domesticated biodiversity is dynamic. African crops and livestock remain closely enough related to their locally occurring wild relatives that gene exchange continues. Minor crops and "weeds" make critical contributions to food security, particularly in marginal environments, and farmers regularly experiment with cultivation of "new" species

(Blench 1997).

- Links between the diversity of resources (species and genetic diversity) and the diversity in supporting processes (ecological diversity) are well recognised. The Damara people of Namibia base their timetables and techniques for harvesting a wide range of grass seeds on detailed knowledge of the habitats and habits of the various harvester ants that store the seeds in nests (Sullivan 1999).

- Maintenance of biodiversity at the community level may be more important than diversity maintained by individuals or households. In Idere, western Nigeria, individual farmers specialise in favourite crops – perhaps indigenous tobacco, a particular green vegetable, or tangerines – and make use of local exchange to maintain diversity in their own consumption (Guyer 1996).

There are some noteworthy contrasts between global and local biodiversity values (Table 2). In particular, global values link conservation primarily with indirect (environmental service) and non-use (option and existence) values of biodiversity rather than with direct use values. Sustainable use of biodiversity tends to be seen as a pragmatic, but not ideal, means to achieve conservation via compromise with local direct use values of the biological resources and their diversity – impacts on global direct use values are seldom mentioned. Meanwhile, local biodiversity values, of all kinds, remain poorly documented and poorly represented in the global political arena.

Table 2. Differences between global and local biodiversity values

GLOBAL	LOCAL
Indirect use and non-use values are primary concerns	Direct use values as important or more important than indirect use and non-use
Emphasis on conservation, with or without sustainable use	Emphasis on sustainable use
Usually no specified user groups	Specified user groups
Endemics (species that occur locally only) and other rare species given high values	Endemics no more important than other species
Focus on genotypes (genetic information)	Focus on phenotypes (observable qualities)
Wild and agricultural diversity treated separately	No clear boundary between wild and agricultural biodiversity

Biodiversity assessment as advocated and practised by national and international bodies – including governments, the private sector and NGOs – is overwhelmingly

predicated on global values, dominated by implicit conservation goals based on the precautionary principle. There are perhaps two main reasons for this. One is the strong influence of the international conservation lobby. The other is the absence of information on local biodiversity values, and a more fundamental dearth of appropriate methods to assess biodiversity in terms of these values.

Many institutions, such as national governments and bilateral donor agencies, are anxious to perform biodiversity assessments that are more useful to decision-making, cost-effective, representative and communicable among different interest groups. One of the biggest challenges is integrating measures of biodiversity that reflect the various values placed on it by different people. The gulf between global and local values is most apparent, but there are many other levels of contrasting values that may be difficult to weigh up against each other or to integrate (Box 9). Rather than holding simple sets of global and local values, real stakeholders fit into a suite of competing and complementary groupings. The diversity of a single forest, for instance, might interest local people, national, provincial and village-level governments, farmers' unions, traditional rights activists, pharmaceutical firms, logging companies, tourism businesses and environmental groups.

The following sections of this report explore opportunities for integrating local and global values. A pluralist approach for every biodiversity assessment is not necessary, nor are local values inherently more important than global values. However, practical decisions about land use and natural resource management would benefit from biodiversity assessments that, case by case, make explicit decisions about which values to incorporate, then use these decisions to shape the process of decision-making throughout the assessment cycle.

Tools to assess biodiversity in terms of local values

National and international policy processes (notably the CBD) are creating demand for assessment of local biodiversity values. What is needed is not so much a means for people to assess local biodiversity for themselves, but a means to *communicate* their values and assessment of local biodiversity to other stakeholders. A number of methods, mostly external in origin, are now emerging as potential tools to evaluate biodiversity as it is perceived locally in ways that are meaningful to outsiders. Here some of the most promising approaches are briefly described.

Ethnobotany

Ethnobotany is the study of how cultural groups classify and use plants. Ethnobotanical surveys typically produce annotated checklists of local plant species, detailing their local uses and names in various languages. The usual aim is to be as comprehensive and as accurate as possible, which means that ethnobotanical checklists can be invaluable sources of information about local use of plants of different types. Information linking biodiversity to local livelihoods can also be included, such as indications of which plants are used in carpentry, herbal medicine, domestic cooking (firewood and food) and so on (e.g. Dounias et al. 2000; Pandey and Kumar 2000).

A major advantage of ethnobotanical checklists is that they present information largely in the terms of local people, for instance without drawing false distinctions between "wild" and "cultivated" species. Ethnobotanical studies have also revealed some fascinating general principles, for example that all over the world ethnobiological systems of classification are based primarily on the affinities that humans observe among the taxa themselves, quite independent of the actual cultural significance and uses of those taxa (Berlin 1992).

In general, ethnobotanical studies are not conducted with the primary aim of informing local or national policy. The usefulness of simple checklists as assessments of local biodiversity utilisation and values may be limited by the absence of prioritisation among species. Furthermore, they do not usually include estimates of abundance and they tend to deal only with species diversity without reference to genetic or ecological diversity. Despite these kinds of technical limitations, ethnobotanical checklists can provide a good starting point for more detailed quantitative or qualitative assessments of biodiversity in terms of local values. Of course, ethnobotanical data can feed into quantitative statistical analyses or other discriminatory techniques (Hoft et al. 1999). However, there remains an ethical challenge in that publication of local knowledge about plants and their uses without full permission can constitute an infringement of intellectual property rights.

Ecological anthropology

Case studies by ecological anthropologists can provide much deeper understanding of local biodiversity values than any of the other methods described here. Ecological anthropologists investigate the links between human beings and their environments, or how culture and nature are interdependent in the broadest sense. Their holistic approach draws on sociology, economics and biology, though with an emphasis on qualitative rather than quantitative perspectives. Not surprisingly, work in this field draws attention to both cultural and biological diversity.

Over time, ecological anthropology has moved from a paradigm of materialism, in which human culture is interpreted as a product of adaptations to our natural environment, towards a less deterministic and more historical approach. Furthermore, many ecological anthropologists now present their work in an explicitly political context, as constructive critiques of prevailing environmental policy. For example, a careful study in Africa has refuted the popular concept of "virgin" rainforest and shown instead that human beings have practised shifting cultivation over wide areas of forest for thousands of years (Fairhead and Leach 1996). This kind of evidence has implications for the level of human activity allowable in protected areas.

Through their particular interest in the cultures of societies who live close to nature, ecological anthropologists regularly act as a voice for poor rural people to the outside world. This role is strengthened by the strenuous efforts that anthropologists make to articulate peoples' own perceptions of their environments. For instance, a recent study in Namibia reveals not only the extensive use and trade among women of a wide variety of perfumed plants, an "invisible" resource to official natural resource

managers, but also conveys the importance that women attach to these plants and their preparation, as manifestations of their identity and autonomy (Sullivan 2000).

To summarize, ecological anthropology tends to be skills-intensive, labour-intensive and academic, but very useful in providing critical insights into local systems of interaction with biodiversity that can inform more standardised assessment methodologies and provide a wider perspective of value than can be expressed in formal economic terms (see below).

Participatory rural appraisal

PRA methodologies are now well known and used throughout the world. They comprise selections of tools to elicit group knowledge and perceptions – tools such as maps, time-lines, transect walks and ranking exercises – used to guide and stimulate discussion. Ideally, the methods are introduced by outsiders but become co-opted and adapted by local people into ongoing planning processes. The methods can also be useful to provide other decision-makers, including regional and national policy-makers, with a practical understanding of how the day-to-day managers of biodiversity use and value their natural environments. PRA has the capacity to draw attention to facts obvious to local people but obscure to outsiders. For instance, PRA can demonstrate how availability of useful species is not simply a function of their abundance per area (as measured in scientific biodiversity assessments) but also of the many factors that limit access to resources, such as tenure rights, seasonality or proximity to roads or paths.

During the 1990s, a great deal of research effort was put into applying the principles of PRA to economic valuation techniques (see below) in order to evaluate the total value of goods and services provided by biological resources to local people. The rationale was that formal methods tend to ignore the wide suite of goods and services that are not marketed in the monetary economy (dubbed the "hidden harvest" by Guijt et al. 1995) and the multiple values co-existing within a single community. The new participatory valuations not only incorporated a wider range of biodiversity and functions of biodiversity, as valued locally, but also drew attention to some of the shortcomings of conventional economic assumptions, for example that households seek to maximise economic welfare, rather than, say, social obligation (Guijt and Hinchcliffe 1998). Put to best use, PRA techniques are a means of empowerment, for example by giving communities tools to track the sustainability of local development (Lee-Smith 1996).

PRA also has several limitations. Direct comparison between questionnaire-based and participatory valuations suggests that many of the claims made for PRA, such as its superior capacity to capture real behaviour and attitudes, are overstated (Davies et al. 1999). Another important problem is that while PRA expresses data in an easily accessible, often visual, format, national-level policy-makers can find micro-macro linkages difficult to make from what appears as very locally specific information. To date participatory valuation has focussed on individual resources, treating biodiversity as the sum of these rather than as the added value of variety and variability. A further need might be to elicit to what extent this bias reflects local perceptions of

biodiversity and, if appropriate, to develop PRA methods for discussing the value of diversity itself.

Economic valuation methods

In recent years economic valuation techniques have become sophisticated tools for comparing and evaluating goods and services from biological resources, with particular emphasis on valuation of non-marketed benefits. There are five broad types of approach (IIED 2001):

- market price valuation, including estimating the benefits of subsistence production and consumption;
- surrogate market approaches, including travel cost models, hedonic pricing and the substitute goods approach;
- production function approaches, which focus on biophysical relationships between forest functions and market activities;
- stated preference approaches, mainly the contingent valuation method and variants;
- cost-based approaches, including replacement cost and defensive expenditure.

These techniques are useful for assessing biodiversity in terms of individual biological resource values. Each technique has a suite of advantages and disadvantages, beyond the scope of the present discussion, but all in all they provide a flexible approach to assessment of local values attached to various taxa (e.g. Grieg-Gran et al. 2002) or to various goods and services provided by one taxon (e.g. Lynam et al. 1994). There are several strengths of these types of economic valuations as assessments of local biodiversity values. They give relative estimates of value that permit comparisons of resources within sites and among sites. By assigning monetary values to non-marketed values they allow direct comparisons among different goods and services. The use of monetary terms also facilitates communication to a wide audience, including local people, though to many people to express a cultural value – say the value of a group of trees as a social meeting place – in monetary terms is meaningless. Another weakness of these techniques for assessing biodiversity is low cost-effectiveness in terms of time and required expertise.

Biodiversity, in the strict sense, is usually classed by economists as being exclusively an option value (Aylward 1991; IIED 2001). Future options are based on utilisation in the pharmaceutical and agro-chemical industries. In an unusual example of economic assessment of the added value of diversity on top of the underlying biological resource value, the biodiversity value of Indonesian forests has been calculated in terms of their pharmaceutical bioprospecting potential based on estimates of the number of plant species in the country, probability of any single species providing a commercial drug and average royalties earned from new drugs (Aylward 1995).

Multidisciplinary landscape assessments

A major initiative to improve methods of assessing biodiversity in terms of local values, and of expressing express this information in ways useful to governmental decision-makers, is presently underway at the Centre for International Forestry Research (CIFOR). The central premise is the same as the central premise of this report: that

biodiversity assessments are predicated on particular value systems. Thus practical methods of assessment require more explicit attention to what is important to whom and how to weigh up alternative land use options in terms of these values.

> *Many biodiversity scientists claim that policy-makers ignore their research. There may be a number of reasons, but perhaps the most important is that the policy-makers do not see why it matters. The research described here is based around the development of a new paradigm that explicitly recognises the value-laden aspects of real world decision making. We cannot just record species, formations and sites and expect that to be useful, we need to indicate the relevance of this information and how it might be weighed against other considerations.*
>
> Sheil (2000)

As a start to developing appropriate methods of local valuation, a multidisciplinary case study is underway at Paya Seturan village in Bulungan, Indonesia (Sheil 2000). The researchers aim to derive what they term "decisive information" about biodiversity, meaning information that is feasible to obtain and that reduces the level of uncertainty in decision-making. The study has combined a short technical biophysical assessment (e.g. soil samples) to give a basic characterisation of the environment with a holistic set of qualitative and quantitative assessments of how the natural landscape is used and valued by local people. Innovative methods are emerging from the research. For example a classic PRA group ranking exercise – in this case ranking a number of forest species (both plants and animals) under various use categories – was combined with a statistical analysis for salience (Smith's S). This technique can give a range of useful outputs, such as overall values of the forest for different uses and the relative values of different landscape types. The results from Paya Seturan revealed that forest products were used for subsistence while most cash income came from non-forest products, but that people did not value the forest below other landscape types.

The study has also identified some key unsolved methodological challenges, such as:

- A way to measure the *accessibility* of products
- A way to measure the *scarcity* of products
- A way to measure the *frequency of use* of products
- A way to measure the *quantity* of a product (i.e. how much product can be harvested from an individual plant)
- How to *weight* species, products and landscapes according to their importance

This pilot study illustrates that there is great possibility for novel approaches to assessing biodiversity in usefully value-specific terms. At the same time the rationale for the CIFOR study is a reminder that we have a long way to go before we arrive at an adequate array of methods for cost-effective, reliable and policy-conversant assessments of local biodiversity values. Some general guidance for undertaking a participatory approach to biodiversity assessment is provided in a subsequent section (Section 6).

Table 6. Summary and comparison of local biodiversity assessments and methods

Process	Goal of assessment	Scale of measurement	Facets of biodiversity measured *	Implicit or explicit values **	Cost-effectiveness	Communicability and potential usefulness as policy tool	Potential for integration of local and global values
Ethnobotany	Documentation of names and uses of local biological resources	Local	1. taxa, gene 2. wild, agricultural 3. structure, impact	1. local 2. direct use, indirect use	Medium: depends on knowledge and reliability of key informants	Low: extrapolation above local levels difficult	Low: remain focussed on local issues with few techniques to scale-up or weigh up against considerations of public good
Ecological anthropology	Open-ended evaluation of biodiversity values	Local	1. ecosystem, taxa, gene 2. wild, agricultural 3. structure, process, impact	1. local 2. direct use, indirect use, non-use	Low: high investment of expertise, communicated mainly to academic audience		
PRA	Multiple applications	Local	1. ecosystem, taxa, gene 2. wild, agricultural 3. structure, process, impact	1. local	Medium to high: mainly simple techniques but sometimes high investment of time demanded from local people		
Economic valuation	Deriving monetary values for non-marketed resources	Local, national, global	1. taxa 2 wild, agricultural 3. structure	1. global, local 2. non-use	Low: reliable estimates require intensive primary data collection	Medium. clear, financially oriented messages, but basis considered dubious	High: explicit means for measuring and combining different values
Multi-disciplinary landscape assessments	Development of tools to express local biodiversity values in terms meaningful to higher-level policy-makers	Local	1. taxa 2. wild 3. structure, impact	1. local 2. direct use	Medium: current high requirements for expertise will decrease when methods have been developed	High: specifically designed to facilitate communication and weigh up alternative land use options	Low: so far focussed on local direct use values

* 1.ecosystem/taxa/gene 2. wild/ agricultural 3.structure/ process/impact ** 1. global / local 2. direct use / indirect use / non-use

4. WHAT DATA AND ASSESSMENTS EXIST?

Most biodiversity assessments begin with a survey of available information. This section provides an overview of key sources of information.

Global data sources

Several overviews of global biodiversity data and sources of synthesised information are available, a selection of which is provided in Table 1. In general, these overviews are intended for a broad audience, ranging from students and the concerned public to policy processes and decision-makers.

Table 1. Selection of global information sources on biodiversity and ecosystems.

Project/Product	Lead organisation	Scope	Format
Global Biodiversity Assessment (GBA) 1995	UNEP	A comprehensive independent analysis of biodiversity, including inventory, monitoring, and ecosystem function. Defines current state of biodiversity knowledge, gaps, critical issues, and research needs.	Hardcopy only.
Living Planet Report (LPR) Annually from 1998	World Wide Fund For Nature (WWF)	Details change in the status of marine, freshwater and forest ecosystems, including species trend indices, and present consumption data. Includes policy recommendations. (http://www.panda.org/news_facts/publications/general/livingplanet/lpr02.cfm)	Hardcopy and from internet.
World Atlas of Biodiversity 2002	UNEP-WCMC (published by University of California Press)	Provides a map-based assessment of global biodiversity. Covers fossil record, distribution and uses, and response measures. Reviews marine, terrestrial and freshwater ecosystems. (http://www.unep-wcmc.org/)	Hardcopy only
IUCN Red List of Threatened Species 2002	IUCN	Provides a global assessment of those taxa considered to be threatened with extinction, according to the IUCN Red List Criteria. (http://www.redlist.org/info/introduction.html)	Hardcopy and from internet
Global 200 Report 2000	World Wide Fund For Nature (WWF)	An overview of the world's most distinctive and important ecoregions (http://www.worldwildlife.org/global200/spaces.cfm)	Hardcopy and from internet
Pilot Analysis of Global Ecosystems (PAGE) 2000	World Resources Institute (WRI)	Reviews and analyses global data on five major ecosystem types; partly incorporated in *World Resources 2000-2001*. (http://www.wri.org/)	Hardcopy and from internet.

A number of ongoing global environmental assessments (GEAs) are currently in progress, which include assessments of biodiversity as part of their activities (see Table 2). Although only the lead organisation is listed here, it should be noted that all of the assessments are collaborative processes, often involving a large number of partners. Each of the assessments produces and disseminates information in a variety of ways; in many cases, the internet is increasingly becoming the main method of dissemination. It should also be noted that while biodiversity is of relevance to all of these assessments, the entire remit is often broader, including other aspects of the environment or socio-economic data.

In addition, in almost every case (with the notable exception of the FAO), these GEA's are not involved in primary data collection, but focus their activities on integrating data obtained from a variety of other sources.

Table 2. Global Environmental Assessments undertaking activities relating to biodiversity assessment

Assessment name	Lead organisation	Internet site	Scope	Scale	Timetable
Dryland Land Degradation Assessment (LADA)	FAO	http://www.fao.org/ag/agl/agll/lada/default.stm	Drylands	Global, regional	In development from 2001.
Forest Resources Assessment (FRA)	FAO	http://www.fao.org/forestry/fo/fra/index.jsp	Forests	Global, regional, national	FRA 2000 Every 10 years.
State of the World Forests				Global, regional, national	Bi-annual reports.
Global Environment Outlook (GEO)	UNEP	http://www.unep.org/GEO/index.htm	Environment	Global, regional	GEO-3 report produced 2002, bi-annual
Global International Waters Assessment (GIWA)	UNEP	http://www.giwa.net/	International (transboundary) waters	Global, regional	1999 - 2002
Intergovernmental Panel on Climate Change (IPCC)	IPCC	http://www.ipcc.ch/	Climate Change	Global, regional	3rd report 2001
Millennium Ecosystem Assessment (MA)	UNEP	http://www.millenniumassessment.org/	Ecosystems – Goods & Services	Global, regional, national, local	2001 – 2005
State of World Fisheries and Aquaculture (SOFIA)	FAO	http://www.fao.org/DOCREP/003/X8002E/x8002e00.htm#TopOfPage	Fisheries	Global, regional	3rd report 2000; reports produced every two years
World Water Assessment Programme (WWAP)	UNESCO	http://www.unesco.org/water/wwap/	Freshwater	Global, regional, basins	2000, 1st Report 2003

The Millennium Ecosystem Assessment (MA) is currently in the process of developing a comprehensive overview of the status of global biodiversity, which should become available in 2004. This assessment could provide a baseline for assessing future trends, for example monitoring progress towards the 2010 target. However, at present there is no global process that has been developed to undertake such monitoring.

In addition to these assessment processes, a number of other initiatives are in progress, aimed at providing information on biodiversity. These include scientific and technical networks, and processes for gathering and exchanging information. Although some are global in scope, others are regional, or focus on one particular element of biodiversity. Details of a selection of relevant initiatives are provided on Table 3.

An abundance of information exists relating to biodiversity within individual countries. Sources include expedition reports, natural history society journals, field study reports, impact assessment documents, taxonomic reviews of particular groups or organisms or areas, museum and herbarium specimen labels and catalogues, technical advice to farmers and breeders, and so forth. A number of countries have recently established national centers for biodiversity assessment and information management, such as INBIO in Costa Rica and CONABIO in Mexico, and these institutions are now important information sources themselves.

Although an enormous body of pertinent data exists, considerable effort is required to create harmonised sets of data that can be readily analysed, and used as a basis for presentation of information to a non-technical audience. Many data, often collected with difficulty and at great expense, remain entirely in specialised and technical spheres, and have never been applied to biodiversity conservation and ecosystem management. The collation, integration and analysis of patchy, inadequate data is one of the most significant challenges to biodiversity assessment, at any scale. This reflects the fact that relatively few systematic surveys of biodiversity are currently being undertaken.

Table 3. A selection of major biodiversity information sources and biodiversity-related initiatives

Title	Origin and status	Role and activities
Clearing-House Mechanism (CHM) of the Convention on Biological Diversity (CBD) http://www.biodiv.org/chm/	The CHM, as part of the Secretariat of the Convention on Biological Diversity, is housed in UNEP.	Established by the 1st COP to promote and facilitate technical and scientific cooperation in support of the Convention and its three principal objectives: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits
Global Taxonomy Initiative (GTI) of the Convention on Biological Diversity http://www.biodiv.org/programmes/cross-cutting/taxonomy/default.asp	The GTI, as part of the Secretariat of the Convention on Biological Diversity, is housed in UNEP.	Established by the Conference of the Parties to address the lack of taxonomic information and expertise available in many parts of the world, and thereby improve decision-making in conservation, sustainable use and equitable sharing of the benefits derived from genetic resources. The GTI is specifically intended to support implementation of the work programmes of the Convention on thematic and cross cutting issues.
Global Biodiversity Information Facility (GBIF) http://www.gbif.org/	GBIF arose from the work of the OECD Megascience Forum Working Group on Biological Informatics that was established in January 1996.	GBIF will be an interoperable network of biodiversity databases and information technology tools that will enable users to access and apply the world's available biodiversity information to produce national economic, environmental and social benefits. It will work in close co-operation with established programmes and organisations, including the Clearing-House Mechanism (CHM). GBIF has been identified as the biodiversity information system that will support the GTI. GBIF and Species 2000 have agreed to work closely to ensure no duplication of effort.

SPECIES 2000 http://www.sp2000.org/	Established by the International Union of Biological Sciences (IUBS), in co-operation with the Committee on Data for Science and Technology (CODATA) and the International Union of Microbiological Societies (IUMS) in September 1994. Founding members include NHM London, RIKEN Tokyo, BIOSIS UK, ETI, FishBase, and ILDIS.	Aiming to create a uniform and validated index of names of all known species in order to provide: (1) an electronic baseline species list for use in inventory projects world-wide; (2) the index for an Internet gateway to species/biodiversity databases world-wide; (3) a reference system for comparison between inventories; and (4) a comprehensive catalogue for checking the status, classification and naming of all species. GBIF and Species 2000 have agreed to work closely to ensure no duplication of effort. Endorsed by the UNEP Biodiversity Work Programme 1996-1997, and associated with the Clearing House Mechanism of the UN Convention on Biological Diversity
DIVERSITAS http://www.icsu.org/DIVERSITAS	An international program of biodiversity science sponsored by UNESCO and several of the members of the International Council of Science (ICSU): the International Union of Biological Sciences, the International Union of Microbiological Societies, the Scientific Committee on Problems of the Environment, and the International Geosphere-Biosphere Program.	The goal is to provide accurate scientific information and predictive models of the status of biodiversity and sustainability of the use of the Earth's biotic resources, and to build a worldwide capacity for the science of biodiversity. Core programme elements in five areas: (1) the effect of biodiversity on ecosystem functioning; (2) origins, maintenance and change of biodiversity; (3) systematics: inventorying and classification; (4) monitoring of biodiversity; (5) conservation, restoration and sustainable use of biodiversity. Six Special Target Areas of Research (STARs): (1) soil and sediment biodiversity; (2) marine biodiversity; (3) microbial biodiversity; (4) inland water biodiversity; (5) human dimensions; (6) invasive species and their effect on biodiversity. Has initiated International Biodiversity Observation Year (IBOY) 2001-2002.
International Working Group on Taxonomic Databases (TDWG) http://www.tdwg.org	An international working group now affiliated with the International Union of Biological Sciences (IUBS) as the Commission on Taxonomic Databases	Set up in 1985 to explore options for standarisation and collaboration between major plant taxonomic database projects, now not restricted to plants. Members include institutions and individuals responsible for biological databases with taxonomic components. TDWG fosters discussion of technical aspects of taxonomic databases, proposed standards, and current developments in taxonomic databases. Aims to promote common terminology, data fields, and data dictionaries, to develop common logical rules and data relationships, and to promote interoperability.

Man and the Biosphere (MAB) http://www.unesco.org/mab/index.htm	A programme of UNESCO.	An interdisciplinary programme of research and training intended to develop the basis for rational use and conservation of biosphere resources, and improve the global relationship between people and the environment. MAB has worked to develop an innovative network of 411 Biosphere Reserves in 94 countries (September 2001) that represent a major tool for meeting the requirements of the CBD. MAB has made developed and available biological inventory databases (MABFlora and MABFauna) for managing information on organisms in protected areas.
Global Terrestrial Observing System (GTOS) http://www.fao.org/gtos/	Etablished in January 1996 by five co-sponsoring organisations (UNEP, FAO, UNESCO, WMO, and ICSU), with FAO providing the support for the GTOS secretariat.	Together with similar global observing systems for climate (GCOS) and the oceans (GOOS), GTOS was created in response to international calls for a deeper understanding of global change in the Earth System. The central mission of GTOS is to provide data for detecting, quantifying, locating and giving early warning of changes in the capacity of terrestrial ecosystems to sustain development and improvements in human welfare. The core of GTOS will be a permanent observing system for the world's key managed and natural ecosystems. The system is based on a five-tier data sampling strategy involving large-scale studies of the Earth's major environmental gradients, agricultural and ecological research centres, field stations and a gridded series of some 10,000 sampling sites.
Global Ocean Observing System (GOOS) http://ioc.unesco.org/goos/	Etablished in by four organisations (UNEP, IOC, WMO, and ICSU), with IOC providing the secretariat for GOOS projects..	Hosted at Intergovernmental Oceanographic Commission, a part of UNESCO. GOOS is a permanent global system for observations, modelling and analysis of marine and ocean variables to support operational ocean services worldwide. GOOS will provide accurate descriptions of the present state of the oceans, including living resources; continuous forecasts of the future conditions of the sea for as far ahead as possible; and the basis for forecasts of climate change.
International Coral Reef Action	Network founding partners: World Fish	A collaborative effort designed to reverse the decline of the world's coral reefs.

Network (ICRAN) http://www.icran.org/	Center (ICLARM), the United Nations Environment Programme (UNEP) and the UNEP-World Conservation Monitoring Centre (UNEP-WCMC), the World Resources Institute (WRI), the Global Coral Reef Monitoring Network (GCRMN), the International Coral Reef Initiative-Coordinating Planning Committee (ICRI-CPC), the Coral Reef Alliance (CORAL), and the South Pacific Regional Environment Program (SPREP) Supported by the United Nations Foundation (UNF),.	ICRAN consists of a set of inter-linked, complementary activities that will facilitate the proliferation of good practices for coral reef management and conservation. The project consists of a one-year start-up phase, now ongoing, and a four-year action phase from 2001 to 2005. One of three operational units of the International Coral Reef Initiative (with the Global Coral Reef Monitoring Network and the International Coral Reef Information Network). The activities of ICRAN fall into three components: Management Action, Assessment and Communication. They combine strategic on-the-ground action with activities to provide information necessary for the development of informed, supportive policy among nations with coral reefs. ICRAN will play a key supportive role in several national and international conservation and resource management programs.
Global Plan of Action for the protection of the Marine Environment from Land-based Activities (GPA) http://www.gpa.unep.org/	The GPA was adopted by 108 Governments, and the European Commission, in Washington D.C. in 1995. UNEP Coordination Office in The Hague, The Netherlands provides the secretariat.	Designed to be a source of conceptual and practical guidance to be drawn upon by national and/or regional authorities for devising and implementing sustained action to prevent, reduce, control and/or eliminate marine degradation from land-based activities. Generic recommedations are made to States to undertake a wide range of relevant identification and assessment studies. The UNEP Regional Seas Programme and the other regional seas programmes and organizations will provide an integrated framework for national action programmes. Particular aims include: contributions to the GEF sponsored Global International Waters Assessment project; decadal assessment (2002) focusing on scenarios & building on the global & regional Visions prepared for the second World Water Forum (The Hague, March 2000); support to national / regional assessments or updates of existing reviews on government request
Regional Seas http://www.unep.ch/seas/rshome.html	A long-term activity coordinated by UNEP, in collaboration with maritime governments.	Aims to foster regional cooperation on marine and coastal environment management. Includes creation of Action Plans to foster sound management for each region, together with a series of regional Conventions (currently nine) designed to protect shared environmental interests. Currently more than 140 coastal States and Territories participate in 17 regional programmes, 14 of which were

		initiated by UNEP. Of these, 13 have formally adopted their own regional Action Plans. There are also three partner programmes (Arctic, OSPAR for the North-East Atlantic, and HELCOM for the Baltic). Crucially the Regional Seas programme has led to creation of regional mechanisms for cooperation between governments and commitment to shared goals.
Global Invasive Species Programme (GISP) http://jasper.stanford.edu/gisp/	Coordinated by the Scientific Committee on Problems of the Environment (SCOPE), in collaboration with the World Conservation Union (IUCN), the Centre for Agriculture and Biosciences International (CAB International) and UNEP.	In Article 8(h) the CBD recognized the importance of alien species and called on contracting Parties to "prevent the introduction of, control or eradicate those alien species whcih threaten ecosystems, habitats and species" GISP was designed to review the current knowledge base on invasive species and develop new tools and approaches to deal with the invasives problem both locally and globally. Initial outputs will be protocols for control methods, a new global data base on invasives, a document detailing the new strategy, a summary of findings and recommendations for future action, and a popular book. Specific attention will be given to a series of target nations that are especially impacted by invasives or offer special opportunities.
Global Register of Migratory Species (GROMS) http://www.biologie.uni-freiburg.de/data/riede/groms.html	Maintained at the Centre for Development Research (ZEF), University of Bonn, Germany.	A developing relational database connected to a Geographical Information System (GIS) containing information on about 4000 migratory species. GROMS is intended to contribute to the information needs of the Convention on Migratory Species (CMS) and serve scientific and conservation goals. As of May 2001, in quality control stage.
Inter-American Biodiversity Information Network (IABIN) http://www.nbii.gov/iabin/index.html	IABIN was called for in Article 31 of the Action Plan arising from the Summit of the Americas on Sustainable Development, held in Santa Cruz, Bolivia, in 1996.	Primary objective is to promote the collection, access to, and exchange of technical, scientific, and supporting information on biodiversity in the Americas. Through IABIN, governmental, non-governmental, academic and private sector entities are working together, in their respective geographic areas, to develop the programs, select the standards and tools, and build the infrastructure necessary to exchange information at regional and subregional levels.

North American Biodiversity Information Network (NABIN) (http://www.cec.org/programs_projects/conserv_biodiv/improve_nab/index.cfm?varlan=english)	Created in 1996 by the Commission on Environmental Cooperation (CEC) of the three countries that are part of the North American Free Trade Agreement (NAFTA).	Major objective is to study the feasibility of sharing biodiversity information over the Internet. With financial support from CEC a tool called The Species Analyst was developed at the University of Kansas (http://habanero.nhm.ukans.edu/). This is designed to search a network of museum label databases that are maintained by the museums holding the specimen collections. The Mexican search engine called Mallos (http://www.conabio.gob.mx/remib/doctos/remib.html), developed under the Mexican Network of Biodiversity Information (REMIB) and The Species Analyst will be made compatible and REMIB and NABIN will operate a single Portal.
European Environmental Agency (EEA) **http://org.eea.eu.int**	The EEA and EIONET were established by EC Regulation in 1990, amended 1999.	Aims to support sustainable development and to help achieve significant and measurable improvement in Europe's environment through the provision of timely, targeted, relevant and reliable information to policy making agents and the public. EEA is central node in the European Environment Information and Observation Network (EIONET) (http://www.eionet.eea.eu.int/).; a network that supports the entire range of information management from data to decisions by building upon the activities and databases of the EU member countries. EEA provides the EC Clearinghouse Mechanism for Biodiversity Service (http://biodiversity-chm.eea.eu.int/) in accordance with the provisions of the UN Convention on Biological Diversity - allowing sharing of biodiversity information held by Community institutions and establishing links and interoperability with national CHMs and other international information sources. The development of the EC CHM is based on the global guidelines set by the CDB secretariat. The CHM is developed, maintained and hosted by the EEA on behalf of the European Commission.
World Federation for Culture Collections (WFCC)	WFCC is a multidisciplinary commission of the International Union of Biological Sciences (IUBS) and a federation within the International Union of Microbiological	The WFCC encourages information exchange among microbial resource centres in the world, and communication between them and their users. The World Data Centre on Microorganisms (WDCM) has pioneered the inter-linking of microbial culture collections worldwide, and plays a major role in the WFCC. WDCM has

http://wdcm.nig.ac.jp/wfcc/index.htm
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Societies.

World Data Centre on Microorganisms
(WDCM)
http://wdcm.nig.ac.jp

been hosted by RIKEN, Japan since 1986. Several databases are accessible through the WDCM. The core databases CCINFO and STRAIN are regularly updated and irregularly printed as the WDC Directory. CCINFO covers information on nearly 500 microbial resource centres in the world, their organisation, the kinds of cultures held, the expertise available, and the services offered. STRAIN lists all microbial species held by registered collections.

Species data

Despite the pivotal importance of species information, there is no single measure of biodiversity at the species level that is of use in all situations. The issue is further complicated by questions of scale. Planning decisions relate to a range of scales: global, regional, national, down to local site levels. Priorities may differ at different scales; for example, key issues at the local level will tend to be different from those at national or regional scales. However, the first step in planning for biodiversity conservation at any geographic scale is to assess the natural resources present and identify those that are most important or most irreplaceable.

The kinds of species data required are chiefly the following:

- *current occurrence of species*, which may provide a baseline for future monitoring,
- *changes in the distribution and abundance of species*, derived by repeated assessment over a specified time period.

The variety of living species in even a small area is almost invariably so great that the identification of all species present is impracticable. Even if microorganisms are excluded, it will not generally be appropriate to attempt compilation of a complete inventory of every species in every higher taxon present in a country. In general, information is more comprehensive for the larger species, those that are subjected to human use, and those that impact on human affairs as pests or pathogens.

Once a basic information resource on the occurrence of species has been assembled, a common approach is to identify areas of high biodiversity value. Emphasis may be on species richness or endemism, or areas having other valued attributes, such as presence of threatened species, species representative of restricted ecosystems, or economically or socially important species (including wild relatives of domestic species). A number of studies have attempted to identify areas of high biodiversity value for some particular group of organisms, but often using or different methodological systems and criteria. Approaches to valuing biodiversity are discussed in the previous section.

Information on patterns of distribution has fundamental value to scientific research in ecology and conservation biology, and is prerequisite for effective global and regional conservation planning. In recent decades an immense volume of information on the biodiversity of individual sites has been collected, typically including data on which species in a range of groups are present, and sometimes including information on abundance. Although this information may have been used or reported in a restricted context, relatively little has been applied to the problems of higher level conservation and development planning. This is mainly because the data exist in many different places, in various different formats, and are often difficult to access.

Assessing species trends

A review of the availability of time-series of species population data undertaken by WCMC in 1990 found useful data for global populations of only about 30 species and subspecies. A decade later an expanded search effort by UNEP-WCMC located time-series data for 730 vertebrate populations (Loh *et al.* 2000). Although an impressive

figure, it still represents an extremely small proportion of the approximately 52,000 vertebrate species now extant.

More data tend to be available for species of widespread interest, either for economic reasons (game animals, marine food fishes, cetaceans) or from a natural history viewpoint (birds and a few butterflies). The greatest monitoring effort for any group of species is devoted to marine fishes of economic importance, and the greatest volume of time-series data relate to stock estimates and catch levels in the marine fish populations targeted by industrialised fisheries of developed countries. Recent years have seen increased awareness of the need to take species interactions into account. Birds come a close second to marine fishery stocks, in terms of data availability. The bird species that are surveyed regularly by networks of mainly amateur ornithologists in developed countries are by far the best known large terrestrial group.

In recent years considerable attention has been devoted to the monitoring of amphibian numbers, against a background of rising concern for the widespread decline and extirpation of local amphibian populations. Although many time-series data are local in scope, and mostly relate to North American or European species, a considerable volume of data is becoming available.

Information on a selection of monitoring programmes is presented in Table 4. The emphasis here is on the field monitoring programmes themselves, with mention of the organisations involved, rather than on organisations that make subsequent use of monitoring data. A limited selection of national or restricted scale projects is also mentioned.

Table 4. Selected biodiversity monitoring programmes

Organisation	Description	Examples of monitoring departments/ programmes	Type of material	How collected	Why collected	Availability
Bird Studies Canada	A not-for-profit organisation for the conservation of wild birds and their habitats.	Project Feederwatch; Winter Surveys of Birds in Cuba; Marsh Monitoring Program (MMP); Canadian Lakes Loon Survey; regional surveys (Nocturnal Owls, Coastal Waterbirds). Canadian Christmas Bird Count partner. Coordinates the analysis of data gathered by The Canadian Migration Monitoring Network (CMMN).	Quantitative counts of bird numbers.	Mainly volunteer-based surveys.	The conservation and appreciation of wild birds and their habitats.	Population trends for migratory species obtained by the CMMN are published on the internet.
Birds Australia	A non-profit membership organisation studying birds through volunteer participation	Australian Bird Count; Bird of Prey Watch Project; Wader Population Monitoring Project.	Quantitative population estimates.	Field observations by volunteers.	To investigate Australian bird distribution and population dynamics.	Spatial data presented in map format
British Trust for Ornithology (BTO)	An independent scientific research trust, monitoring wild birds in the UK.	Common Bird Census; Waterways Bird Survey; Waterways Breeding Bird Survey; Breeding Bird Survey (BBS); Heronries Census; Wetland Bird Survey (WeBS); Nest Record Scheme; Single Species Survey; Constant Effort Sites (CES) scheme.	Quantitative estimates from surveys.	Data collection undertaken by coordinated volunteers.	To alert the JNCC and Country Agencies to changes in status of bird species.	Analysed data published as reports.
Canadian Department of Fisheries and Oceans (DFO)	Develops policies supporting Canadian use of marine (and freshwater) biological resources and environment.	Canadian Stock Assessment Secretariat. Five regional research institutes (Laurentian, Newfoundland, Pacific, Central and Arctic and Maritime).	Quantitative estimates of stock status.	Research trawl surveys.	Monitoring and conservation of commercial biological resources, principally commercial fishes.	Published as Stock Status Reports. Available as hard copy and on the internet.

Canadian Wildlife Service (CWS)	Wildlife service of the Environment Canada Government Department. CWS undertake all federal wildlife matters.	North American Breeding Bird Survey (BBS); Populations of Geese in Canada; Status of Migratory Game Birds in Canada; Canadian Migration Monitoring Network (CMMN).	Quantitative estimates population changes.	Direct field observations; volunteer surveys (eg BBS)	Conservation of wildlife resources.	Canadian Bird Trends Database; the Canadian Breeding Bird (Mapping) Census Database.
Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).	Intergovernmental Commission concerned with the rational use of Antarctic biological resources.	Estimates of harvested and dependent species undertaken within the CCAMLR Ecosystem Monitoring Program (CEMP).	Quantitative (changes in stock size etc.) and qualitative (population status) generated.	Commission member reports; commissioned observers; directed research surveys.	Undertaken towards the wise use of Antarctic resources.	Reports compiled by the CCAMLR Scientific Working Groups.
Declining Amphibian Populations Task Force (DAPTF).	A network of scientists and conservationists examining amphibian declines and conservation issues.	Maya Forest Anuran Monitoring Project (MAYAMON) initiated by the Belize Working Group of the (DAPTF) during 1997. DAPTF is generally linked to most ongoing amphibian monitoring programmes eg. the *North American Amphibian Monitoring Program* (See USGS).	Collection of quantitative data for selected populations of amphibian in Belize and Quintana Roo (Mexico).	Direct field observations by volunteer biologists.	Information collected towards the development of an 'early warning' system for regional amphibian populations.	Early graphical material available on the internet. Raw data are maintained in a database awaiting statistical analysis.
Environment Australia – Department of Environment and Heritage.	Australian Government Department of the Environment and Heritage.	Investigates and monitors wildlife and ecological issues such as the management of wildlife resources (eg. kangaroos); the spread of invasive/non-native species; wetland conservation. The Australian Bird and Bat Banding Scheme monitors long-term changes in population dynamics and distribution.	Various quantitative and qualitative indicators and counts used.	Generally directed professional research.	Monitoring of national natural resources.	Extensive quantity of data available at the internet site, much of it spatially based. Interactive map service available at internet site. Key publications are the State of the Environment Report for Australia.

Environment Canada	Government Office for monitoring the natural environment. The Canadian Wildlife Service is a department of Environment Canada.	Coordinates the Ecological Monitoring and Assessment Network (EMAN) (http://www.cciw.ca/eman/intro.html) that aims to operate as an early warning system for Canada's environment (includes amphibian volunteer surveying programme). Hosts the Canadian National Environmental Indicator Series.	A wide range of quantitative and qualitative material eg. species population dynamics to emissions of ozone depleting substances.	Much of the material available has been collated from studies or programmes undertaken by related departments eg. Canadian Wildlife Service.	Provision of environmental material towards informed decision making	Material generally available on the internet as published reports or services, including the Canadian National Environmental Indicator Series: http://www.ec.gc.ca/Ind/English/TOC/toc_e.HTM
International Commission for the Conservation of Atlantic Tunas (ICCAT)	Intergovernmental organisation responsible for the conservation of tunas and tuna-like species in the Atlantic Ocean and its adjacent seas.	The secretariat maintains details of reported catches and landings of tuna and tuna-like species, and develops detailed annual stock assessments.	Quantitative (landings, stock size etc.) and qualitative (stock status) material available.	Analysis of catches and landings reported by Contracting Parties.	Sustainable use of commercial fish stocks.	Statistics and reports published by ICCAT are available in hard-copy and internet format
International Council for the Exploration of the Sea (ICES)	Intergovernmental marine science organisation.	The secretariat maintains large databases on the North East Atlantic marine environment, including statistics about the status commercial fish stocks.	Both quantitative and qualitative information is available for major fish stocks.	Directed professional surveys.	Protection of North Atlantic marine ecosystems and biological resources.	Fisheries statistics available as published reports from ICES in hard-copy and internet format.
International Whaling Commission (IWC)	Intergovernmental Commission concerned with regulating whaling.	The Commission sponsors and promotes international research including field-based surveys. The IWC Scientific Committee undertakes assessment of whale stocks.	Where possible quantitative estimates are provided.	Scientific surveys by commissioned research vessels. Member governments also collect data.	Conservation of whale stocks towards a sustainable whaling industry.	Data are only provided for those stocks that have been assessed in detail.

Makerere University, Institute of Environment and Natural Resources, Uganda.	University based institute managing the National Biodiversity Data Bank (NBDB) of Uganda.	The institute maintains the NBDB data from which are used to assess the state of Uganda's biological diversity.	Large sets of both quantitative and qualitative information.	Generally directed surveys by professionals and academics.	Conservation and monitoring of national biological resources.	Data collated into overview report '*The State of Uganda's Biodiversity 2000*'.
National Audubon Society	A non-profit organisation towards conserving and restoring natural ecosystems, with a focus on birds and other wildlife.	Christmas Bird Count; Project FeederWatch; Great Backyard Bird Count; the North American Breeding Bird Survey. US Important Bird Areas (IBA) coordinator.	Quantitative counts of bird numbers. Identification and mapping of IBA's.	Volunteer-based surveys	To conserve and restore natural ecosystems, for the benefit of humanity and the earth's biological diversity.	Population trends data available in database format published on the internet. Maps of IBA area published on internet and as hard copy.
Northwest Atlantic Fisheries Organisation (NAFO)	Intergovernmental convention for the rational management of fishery resources for the North West Atlantic.	Details of catches and landing statistics reported by Contracting Parties. The secretariat develops detailed annual stock assessments.	Both quantitative and qualitative information is available for major fish stocks.	Analysis of catches and landings reported by Contracting Parties.	Conservation and sustainable use of the commercial fish stocks of the North West Atlantic.	Statistics and reports available in hard-copy and internet format from the NAFO Secretariat.
Royal Society for the Protection of Birds (RSPB)	Europe's largest wildlife conservation charity.	Wetland Bird Survey (WeBS); Breeding Bird Survey (BBS); directed surveys for specific species; partner for many international monitoring programmes.	Quantitative estimates from volunteer surveys. Directed counts for threatened species.	Larger surveys undertaken by coordinated volunteers. Surveys by specialist for more limited projects.	Monitoring the status of bird populations including the success of conservation measures.	Data from larger surveys such as WeBS, in which the Society is a partner, are published on the internet.
U.S. Fish and Wildlife Service (USFWS)	US Government agency with the primary objective of fish, wildlife and plant conservation.	Endangered Species Program. Division of Habitat Conservation (incl. National Wetlands Inventory). There are seven regional offices, and individual state departments that monitor trends in wildlife and habitats.	Quantitative and qualitative material. Some spatial data available.	Generally directed professional surveys. Some coordinated volunteer surveys.	Monitoring and use of wildlife resources.	Generally available from US FWS.

U.S. Geological Survey (USGS)	US Government agency providing scientific research and information in the natural sciences.	There are a number of important regional and thematic science research centres, including: Patuxent Wildlife Research Center (involved with numerous monitoring programmes including, The North American Breeding Bird Survey, and the North American Amphibian Monitoring Program).	Quantitative and qualitative data; spatial data available through the USGS Geospatial Data Clearinghouse.	Mostly through directed scientific survey. Certain projects use information gathered by coordinated volunteers.	Monitoring, conservation and sustainable use of natural resources.	Raw data and published reports are generally available from the appropriate USGS body.
U.S. National Marine Fisheries Service (NMFS)	NMFS administers US National Oceanic And Administration (NOAA) programmes supporting the conservation and management of living marine resources	Office of Protected Resources; Office of Habitat Conservation; Office of Sustainable Fisheries. Five Regional Offices and Science Centres.	Quantitative estimates from surveys; spatial data.	Directed government surveys.	Monitoring and conservation of biological resources, including commercial fishery stocks and endangered species.	Both raw data and analysed reports in hard copy and internet format. Habitat and species conservation plans, including maps eg. coral diesase.
Wetlands International (WI)	An international non-profit organisation concerned with the conservation of wetlands and wetland species.	A large number of thematic and species specialist groups concentrating on waterfowl. There are four regional offices.	Quantitative and qualitative trend estimates.	A global network of governmental and non-governmental experts. Activities are undertaken in more than 120 countries.	Conservation and sustainable use of wetlands and wetland species.	Reports available from WI.
Wildfowl & Wetlands Trust (WWT)	A charity promoting the conservation of wetlands, focusing on rare wetland birds.	Secretariat for the Wetland Bird Survey (WeBS)	Time-series of quantitative estimates from volunteer surveys (eg. Bewick's swans, barnacle geese).	Coordinate surveys by large group of volunteers.	Monitoring wetland conservation.	WeBS results published on the JNCC internet site.

Ecosystem data

In the context of sustainable development, maintaining ecosystem condition and the integrity of ecological processes at large geographical scale over many human generations is the ultimate objective. However, ecosystem 'health' or condition is a complex concept, and one that is difficult to evaluate because it is based on concepts of ecosystem structure and function that remain weakly defined and primarily qualitative. Although some level of diversity is essential to maintain ecosystem processes, the relationship between diversity and ecological function remains poorly defined. In practice, ecosystem trends are chiefly assessed in terms of:

- *current extent of habitats*, which may provide a baseline for future monitoring,
- *change in the area of each habitat type*, derived by repeated assessment of extent over a specified time period,
- *change in the apparent quality or integrity of habitats*, eg. in terms of community composition, spatial integrity or physico-chemical features.

None of these options is straightforward, and not all of them are applicable to all systems. For example, change in area is of little relevance to assessing the condition of Lake Baikal or the pelagic ocean ecosystem.

Habitat monitoring is technically difficult and is further complicated by the lack of universally accepted habitat or ecosystem definitions and classification systems. Terrestrial habitats are usually defined by reference to the major plant species of which they are composed, often in conjunction with notable structural, topographic or geological features. The problem is that species distributions intergrade gradually, and boundaries between particular assemblages of species are almost impossible to delimit.

Many ecological processes operate over decades and therefore require series of data collected over several decades before it is possible to begin to understand them. However, field research and environmental decision-making typically take place over far shorter time-scales. There is no ready answer to this problem apart from recommending a strongly precautionary approach to the large-scale alteration of ecosystems and ecological processes. Ecological models offer the only practical tool for assessing the possible long-term environmental consequences of any management intervention or other human activity.

Measurement of ecosystem or habitat condition is problematic and many different variables can be chosen for measurement according to the primary interests of the investigator. For example, a forester is likely to assess condition in terms of standing woody biomass, the size-class distribution and the frequency of commercial tree species; an ecologist may be interested in nutrient and water cycling or other aspects of ecosystem function; a conservation biologist may be most interested in the diversity of species present and trends in their population size.

Measuring and monitoring ecosystem extent

Assessment of change in ecosystem area primarily requires a consistent series of measurements taken over a significant period of time. Coarse scale change in terrestrial habitats, e.g. loss of forest cover, can be measured most easily by remote sensing. Of remote sensing options, satellite imagery is rapid and relatively cheap but aerial photographs from

systematic reconnaissance flights (SRFs) can be more useful in small areas and to check visually on data collected by satellite. Finer scale on-the-ground investigation is important to verify evidence gathered by remote sensing, and is essential for assessment of many aspects of habitat change, such as the condition of understorey vegetation or water quality in rivers. Habitat area, configuration and continuity, ie. the size, shape and connectedness of habitat patches, are related to the biodiversity present. Reducing habitat area and increasing habitat fragmentation tends to eliminate species.

The Olson and Watts (1982) *Map of Major World Ecosystem Complexes* was a landmark attempt to determine the actual global extent of different ecosystems. This was elaborated to show global distribution of carbon in live vegetation, based primarily on the authors' extensive knowledge of global land cover. More recently, Olson et al. (2001) have provided a new map of the world focusing on identification of different ecoregions. In 1993, UNEP and Moscow State University prepared the *World Map of Present-Day Landscapes* (Milanova and Kushlin, 1993) based on a combination of bio-climatic and soil information with expert input. The combination of the coarse spatial scale of these overviews and the central role of expert knowledge in their compilation means that they are not well suited to serve as baselines for monitoring changes in ecosystem extent. However, they do provide a valuable context for global level assessments at the level of ecoregions or biomes.

Most recent attempts to monitor ecosystem extent and condition rely on satellite remote sensing. Owing to global concern about tropical deforestation since the 1980s, much of this attention has focused on forests.

Forest ecosystems

Of the principal global programmes summarised in Table 3, all except the FAO Forest Resources Assessment are entirely dependent on remotely sensed data. Only the IGBP/EROS Data Centre *Global Land Cover Characteristics Database* (GLCCD) addresses ecosystems other than forests. However, the seasonal landcover classification differs among regions and is too complex to be useful at the global scale. Its dependence on seasonal variation has also led to misclassification of landcover in some areas due to cloud contamination. The much simpler IGBP classification of the same data set suffers from some of the same errors and allows for limited distinction among ecosystem types.

In general, the detail that can be derived from satellite sensors is directly related to the number and types of spectral bands that they record. Thus, LANDSAT data provide more detail on vegetation than Advanced Very High Resolution Radiometer (AVHRR) data because the sensor records reflectance in more spectral bands that are more relevant to vegetation. The SPOT-Vegetation sensor also provides appropriate spectral resolution for distinguishing detail in land cover, but has lower spatial detail than LANDSAT. In general, satellite remote sensing provides limited resolution of ecosystem types unless it is combined with substantial amounts of ancillary information. This means that in order to address many biodiversity-related questions effectively, satellite data need to be used in combination with other data types, such as topographic, edaphic and climatic data.

Coverage of a full range of ecosystem types is further complicated by considerations of data availability and cost. Cloud cover impedes the effectiveness of many satellite-based sensors, so humid or otherwise clouded regions are far more difficult to assess than less clouded ones. A higher temporal frequency of return improves the chances of obtaining cloud-free imagery

(hence the common use of AVHRR data, which are acquired daily), but increases the costs of handling large volumes of data. Programmes that depend on sensors with a low frequency of return have greater difficulties with the availability of good quality data, which are seen in the gaps in the Pathfinder data set and in the constraints on the TM sampling programmes of the TREES project and FAO.

FAO and the TREES and Pathfinder programmes are the only global ones with activities underway that are explicitly directed at monitoring rather than one-off assessment. A number of assessment programmes, such as the EROS GLCCD include no specific provision for repeated assessment over time, but apparently end with the production of an assessment for a single point in time.

Even the programmes that anticipate monitoring suffer from problems of standardisation and comparability of data over time. For example, each of the two different phases of the TREES project used a different approach for processing and classifying digital AVHRR data. To some degree this problem is inherent in the rapidly evolving discipline of remote sensing, in which sensors and methods of data processing are changing constantly. As the TREES projects, like most others, set out to deliver improved methods as much as results so the change in methods over time is one appropriate outcome. However, when setting goals for project, inadequate care has been taken to ensure that improved methods are inter-calibrated with more antiquated ones so that data sets may be comparable over time. The data generated by FAO from national inventories and statistical reporting are also subject to comparability problems that limit their utility for true monitoring because of changes in definitions and modelling approaches between assessments.

In sum, no programme has yet produced consistent and comparable time series data on changes in global ecosystem extent. GOFC (Global Observations of Forest Cover) is the only remote sensing-based programme to explicitly specify monitoring as a major function with specified assessment intervals, but it is not yet clear how this will be achieved. The FAO has a mandate for producing periodic assessments of forest cover, but has changed approaches and definitions between assessments. It currently anticipates increased investment in on-the-ground inventory, which may well provide an improvement in accuracy, but will yet again raise issues of comparability over time. To avoid these problems in future, it is essential that the requirements for monitoring be emphasised when setting goals and procedures for projects.

A number of national and regional assessments also provide baseline data, and in a few cases, have made significant progress in establishing effective monitoring programmes. This overview does not attempt to list comprehensively or evaluate national and regional programmes. Selected examples in Table 3 include the recent development in seven Central American countries of national vegetation maps based on Landsat data interpreted at 1:250,000 and extensive ancillary information. These may provide useful baselines for subsequent monitoring efforts, but only if resources are available and effort is made to ensure consistency of approach. Regional assessments, such as that for South America provided by the Woods Hole Research Centre, can also serve this function, but frequently suffer from the problems of coarse spatial resolution. The Amazon deforestation monitoring conducted by the Brazilian National Institute for Space Research is an example of a purpose-driven monitoring programme. Although there have been some problems of comparability in the early years of this programme, it has at least recognised the need to establish and maintain

consistency of approach over different sampling intervals. An important challenge is to consider ways in which such geographically restricted efforts can contribute to global assessment and monitoring programmes.

There remains a clear need for increased co-ordination in the collection of data on global ecosystem extent, for wider institutional recognition of the need for such data, and for the remote sensing community to ensure that its many advances are adequately inter-calibrated with previous approaches. It is possible that an important role for umbrella programmes and processes such as GOFC, GTOS and CEOS will be in promoting the inter-calibration of new methods with old ones and the establishment of appropriate and comparable time series data on ecosystem extent.

Another possible avenue for progress is in the use and integration of data sets covering more restricted areas. For example, the high-resolution data sets used by FAO and TREES for detailed sampling and calibration of estimates of forest cover and/or deforestation rates are potentially an important resource. They are high-quality images and, at least in the case of TREES, are a carefully stratified sample designed to represent a full range of deforestation scenarios. The full utility of data sets of this type for inter-calibration between broader scale assessments, and/or for the generation of representative time series data, remains to be explored.

The above overview has dealt mainly with areas where significant tree cover is present. Measuring area and assessing condition in other terrestrial habitats present additional difficulties, mainly arising from the lack of a consistent global classification framework, and the fact that information of interest is less readily derived from remote sensed data. Photosynthetic activity can be assessed from satellite data and this, to the extent that within and between year variability can be taken into account, can provide some indication of variation in land cover.

Marine ecosystems

Oceanic ecosystems, which cover 71% of the earth's surface, are in general much less well understood than terrestrial ecosystems. Biogeographic classification of oceanic ecosystems are made problematic because they are significantly more dynamic than terrestrial systems, with far fewer natural boundaries. However, a classification system is necessary if effective monitoring and management of the marine biosphere is to be developed.

Several classifications of the marine realm exist, some based on biogeography, others, as in the case of two recent systems, on oceanographic and ecological features. Longhurst (1995) classified the world ocean into four ecological domains and 56 biogeochemical provinces, largely on the basis of estimates of primary production rates, and changes over time, plotted on a one-degree grid. These values were derived from long-term and geographically extensive data on sea surface colour obtained during 1978-1986 by the CZCS radiometer carried on the Nimbus orbiting satellite. The Large Marine Ecosystem (LME) scheme elaborated by Sherman and Busch (1995) is a widely used alternative system, although this is selective in that it concentrates on shelf waters, and did not initially cover all such areas.

Core monitoring activities which would be central to development of marine biodiversity indicators include the use of Continuous Plankton Recorders (CPRs) for plankton and water quality data, assessment of change in the fish community by bottom trawling or other techniques according to substrate, and environmental pollution assessments. Further sampling techniques

are required for particular habitat types, but the sampling and monitoring efforts undertaken by the US National Oceanic and Atmospheric Administration (NOAA) illustrate a range of information relevant to the marine environment in general:

- systematic collection and analysis of catch-statistics;
- fisheries-independent bottom and midwater trawl surveys, or other appropriate technique, for adults and juvenile fishes;
- ichthyoplankton surveys for larvae and eggs;
- measurements of zooplankton standing stock, primary productivity, nutrient concentrations;
- measurements of important physical parameters such as water temperature, salinity, density, current velocity and direction, air temperature, cloud cover, light conditions; and in some habitats, measurement of contaminants and their effects.

Inland waters

Traditional assessment of freshwater ecosystem quality has largely focused on measuring organic and inorganic pollutants, including suspended matter and salinity levels. Monitoring of trends in species abundance has mostly concentrated on human pathogens (such as coliforms), a select few commercially managed fish species, and a number of aquatic bird and mammal species.

For the majority of freshwater species (non-commercial fishes, invertebrates and plants) in developed temperate countries, trends in distribution area or abundance numbers are poorly known, and even fewer species have been monitored in tropical countries. A few high-profile species and a few sampling sites are relatively well known, and so some data are available on increasing rarity of occurrence or declining river length occupied, for example. While the general lack of information on trends in aquatic species is partly a result of the difficulty of assessing abundance in aquatic habitats, more generally it stems from the low level of attention previously paid to these species by both resource managers and conservation organisations.

Table 3. Some current processes providing global monitoring of ecosystem extent based on remote sensing data

Programme	Data Source	Spatial Resolution	Outputs	Potential for Monitoring
TREES -I	AVHRR 92-93	1km	Vegetation Maps of Central Africa, Humid Tropical South America, Continental SE Asia and Insular SE Asia. Pantropical datasets on forest fragmentation and forest proportion. Calibrated forest cover estimates	Coarse-resolution initial baseline for the humid topics that is incomplete in some regions (SE Asia cloud cover problems, no Central America). The calibration of the coarse resolution data with high-resolution imagery is helpful, but the high-resolution sample is opportunistic rather than statistically designed.
TREES – II	SPOT Vegetation and ATSR 96-97	1km	*In preparation* new versions of the above maps, including clear sky version of SE Asia	Builds on TREES I, but alters methodology, therefore direct comparison is not feasible, but could be done via calibration with high-resolution imagery
	Landsat TM samples, nominally 1992 and 97	30m	Deforestation estimates	Statistically designed to be a representative sample, stratified for deforestation assessment
Pathfinder	Landsat MSS and TM nominally late 1970s, mid-80s & 90s	30 m	Regional scale statistical estimates of deforestation, digital Landsat datasets	Could be a useful time series, but there are some methodological concerns attached to classification and interpretation methods.
IGBP-DIS-GLCCD (EDC)	AVHRR 92-93	1 km	Regional land cover maps using five different classification schemes, ranging from 17 to 255 classes per region.	Uses seasonal variation for some aspects of classification, which can cause problems. Many land cover classes are complex and not comparable between regions. There is no high-resolution calibration of area estimates

FAO	Inventories & reports	National summary	Global Forest Resources Assessment 1980, 1990, 2000	A useful time series statistical data set, but with problems of changing approaches and definitions used in standardising nationally reported data
	AVHRR 92-93	1 km	Global Map of Forest Cover	Derived from GLCCD and ancillary data. A potential baseline, but suffers classification and spatial resolution limitations
	Landsat TM samples, 117 scenes nominally 1990 & 2000	30 m	Estimates of deforestation based on high resolution samples	Distribution of images is opportunistic rather than statistically designed. Sampling grid within images loses much of the detail of the high resolution and is associated with registration problems between time periods.
Vegetation 2000	SPOT Vegetation late 1990s	1 km	Global maps of vegetation cover	Potential as baseline if adequately calibrated
Global Forest Mapping Program	Synthetic aperture radar (SAR) data from JERS-1 and FUYO-1	100 m	Maps of global cover of rain forests and boreal forest.	Data obtained at different seasons, but principally to support improved classification. No monitoring function envisaged specifically, potential for detailed forest structure and biomass information to come from these data.
Global Observation of Forest Cover (GOFC)	various	250-1000 m	Periodic mapping of land cover at coarse resolution on a 5-year cycle, plus forest areas at 25 m resolution.	Global umbrella initiative intended to provide co-ordination among the many different remote sensing programmes working on forest cover and links between them and the user community. The initiative has the potential to deliver guidelines and standards that encourage inter-calibration between older and improved methods for analysing and interpreting satellite data.

NATIONAL/ REGIONAL INITIATIVES				
INPE, Brazil	Landsat TM	30 m, interpreted at 1:250,000		
Seven Central American countries (Panama, Costa Rica, Nicaragua, Honduras, Guatemala, El Salvador, Belize)	Landsat TM plus ancillary data	30 m interpreted visually at 1:250,000	**National vegetation maps at 1:250,000** *In preparation* regional scale map	Useful baselines and important initiative because of similar approach applied among countries while addressing national expert perspective, but monitoring potential only with significant investment of resources to ensure methodological consistency over time within and between countries. Regional harmonisation still under way.
Woods Hole Research Center	AVHRR greenness indices and ancillary data	1-15 km	Land cover map of South America http //www whrc org/science/Globfor/globfor htm *In preparation* Land cover map of the former Soviet Union	Coarse spatial resolution, but useful classification. No calibration with high-resolution data, but could form a useful baseline. No repeat explicitly anticipated.

Adequacy of available data and information

Because of the very broad range of information needs that exists among potential users of biodiversity information, it is difficult to assess in a rigorous fashion the suitability of the data and information products that are available.

Most countries have a reasonable working knowledge at the inventory level of at least the terrestrial vertebrates, vascular plants and main ecosystem types within their territory. Some have very detailed information on a wide range of organisms, sometimes with supporting data on abundance and trends. In general, information on threats to biodiversity and ecosystem integrity has not been collected in a systematic fashion, and trends have typically been identified on the basis of anecdotal or qualitative information.

Land cover data available tend to be patchy in coverage, with much variation in origin, date, resolution and quality, and linked to inconsistent ecosystem classifications. For example, within the OECD, probably the largest political and economic grouping where generally good quality data are available for each national or regional component, each such source typically uses a different ecosystem or vegetation classification. Nevertheless, and despite many gaps, all developed countries have a body of information that is potentially available for assessment purposes.

Although a considerable amount of information exists within the world scientific community, it is often scattered, relatively inaccessible and in a form that is not easy to understand or synthesise. Drawing this information together to produce reliable assessments has proved problematic, and the needs for development and adoption of reliable standard methodologies, and for long-term funding support remain to be met.

5. HOW CAN BIODIVERSITY BE MEASURED?

Introduction

Biodiversity assessments can be elaborate and complex processes, involving a large number of different participants and technical approaches, and generating a great deal of complex information, which can be challenging to manage and simplify. This report does not attempt to provide a comprehensive overview of different assessment methods, as numerous other sources of information are available that deal with such technical aspects. Rather, the intention here is to highlight a limited number of key concepts and principles, which may be of use in designing a biodiversity assessment.

This section first considers different analytical frameworks that are available for biodiversity assessment, then considers the selection of appropriate variables to measure. The design and implementation of a biodiversity survey or inventory is then considered in detail. Finally, some examples of current assessments are provided, to illustrate the different approaches adopted in practice.

Developing a conceptual framework

Some form of framework or conceptual model is required to structure the process of information gathering and analysis. The most widely used is the 'pressure-state-response' (P-S-R) framework, which was developed by the OECD (OECD 1993) on the basis of the "stress-response" model developed by Friend and Rapport (1979). The P-S-R framework states that human activities exert pressures on the environment (such as clearance of forest for agriculture), which can induce changes in the state of the environment (for example, the extent of forest cover). Society may then respond to changes in pressures or state with policies and programs intended to prevent, reduce or mitigate pressures and thereby reduce environmental damage. Indicators provide tools for identifying P-S-R relationships, both at the reporting stage and during policy analysis.

The P-S-R framework has been widely applied to biodiversity assessment; for example it is explicitly recognised by the CBD. A variant of this approach, namely the "Driving Force - State – Response" (D-S-R), has been applied by the CSD (CSD 2001). In the D-S-R framework, the term "pressure" has been replaced by that of "driving force" in order to accommodate more accurately the addition of social, economic, and institutional indicators. In addition, the use of the term "driving force" allows that the impact on sustainable development may be both positive and negative, as is often the case for social, economic and institutional indicators.

The PSR scheme was further expanded by the European Environment Agency to include drivers and impacts, forming the DPSIR framework (EEA 1998). Both the PSR and the extended DPSIR models are based on the fact that different societal activities (drivers) cause a pressure on the environment, causing quantitative and qualitative changes of it (changing state and impact). Society has to respond to these changes in order to achieve sustainable development. According to the DPSIR framework, different indicators of sustainability may be developed, relating to drivers, pressure, state, impact and response.

A number of additional frameworks have been proposed by different scientific researchers. There is no general consensus about which framework provides the best basis for any given biodiversity assessment. However, various versions of the P-S-R model are now commonly used within different policy processes, and therefore if the results of the assessment are intended to be communicated to a policy-related audience, then adoption of a policy-relevant framework such as P-S-R is of key importance.

Selecting which variables to measure

The choice of variables to be included in the assessment will obviously depend on the choice of values, objectives, and availability of existing data. Any assessment or monitoring programme will be subject to limitations in terms of scope, financial support, technical capacity etc., and these limitations will also influence the choice of variables to be measured. Ideally, the conceptual framework selected at the outset should help guide the selection of those key variables of interest; for example, it may often be desirable to assess a particular threat or environmental pressure, and examine the impact that this is having on the state of biodiversity within a given area (according to the DPSIR framework). The appropriate variables in this case might include those describing the principal threat occurring in the area (for example, the amount of harvesting of wildlife), and the abundance of those species at greatest risk (for example, those species being harvested).

Biodiversity indicators
As it is impossible to measure every aspect of biodiversity, variables are selected that summarise, or act as proxies for the biodiversity component of interest. A great deal of research has been devoted to the development and selection of such biodiversity 'indicators'. Again, a comprehensive treatment of this subject is beyond the scope of this report, but the following guidelines may be of value in defining appropriate indicators for any given assessment:

- *Policy context.* The importance of developing biodiversity indicators for summarising complex information in a way that can support policy development and implementation is recognised by many policy processes, which have devoted a great deal of effort to indicator development. For example, the UN Conference on Environment and Development (UNCED) in 1992 recognised the importance of indicators for enabling countries to make informed decisions regarding sustainable development, including biodiversity. The Convention on Biological Diversity (CBD) provides a more explicit policy context for indicators of biodiversity. CBD (2001) provides an overview of how the issue of biodiversity indicators has been dealt with by the Convention. Proposals have also been made for a 'core set' of biodiversity indicators suitable for use by Parties in compiling their national reports, and to enable the effectiveness of measures taken to be evaluated (CBD 1997a). Many biodiversity indicators have also been developed by the various regional and national processes focusing on evaluating sustainable forest management.

- *Frameworks.* The frameworks discussed earlier, such as P-S-R and DPSIR, provide a framework for indicator development. For examples, indicators can be developed separately for each of the different elements of the framework (e.g. for pressures, state and response,

etc.). Such frameworks are often referred to explicitly by policy development processes, in the context of indicator development.

- *Consultation.* Those involved in policy development and implementation often find it difficult to identify and articulate their needs for biodiversity-related information. This problem is exacerbated by their lack of awareness of what is feasible. There may therefore be a need to work with groups of such stakeholders to help them identify the most important biodiversity-related questions to which they need answers. These questions will in turn help direct the development of appropriate indicators to help provide answers. The biodiversity-related questions of interest to most stakeholders address the status of key resources, the factors that influence their status and the impacts of resource exploitation. Therefore, most key questions at the national level will derive from national and sub-national policies governing resource management and use, and the commitments, goals and targets within them. It is important, therefore, to involve in the consultations decision-makers from as many of these sectors as possible, as well as representatives of resource users themselves, including the poor, and of organisations devoted to influencing resource use and policy (e.g. NGOs).

- *Characteristics of appropriate indicators.* Indicators should supply the maximum amount of information with the minimum amount of work. To be effective, indicators must be readily quantifiable, easily assessed in the field, repeatable and subject to minimal observer bias, cost effective, and ecologically meaningful.

- *Selection of indicator species.* Species, or species groups, may be selected as indicators. Such indicator groups should be (after Noss 1990):
  - Taxonomically well-known so that populations can be reliably identified and named
  - Biologically well-understood
  - Easy to survey (eg. abundant, non-cryptic) and manipulate
  - Widely distributed at higher taxonomic levels (eg. order, family, tribe, genus) across a large geographic and habitat range
  - Diverse and include many specialist taxa at lower taxonomic levels (ie. species, subspecies) which would be sensitive to habitat change
  - Representative (as far as is known) of distribution and abundance patterns in other related and unrelated taxa
  - Actually or potentially of economic importance

Further information on the development and application of biodiversity indicators is available on the website of UNEP WCMC (http://www.unep-wcmc.org/). A number of other relevant resources, including case studies involving monitoring and evaluation of conservation projects, is provided by the Foundations of Success website (http://www.fosonline.org/fos/default.asp).

Developing a measurement programme

Once the variables or indicators to be included in the assessment programme have been identified, there may be a need to undertake a programme of data collection, to supplement or augment the available data. Data gathering may occur only once, as a one-off assessment, or may be repeated at regular intervals if some form of monitoring is required. A field survey or

inventory will need to be designed according to an appropriate sampling protocol. In addition, appropriate methods for measuring the variables of interest will also need to be identified.

If a biodiversity survey or inventory is undertaken, the following elements may form part of the planning and design process (Parker *et al.* 1993, Burley and Gauld 1995, Stohlgren *et al.* 1997, Wright *et al.* 1998):

- Assemble existing information and perform an information needs assessment
- Define and justify what is to be monitored
- Develop or update vegetation maps. Divide the landscape into ecosystem types based upon enduring physical features such as soil texture and landform.
- Use remote sensing to detect, map and monitor ecosystem boundary and structural changes plus GIS to portray all levels of biodiversity currently known.
- Select areas to sample, using the GIS as a basis for stratification. Use unbiased site selection based upon remotely sensed information
- Use multi-scale field techniques to assess plant diversity
- Use molecular sampling methods to determine intra-specific variation of focal groups: this will require resolution of the debate over the 'best' method.
- Select optimal quadrat size, number of samples, and number of sampling sites for obtaining accurate estimates of plant species diversity
- Establish "plots" and collect the data.
- Involve local human populations and indigenous knowledge in recording species occurrence, distribution and use (see Chapter 6)
- Progressively increase sampling proportion among permanent sample plots until acceptable accuracy is achieved.
- Use mathematical models (eg species-area curves) to estimate the number of species in large areas corrected for within-type heterogeneity
- Use mathematical techniques to estimate total species richness and patterns of plant diversity in a landscape.
- Manage the data for analysis and long- term security

The following guidelines relating to collection of biodiversity data have been modified from the UNEP Guidelines for Country Studies on Biological Diversity (see also Box 2):

- *Data-gathering is a tool for decision-making* and not an end in itself - the agenda for data acquisition must be constituent-driven and issue-based. It must be appreciated that the gathering of data can be an endless process unless clear boundaries are specified and linked to unambiguous objectives. One of the most common errors in conservation planning is to allow researchers and data managers to set the parameters for data acquisition independent of the interests of the information users. In determining what data to collect, the question must always be asked, "How does this information contribute to the biodiversity planning process?" An information management strategy should be developed as part of the action planning process and, as part of this, the information needs of the users should be determined through a continuing dialogue that identifies or prioritizes the types of data to be gathered.

- *It is essential to set priorities* as not all data are of equal value to the planning process. With limited resources available, the setting of priorities for the types of data to collect is critical.

These will vary according to the planning needs and requirements of the country. A generic list of possible priorities for data gathering is presented in Box 2, although this will need refining in the context of the circumstances of each individual situation

- *Information about the data should be collected.* Whenever possible, the following attributes should be provided for data included in the study:
  - source - who collected the data or where did it come from?
  - method - what method was used for its collection?
  - date - when was it collected?
  - scale - for mapped data, at what scale was the data collected?
  - reliability - what is the quality/reliability of the data? It is suggested that a simple four category reliability classification should be adopted, based mainly on the method of derivation:
    - Category A - high reliability: data derived from systematic scientific survey or sampling
    - Category B - medium reliability: data derived from extrapolation, approximation or other imprecise methods
    - Category C - low reliability: anecdotal data or guestimates
    - Category X - unknown reliability: derivation of the data unknown

- *Data-gathering should focus on the interaction of social factors, economic sectors and biological systems.* Biodiversity planning aims to influence the interface between human and biological systems. Assessments should therefore demonstrate how the biological data relate to, and are affected by, such socioeconomic factors as human population demography, land use and resource ownership. For instance, how does agricultural price intervention affect land use and thus biological diversity, or what effect will a change in the rights of access by local people to biological resources have upon patterns of consumption and thus the loss of biological diversity? These socioeconomic parameters provide the framework within which to interpret the biological data. It is often the dynamic relationship between the different systems that generates the changes critical to an understanding of the factors that influence biological diversity.

- *The biodiversity data should incorporate human uses of biological resources and the functional benefits of biological diversity.* As well as focusing on the planning interface between human and biological systems, the data-gathering should concentrate on the utilization of biological resources, and the functional uses of biodiversity to human society. It must be recognised that these values will vary at different levels - internationally-traded commodities, resources for local communities, and the needs of individual farmers for sustainability. Resource utilization, whether at the national, local or individual level, must be a key criterion for selecting biodiversity data.

- *Data on processes or activities that are likely to have an adverse impact on biological diversity should be compiled.* The identification of threats should be a key consideration in biological diversity strategies with recommendations for their reversal included in action plans. Threats may arise from natural hazards; from the indirect consequences of human processes, or externalities such as changes in agricultural commodity prices or the servicing

of international debt; and from direct human activities such as shifting agriculture, logging, poaching or pollution. The initial focus should be on the direct human-induced threats that can be most readily monitored and reversed, for example by the enforcement of existing national legislation. It must be recognized that most threats are created by a potential beneficiary, normally the causal agent of the threat, and that actions for threat relief therefore involve an economic trade-off.

- *Priorities for filling gaps in the data coverage should be based on the needs of decision makers to improve their management of biological diversity.* Analyses of data holdings will assist the identification of data gaps. Priorities for filling these gaps should be based on the principle of asking managers what additional information they need. The tendency of scientists and data managers to gather data for the sake of the completeness of the coverage should be resisted.

- *The biodiversity data gathering should not be confined to national parks and protected areas* but should cover the whole landscape: data on protected areas should seek to emphasize their relationship with other components of the landscape. To many politicians, biodiversity conservation is viewed in the narrow context of managing protected areas. The data gathering exercise should be multi-sectoral, including the agricultural, forestry and fisheries sectors. As reservoirs of biological diversity, protected areas will obviously form a key component, but data relating to surrounding areas should also be compiled to ensure the fullest integration with the entire rural development process.

- *The undertaking of a biodiversity assessment should not become an over-onerous task because of the excessive demands for data-gathering.* For many countries, most species have yet to be identified, habitats are inadequately mapped, and genetic resources have been barely inventoried and understood except for those in current economic use. The purpose of an assessment may therefore be to collate what little is known and to identify the gaps in the knowledge, but not necessarily to seek to fill those gaps. The need for comprehensive data coverage must be balanced against the resources and time needed to compile such data. Each country or organisation will need to identify this balance in the light of its own circumstances, and set its own priorities for data-gathering in the context of the resources available.

Box 2 General priorities for types of data to be compiled in national biodiversity assessments

Decisions relating to the types of data to be included in the assessment must be made in the context of the planning needs of each country and the resources available, but in general the following kinds of data are likely to be priorities:

* data that will provide a practical baseline for monitoring the effectiveness of action
* data identified by biodiversity managers as being important for decision-making
* species of actual or potential economic value
* plant and animal genetic resources, including medicinal plants, land races and wild ancestors of domestic breeds and cultivars

* species that could serve as indicators of ecosystem health, particularly predators at the top of the food-chain or invasive colonizing species that may indicate, ecosystem disturbance
* "flagship" species, the conservation of which will also protect a diversity of other species and habitats
* alien or exotic species, the spread of which could threaten indigenous biological diversity
* species threatened at the national and regional level
* species already protected within conservation areas
* data on threats to species and habitats
* time-interval data on rates of loss or endangerment of species and habitats
* geographical information, particularly data that can be mapped, on species and habitat distributions
* data on biodiversity function and benefits, particularly the service functions of ecosystems and protected areas
* data on species and sites of special significance for the conservation of biological diversity outside existing protected areas
* status and distribution of protected areas, including the species and habitats they contain
* data on the socio-economic values of protected areas
* policy, conservation programmes, legislative and institution-related information

> End of box

A detailed discussion of sampling protocols and ecological methods is beyond the scope of this report. An overview of different survey methods, in relation to different monitoring questions, is provided on Figure 1. The following section provides some general guidance regarding the design of a biodiversity survey or inventory programme.

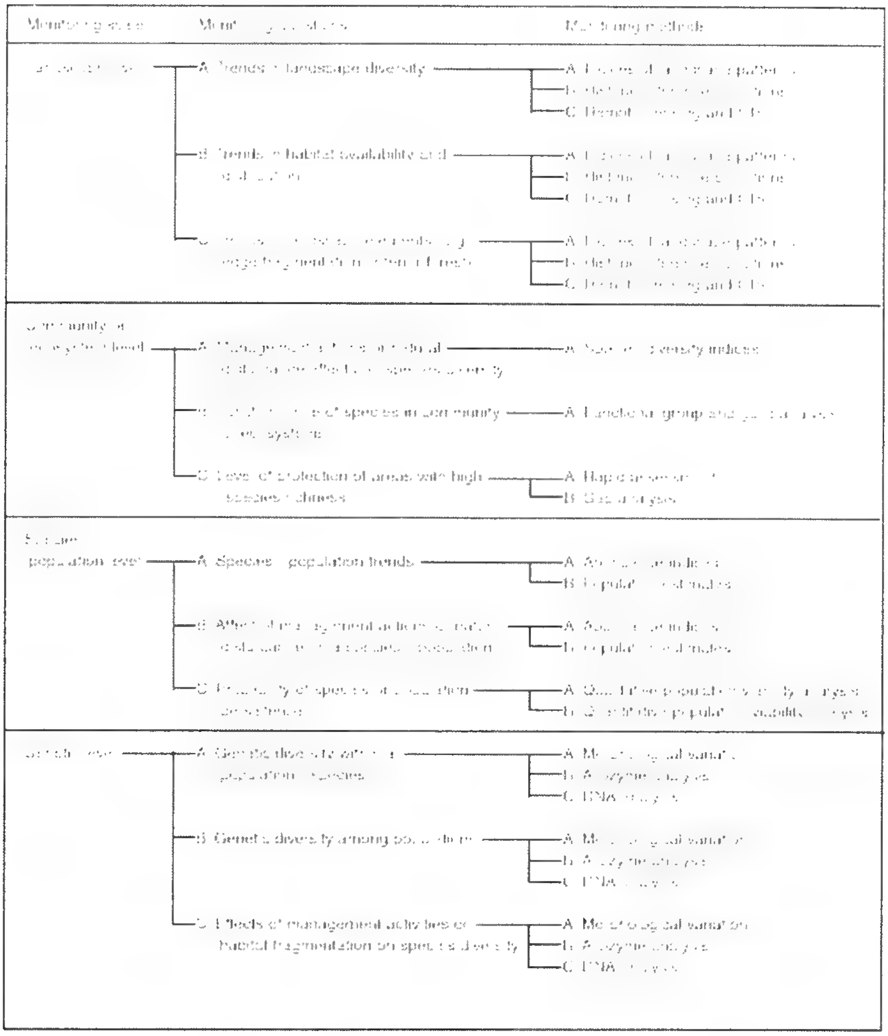


Figure 1: Examples of monitoring questions and methods for each level of ecological organization (Source: Gaines, *et al.* 1999).

Principles of survey design

Two forms of survey or inventory may be required: extensive and intensive. Extensive inventories are generally conducted rapidly on a national basis to supply information necessary for the selection of conservation areas and other types of land-use planning. Speed is critical in this approach, so generally the focus of inventory should be well known and easily recognized organisms, such as mammals, birds, trees and butterflies. Surrogates, such as higher taxon richness (e.g., family-richness), can potentially be used as a substitute for species richness. Various types of remote sensing also have a prominent role to play in extensive inventorying (see later).

Intensive inventories are undertaken at relatively small scales, and generally focus on species or habitat characteristics. Sampling approaches may include plots (either temporary or permanent) or transects, or plot-less approaches such as wildlife counts or point sampling. Some commonly used sampling approaches are listed on Table 9.

Table 9- Direct and indirect methods of gathering field data (Correll *et al.*1997)

Direct methods include	**Indirect sampling includes**
Mark-recapture (banding/tagging)	Visual observation (counts of wildlife)
Quadrat plots (circular, rectangular, etc.)	Fixed-point/ground based photography
Point sampling (horizontal and vertical)	Aerial photography and videography
Transect/traverse sampling	Satellite imagery
Profile/content sampling (soils)	Laser profiling
Volume/content/flow sampling (air and water)	Radio telemetry
	Radar/sonar and other remote sensing systems

Conant *et al.*(1983) describe inventory methods for developing baseline information. Guidance is available on how to sample for wildlife (Cooperider *et al.*1983), vegetation (Francis 1982), rangeland (National Research Council 1994), forests (Päivinen *et al.*1994), and agroforestry (Kohli *et al.*1996 and Leakey *et al.*1996).

There two general types of sampling options - purposive and statistical. Table 16 provides a comparison of the two alternatives.

Table 16 - Key to some alternative sampling designs showing selected criteria and some possible consequences (Vanclay 1998)

Steps and Criteria	**Inventory alternatives and possible consequences**	
Step 1 - If:		
Nature of the estimate is →	Critical ↓	Unimportant/personal ↓
Vegetation characteristics are →	Unknown/diverse ↓	Familiar or uniform ↓
Representative selection is →	Unreliable ↓	Reliable ↓
Time and resources are →	Sufficient ↓	Very limited ↓
Then →	***Go to Step 2***	***Use subjective sampling***
Bias will be →	Absent	Unavoidable

Table 16 - Key to some alternative sampling designs showing selected criteria and some possible consequences (Vanclay 1998)		
Steps and Criteria	**Inventory alternatives and possible consequences**	
Precision can be →	Estimated	Unknown
Step 2 - If:		
Periodicity is →	Possible/unknown ↓	Unlikely or known ↓
Interpolation is →	Not required ↓	Necessary ↓
Estimate of precision is →	Required ↓	Unimportant ↓
Then use →	***Random sampling and go to Step 3***	***Systematic sampling***
Sampling error estimate will be →	Correct	Probably inflated
Periodic bias will be→	Unlikely	Possible
Step 3 - If:		
Pattern in population is →	Clear or likely ↓	Absent or unlikely ↓
Sampling intensity will be →	Relatively low ↓	High ↓
Then use→	***Stratified sampling and go to Step 4***	***Unrestricted sampling***
Inherent risks will be→	Misjudged pattern	Sample clustering
Step 4 - If:		
Pattern in population is →	Obscure or unknown	Visible or well known ↓
Then use →	***Geometrical blocks***	***Statistical blocking***
Calculations will be →	Simple	Possibly complicated

Purposive sampling is generally used when time or financial resources are lacking. The advantages are that it is quick, cheap and focuses on areas of immediate need. The disadvantages are that one may miss important areas, the approach is not very useful for extrapolation and expansion, and is not statistically reliable. Lund and Thomas (1989) provide illustrations of various statistical designs, which although statistically robust, tend to be more demanding in terms of time and resources.

Most biodiversity inventory designs employ some form of stratification, the process of dividing an inventory unit into relatively homogeneous areas, usually based on what can be interpreted from imagery or maps. If stratification is done before sample selection (pre-stratification), it will reduce the number of field plots that are needed. If stratification is done after sample selection and establishment (post-stratification), it will reduce the sampling error compared to that achieved had stratification not been used (Lund and Wigton 1996). For statistical sampling, samples should be replicated within stratified levels, with sufficient plots to characterize the variance in characteristics of the habitat type being sampled.

Pre-stratification requires that strata be formed before sample selection. Thus some type of classification and often mapping system has to be developed in the early stages of the inventory. Pre-stratification may preferred in the following instances:

- If the classes or strata show extreme differences, such as croplands versus forestland, and for which different information is needed.

- If the classes, strata, or mapped polygons are fairly large so that distinction between the classes both on the ground and in imagery is relatively easy (i.e., the strata are not intermixed giving a mottled appearance).
- If the field sampling or data collection process in several of the strata are considerably different than what would be collected in other strata (again vegetation data collected on crop lands intuitively is different from that collected on forest lands).
- If the objectives of the inventory are clearly set, and the need for reshuffling of field plot information across strata is not expected.
- If data are needed for every strata.

When using pre-stratification, one has the choice of proportional allocation versus optimum allocation for the distribution of field plots. With proportional allocation, the strata having the largest area will receive the most plots and the stratum having the smallest will receive the least. The advantage of proportional allocation is that the field plots have nearly the same weight. The impact of errors or changes in classifications will not be so great as through optimum allocation.

Under optimum allocation, the most field plots are assigned to the stratum in which the variances of items of interest are expected to be the highest. Thus strata that are relatively small but very heterogeneous internally could require the most plots. Here, errors or changes in the classification of field plots could have large impacts on the results of the inventory. On the positive side, optimum allocation will result in the least amount of field plots for a given cost.

Post-stratification is generally used following a systematic sample of some sort. A systematic sample with post-stratification is generally used:
- If mapping or imagery is not available in time for the inventory.
- If the mapping is so interspersed that developing a stratified sampling frame is cumbersome to impossible.
- If the strata or questions are apt to change over time.
- If it is more important to have data on all lands than to have information on specific classes of land.

Systematic sampling with post-stratification is also used for long-term monitoring. This is generally because boundaries of vegetation types can change over time that can raise havoc with plot weights if pre-stratification and especially if optimum allocation were used. A systematic sample with post-stratification will also yield a sampling of strata proportional to size.

A disadvantage of the systematic sample with post-stratification, is the possibility that a certain stratum may not be sampled. This often occurs when there are very small strata or when the distributions of the polygons are such as they fall between the systematic samples.

In summary, pre-stratification is more efficient for a set of specific goals. If the inventory objectives become moving targets, a systematic sample of permanent plots with post-stratification may be the best design over the long term. The sample should be linked to vegetation mapping.

Sample intensity

Specifying a set of general rules for sampling intensity for biological diversity inventories is difficult. Much depends on the inventory goals, the nature of the habitat being inventoried, the size and skill of the crews, access, the amount of time and funding available to do the inventory, and allowable sampling error.

Of the above, probably the allowable sampling error has the least influence as inventories are often more constrained by time, funding, and person-power. Sampling intensity is more often dictated by those three factors than by anything else. Sampling intensity, coupled with terrain, vegetation, and size of crews may dictate the plot configuration.

Plot design

There are two ways of gathering field data to consider. One involves a plotless method and the other employs plots. Plotless methods are generally based upon some measurement of search time. Plots may be classified as either transects or quadrats. Transects are strip or linear samples. If they cross more than one ecotone, they are called gradients. Table 18 compares various sample units commonly used in biological diversity surveys.

Table 18 - A comparison of various sample units used in biological diversity surveys

Sample unit	**Description**	**Advantage**	**Disadvantage**
Plotless	The plotless method is based on time. The crew records species for two hours in the area of interest. The plotless samples are defined by parts of the landscape where all plant species were collected or recorded when met. These samples covered hilltops, slopes, swamps, riversides, flat grounds, valley bottoms, skid trails and occasionally quick samples along a roadside. The sampling ends when, after some time (usually two hours), the discovery of unrecorded species is one in two minutes. (Musah 1997). See	Quick. Provides a list of species present.	As the location of observed plants is not recorded, the use of the technique for monitoring change may be limited.

Table 18 - A comparison of various sample units used in biological diversity surveys			
Sample unit	**Description**	**Advantage**	**Disadvantage**
	also Ndam (1997).		
Transect	A "line" plot. Species are recorded that are intercepted by the transect.	Narrow transects generally sample greater micro-habitat than do quadrat-based sampling methods of equivalent area or effort as species composition often becomes less similar with distance. Area parameters such as stand density and relative abundance of species are readily calculated from strip transects. They may be estimated in variable-area transects by keeping track of the distance walked while sampling individuals (Stern 1998). The transects may provide estimates of density and abundance of a population (Buckland *et al.* 1993)	May result in fewer independent replicates than if quadrats employed, reducing statistical power of design
Gradient	A transect set to sample the steepest environmental gradients present in an area. May cross several different ecosystems	Samples many ecosystems or vegetation types at once.	Difficult to extrapolate to other areas
Quadrat	Fixed area plots. May be circular or rectangular. May range in size from less than 1 ha to 50 ha depending on mission. Plots may be nested -	Excellent for establishing a monitoring program	Data can be used for extrapolation if plots are unbiased in location and some type of stratification is used.

Table 18 - A comparison of various sample units used in biological diversity surveys			
Sample unit	**Description**	**Advantage**	**Disadvantage**
	several size subplots within the main plot on which different variables are measured.		

The limitations of search-type inventories include non-repeatability due to lack of predetermined and documented sampling protocols. The advantage of searching is that it provides the most taxonomically complete inventory (Báldi 1999).

In line transect sampling, the surveyor walks through the sample area along lines (Figure 8). When a plant of interest is noticed, the perpendicular distance between the plant and line is measured. Then a probability-of-detection is estimated. Unbiased estimates are thereby obtained.

Narrow transects generally sample greater micro-habitat than do quadrat-based sampling methods of equivalent area or effort as species composition often becomes less similar with distance (Stern 1998). Area parameters such as stand density and relative abundance of species are readily calculated from strip transects. They may be estimated in variable-area transects by keeping track of the distance walked while sampling individuals.

Gradient transects are selected deliberately to transverse the steepest environmental gradients present in the area, while taking into account access routes. This technique is considered appropriate for rapidly assessing species diversity in natural forests, while minimizing costs, since gradient transects capture more biological information than randomly placed transects of similar length (Fabbro 2000).

Transects facilitate access for study and monitoring and can aid inventory. They greatly aid mapping of species since once a GPS reading has been taken at one point on a line (Cheek and Cable 1997), efforts should be directed to multiple replicates of short transects per vegetation type rather than a single or few long transects (Stern 1998).

Buckland *et al.* (1993) describe a distance sampling software program that provides an analysis of distance sampling data to estimate density and abundance of a population. It covers both line transect and point transect (variable circular plot) methods in detail, as well as discussing other less widely used methods such as cue counts and trapping webs

With respect to plot shapes, some people prefer circular plots and others rectangular. With a rectangular plot, as one can stake out corners, then look along the lines of the plot to see what vegetation is in or out. Circular plots are useful particularly if they are relatively small or the vegetation type open. One can walk out to the end of the radius, and swing the line around to determine what vegetation to tally.

Often nested fixed area plots are used for tallying multiple resource data - a large area plot for tallying big trees, a mid-size plot for saplings and poles, and a very small one for tallying seedlings and lesser vegetation. A nested plot may be particularly useful in the moist tropics where there are large numbers of plant species.

Stohlgren *et al.* (1996) tested 4 plot designs - Modified-Whittaker multi scale vegetation plot, etc. and found that the Parker, large quadrat and Daubenmre transects significantly underestimated the total species richness and number of native species in prairie types. All four methods capture most of the dominant species at each site and produce similar results for total foliar cover and soil cover. The multi-scale sampling enhanced the detection and measurement of exotic plants. To evaluate the status and trends of common, rare, and exotic species innovative multi-scale methods must replace commonly used transect methods.

The field observation unit may be further classed as to whether it is permanent or temporary. Permanent plots are those established in such a manner so they can be relocated exactly and vegetation remeasured within their boundaries at a later time. A temporary sample unit is quick to establish but has limited value for monitoring change. Permanent sample units, on the other hand, have defined and monumented start and end points in the case of transects or boundaries in the case of quadrats. Monumentation means marking and recording the location of the plot center or plot boundaries and measured trees that the plot and trees can be remeasured as a later time.

Replication of measurements and observations are relatively easy making permanent plots very useful for measuring or detecting changes. Of course, monumentation takes time, so permanent plots are more costly to establish than temporary plots. Establishing permanent plots is essential if the inventory is to be used as a base for monitoring.

With the increased use of remote sensing data, ground-truthing is essential to interpret the data. Permanent monitoring plots that collect reliable data can act as standard reference points for the interpretation of changes observed by satellite and other remote sensing platforms. In effect, the plots become permanent ground-truthing stations (Lund et al. 1998 and Roberts-Pichette and Gillespie 1999). Whenever there is the possibility that a sampling area may again be visited for further study, the plots should be marked permanently, as surprisingly worthwhile results may be obtained by restudying identical areas over a period of years. Such results are often disproportionately valuable for the effort required, especially when compared to the initial study (Roberts-Pichette and Gillespie 1999).

Tools for data analysis and presentation

The final phase of any biodiversity assessment will focus on analysis of the data, and presentation in a suitable form for use by its intended audience. IUCN (2000) and Leslie et al. (1996) provide excellent guidance in assessing biological diversity once inventories are complete. A number of analytical tools are now widely used to support these activities (see Table 20); some of the most important examples are described briefly below.

Geographical Information Systems (GIS)

It is impossible in practice to inventory every site. However, knowledge of a species' habitat requirements, coupled with baseline data on climate, altitude, soil type, or vegetation cover, can be used to predict their occurrence in areas not inventoried. A geographic information system (GIS) is commonly used for this purpose. A GIS is a spatially referenced database that allows multiple levels of data, in any desired combination, to be displayed as maps on either a workstation or a personal computer. It is the ability to overlay datasets that gives GIS a unique role in exploratory analysis. The distribution of a species can be overlaid onto maps of land cover, soil type, climate variables, drainage, the distribution of other species, or whatever data are available.

GIS can be employed to generate maps of the expected distribution of species from maps of the key environmental factors known to affect their distribution. Analysis of maps of species ranges superimposed allows the identification of areas potentially high in biodiversity. These predictions can be verified (or 'ground-truthed') if required by field surveys. The baseline GIS maps used may be generated from satellite data, aerial survey, and existing maps, or created by field survey and expert advice. A major advantage of GIS is that it enables the standard formatting of all maps used, no matter what their source. Use of GIS implies an advanced and highly technical approach; this will not always be preferred, particularly where capacity of the personnel involved is not appropriate and where staff continuity cannot be secured.

The GIS can be used to derive landscape measures that are needed to act as dependent variables within ecological models. GIS packages contain a variety of spatial analysis procedures to calculate areas, perimeters, distances, percentage covers and other measures, but the answers may be very dependent upon the scale of the data and the algorithms used; for example, a coarse data set might group together two woodlands which a finer resolution map treats as separate (Firbank et al. 1997).

GIS is particularly valuable for modeling at the landscape level. The modeling process typically involves exploratory data analysis, followed by correlative modeling, and, where possible, process-based modeling. Models may be required to support scenario analysis (eg to assess potential future impacts of environmental change or vulnerability of different areas to specific threats). While conventional correlation or regression techniques work equally well in mathematical terms, the ability of GIS to communicate information is much greater because spatial data are presented in a spatial way (Firbank et al. 1997).

Finally, the GIS can be used as a means of visualizing the results of landscape ecological models. For rule-based models, this is easily achieved; for example, supposing that a particular species lives in all woodlands greater than 5 ha, and nowhere else, then the supplied functions of the GIS can be used to display all woodlands of the relevant area - thus giving a distribution map of the species. More complex models require more complex manipulations, which can take place either inside the GIS or by modeling routines in a high level language, which generate results that can be fed back into the GIS for presentation (Firbank et al. 1997). Steps involved in generating such an information set include clarification of objectives, derivation of indicators related to the objectives, formulation of a linear program, construction of a stand projection model, generation of alternatives, and repeated generation of solutions using the linear program (Carlsson 1999).

Table 20 Some software tools useful for measuring, monitoring, and analyzing biological diversity.

Type of tool	Name	Use	Internet site
Image analysis	Diversidad (Podolsky 1998)	Diversidad scans earth imagery and filters it in such a way as to indicate areas of high heterogeneity. These areas correlate with high biodiversity. Hence, the Diversidad filter is a very useful, cost-effective surrogate for biodiversity. Use to produce first-cut maps of biodiversity hot spots. Use to help stratify areas for further sampling.	http://home.att.net/~podolsky/divcov.htm
Planning reserve networks	CODA : Conservation Options and Decisions Analysis	CODA is a nature conservation software package which "assists in the design of networks of nature reserves or protected areas." The program has been compiled by Michael Bedward, an Australian ecological consultant, and is offered free from this site.	http://members.ozemail.com.au/~mbedward/coda/coda.html
Predicting distributions	GARP	DesktopGarp is a software package for biodiversity and ecological research that allows the user to predict and analyse wild species distributions" and is a desktop version of the GARP (Genetic Algorithm for Rule-set Production) algorithm.	http://beta.lifemapper.org/desktopgarp/
Calculating diversity measures and statistics	Species Diversity and Richness III	Offers a wide range of alpha and beta diversity related methods, graphical data representation, abundance distributions, etc.	http://www.pisces-conservation.com/indexinaction.html
Calculating diversity and complementarity measures	Worldmap	WORLDMAP is easy-to-use software for exploring geographical patterns in diversity, rarity and conservation priorities from large biological datasets.	http://www.nhm.ac.uk/science/projects/worldmap/worldmap/info.htm

Type of tool	Name	Use	Internet site
Selecting priority sites for conservation	SITES	SITES was developed with funding from The Nature Conservancy to be user-friendly for non-GIS specialists. It is a customized Arc View 3.x project that uses heuristic algorithms to identify multiple sets of near optimal conservation reserves.	http://www.biogeog.ucsb.edu/projects/tnc/toolbox.html
Reserve selection	CPLAN	C-Plan (Conservation Planning System) was developed by the National Parks and Wildlife Service in Australia to identify conservation areas in heavily influenced landscapes It links to ESRI's ArcView 3.x to display various contributions of individual sites to conservation goals.	http://members.ozemail.com.au/~cplan/.
Population viability	RAMAS	A number of products focusing on modelling population viability, assessing threat status of species, etc. Integrates with GIS	http://www.ramas.com/
Monitoring software	VORTEX	Population viability modelling	http://pw1.netcom.com/~rlacy/vortex.html

Remote sensing

To conduct biological diversity inventories, as a minimum there will be a need to produce a relatively current map of existing vegetation. The more detailed the map, the more useful it will be for stratification and further sampling and modeling. Remote sensing data may be used to develop such maps. The technique of remote sensing, using spectral data from reflected sun radiation and back-scattered radar data, also provides surrogate measures for biodiversity, such as diversity of terrain, habitat and vegetation. Thus spectral data (LANDSAT TM, ENVISAT MERIS) can provide chemical-physical information, while backscattered radar data (ERS SAR, JERS SAR, ENVISAT ASAR) can provide morphological information. The two types of remotely sensed data can be processed synergistically to provide significant information (such as vegetation indices and habitat patches) of use in the generation of map layers (Fabbro 2000).

In general, remote sensing can provide:

- land cover/vegetation and condition information
- information on common land units and water units
- an interface between smaller scale imagery and ground data
- a base for collection of ground data
- an information base for public evaluation of ecological mapping concepts

According to Hunsaker *et al.* (1998), the following vegetation attributes may be measured or interpreted from remote sensing imagery for various geographic extents, including the within patch (plot), patch, and landscape mosaic:

- Canopy cover (e.g., percent cover, leaf area index, contagion).
- Physiognomic or life form diversity (e.g., conifer with very little shrub understory vs. conifer with high shrub understory).
- Large tree density (e.g., trees per hectare > 76 cm diameter at breast height (DBH)).
- Tree size (e.g., dominant and/or average size, distribution or diversity of sizes).
- Vertical diversity (e.g., canopy layers, foliage height diversity).
- Biomass or phytomass.
- Crown volume or bulk density
- Height to live crown (height from ground to live foliage).
- Surface dead material (e.g., snags or mortality, downed logs, litter depth and volume/mass).
- Moisture content (soil, foliar, and dead).

There are numerous kinds and sources of imagery available including panchromatic and multispectral imagery from airborne platforms and satellites. Every year the list of sources grows.

Remote-sensing images from orbiting satellites can play an important role in the collection of baseline vegetation data and in monitoring their status. Coarse-resolution data such as 1-km (0.62-mi) Advanced Very High Resolution Radiometer (AVHRR) imagery offer a means to view landscapes with daily frequency, thereby allowing the monitoring of vegetation condition both within a growing period and between years. Over a long period, AVHRR may provide a means for monitoring the subtle changes in the vegetation that may relate to such events as long-term drought. However

AVHRR data are not adequate for assessing the effects of more local changes. Landscape changes at the local level will be better understood with higher resolution imagery such as that provided by Landsat systems (Loveland and Hutchenson 1996).

Obtaining sufficient geographically unbiased verification and validation data on vegetative communities is one of the greatest challenges in developing base vegetation maps. These data are essential for classifying the Landsat Thematic Mapper (TM) imagery used in many assessments, and for assessing the accuracy of vegetation maps developed. Airborne video data systems that tag each frame with geographic coordinates from a global positioning system (GPS), in combination with interpretation and ground-truthing procedures, provide a cost- and time-effective method for obtaining data on vegetative communities over large geographic areas (Slaymaker et al. 1996).

Imagery not only varies in source and scale, but also varies in quality and suitability. Imagery interpretability rating scales are tools for making quantitative judgments about the potential interpretability of an image. The U.S. Government has recently developed two such tools - The National Imagery Interpretability Rating Scale (NIIRS) for panchromatic imagery (IRARS 1996) and Multispectral Imagery Interpretability Rating Scale (MSIIRS) for multispectral imagery (IRARS 1995). Both scales apply to imagery acquired from airborne and satellite imaging systems.

The most common use of remote sensing imagery is for delineating or mapping common vegetation or land cover units (Lund *et al.* 1997). This is generally done by delineating polygons or stands by physiognomic class, dominant species, canopy cover, size, crown condition, and vertical and horizontal diversity. Stands are areas of existing vegetation that are distinguishable from adjacent vegetation (usually in species, size, or density) and which are useful to management for physical, biological, or organizational reasons. On the whole, the stand is the largest piece of land having boundaries related (except coincidentally) to a resource. In all cases stand boundaries should:

- reflect actual vegetation differences or other differences which may affect administration or management, and
- be locatable on the ground and on imagery.

Eventually, the delineated stands should be transferred to a base map or stored in a geographic information system (GIS) for use in sampling and further analysis. The transfer of polygons into electronic format for use in a GIS can be done with various electronic tools such as analytical stereoplotters and other methods.

When utilizing imagery for ecological and biological diversity mapping, one needs to be cognizant of other parameters such as soils, landform, and hydrology, since ecological units incorporate all these and other parameters. If soil and land type boundaries are congruent with actual vegetation boundaries, then soil type and land type automatically contribute to stand boundaries. If they are not congruent, any union or intersection of actual vegetation with soil or land type that may be desired in a particular case can be obtained by manipulation of the map layers with a GIS system. This avoids contaminating the vegetation layer based on what can actually be seen, with other information that cannot be so easily identified on the imagery.

One of the primary uses of mapping ecological polygons is not only for location information but also for sampling to gather species information. The accuracy of remotely sensed data is highly dependent on the designed sampling scheme used for the collection of ground data. The most important steps when designing a sampling scheme for collecting ground data can be summarized as follows:

- A stratified random sampling scheme is suggested as the best choice in most situations.
- The number of samples within each category of interest ought to be at least 50 if no prior probabilities are available. Confidence intervals for the accuracy assessment should be presented along with error matrices.
- The area of each sample site should be governed by the pixel size of the sensor and the geometric accuracy of the satellite image.
- When using a subplot assessment a pilot study should be used to give the number of plots to be sampled in order to achieve a given accuracy. The size of the subplot should be based on the homogeneity of the studied parameter and the applied sampling technique.

Examples of biodiversity assessment approaches

In recent years, a number of approaches have been developed for the assessment of biodiversity. Examples of some of these approaches are summarised here, to illustrate how biodiversity assessments may be implemented in practice. These examples include assessments that have been applied at both national and sub-national levels, often to identify priority areas (those of high biodiversity or possessing large numbers of restricted-range or threatened species) to which the limited funds available for conservation should be directed. The techniques rely on the compilation of existing data, the collection of new data, or, as in the majority of cases, both. Data compilation, during which existing information from a variety of sources is generally synthesised to provide an overall view of the known state of biodiversity, an important phase of all national-scale biodiversity assessments. From this analysis priorities for conservation or further data collection can be identified. Consultation with national and international experts is often an explicit and integral part of the data compilation process. The collection of new data may be conducted on the ground, or remotely *via* satellite or aerial survey.

The examples given here differ in terms of scope and precise objectives, as well as depth of coverage, ranging from the intensive All Taxon Biological Inventory to more rapid assessments such as RBA and RAP.

Gap Analysis

Gap Analysis, originally developed by US Fish and Wildlife Service and others, is essentially a coarse-filter approach to biodiversity conservation. It is used to identify gaps in the representation of biodiversity within reserves (ie. areas managed solely or primarily for the purpose of biodiversity conservation). Once identified, such gaps are filled through the creation of new reserves, changes in the designation of existing reserves, or changes in management practices in existing reserves. The goal is to ensure that all ecosystems and areas rich in species diversity are adequately represented in reserves. Gaps in the protection of biodiversity are identified by superimposing three

digital layers in a Geographical Information System (GIS), namely maps of vegetation types, species distributions and land management use. A combination of all three layers can be used to identify individual species, species-rich areas and vegetation types that are either not represented at all or are under-represented in existing reserves. In practice, vegetation, common terrestrial vertebrate species, and endangered species are used as surrogates to represent overall biodiversity.

Methods for assessing Europe's biodiversity
http://nature.eionet.eu.int/publications/ECNC_NINA.pdf

A method for assessing European biodiversity has been developed by the European Topic Centre on Nature Conservation, which is comprised of four elements:

- Analysis of existing biophysical data at the European scale to identify the profiles of ecological regions, potential centres of biodiversity with regard to habitats and species, and baseline data on vegetation changes
- Standardised description of the ecological and land management profiles for priority species and habitats as a reference base that allows a qualitative assessment of their current status and conservation needs
- Update and validation of existing atlas inventories on species, habitats, land cover and human activity to improve future 'coarse filter' analysis
- Monitoring programmes at the site, ecosystem and landscape levels to build upon and contribute to the successive improvement of the elements described above.

BioRAP: for Rapid Assessment of Biological Diversity

http://www.amonline.net.au/systematics/faith5.htm#introduction

The BioRap Toolbox consists of a set of coordinated analytical tools that can be used to identify, with high spatial resolution, and within a period of one year, priority areas for the conservation and sustainable management of biodiversity. These tools were developed by the Australian Museum, CSIRO and other partners, for initial application in Papua New Guinea (PNG). The principal components of the BioRap Toolbox are spatial modeling tools and classification and biodiversity-priority setting tools. These tools support high spatial resolution biodiversity assessments that are readily integrated with existing spatially distributed planning information, as was available for PNG in the form of PNGRIS, the Papua New Guinea Resource Information System. Further, the BioRap approach departs from conventional planning approaches in explicitly treating "opportunity costs" for conservation, not just for land-use allocations, but also for the use of economic instruments such as environmental levies and carbon offsets. BioRap introduces socio-economic factors along with biodiversity at the earliest stage of analysis.

World Bank Toolkit
This document summarizes best practice in treatment of biodiversity within an environmental assessment, with a particular focus on determining the potential impacts of development projects

http://lnweb18.worldbank.org/ESSD/essdext.nsf/48DocByUnid/9F6DD9C2455B038A85256B8F0054CFF4/$FILE/ToolkitFullEnglish.pdf

ATBI: All Taxa Biodiversity Inventory
The aim of an All Taxa Biodiversity Inventory, developed by the University of Pennsylvania in conjunction with INBio (Costa Rica), is to make a thorough inventory or description of all the species present in a particular area, using highly trained taxonomic specialists recruited internationally and nationally. The rationale behind this approach is that species have to be used (ie. must have a utilitarian value to human societies) in order to be preserved, and have to be described and understood before appropriate uses can be found for them. The goals of ATBI are: to recognise and describe species and assign stable scientific binomial names (facilitating information exchange between researchers in different parts of the world); determine where at least some of the members of each taxon or species live and can be found; and, through accumulation of ecological and behavioural information, determine their role in the ecosystem.

RBA: Rapid Biodiversity Assessment
Rapid Biodiversity Assessment, developed by MacQuarie University (Australia) and others, is based on the premise that certain aspects of biological diversity can be quantified without knowing the scientific names of the species involved. Data are gathered on certain groups of organisms. Several groups, chosen as good 'predictor sets' or 'biodiversity surrogates' of biodiversity are needed at each location inventoried. The main characteristic of RBA is reduction of the formal taxonomic content in the classification and identification of organisms. There are two methods by which this can be achieved:

Ordinal RBA In this approach only those taxonomic levels needed to achieve the goals of the assessment in question are used. Ordinal RBA is frequently used in environmental monitoring. For example, if it is known from prior studies that the presence or absence of a particular family or genus indicates disturbance or pollution, it may only be necessary to resolve the species collected at a site to the level of family or genus to ascertain environmental quality.

Basic RBA The identification of large numbers of specimens obtained from a particular area during a biodiversity inventory may be problematic. An alternative to formal and correct species identification by expert taxonomists is the creation of locally functional schemes for classification and identification, using easily observable morphological criteria. For example, butterflies might be distinguished on the basis of wing colour, pattern and size resulting in classifications such as 'Small, red with white spots.' The units of variety recorded by such a scheme may be called morphospecies, operational taxonomic units (OTUs) or recognisable taxonomic units (RTUs). Depending on whether operational procedures have been standardised and calibrated by conventional taxonomic measures, these units may or may not be less representative of natural biological variation than species *per se.* Biodiversity technicians trained by taxonomists can be used to separate specimens into RTUs. Studies show that if properly trained such personnel can be very effective.

RAP: Rapid Assessment Programme
(http://www.biodiversityscience.org/xp/CABS/research/rap/methods/rapmethods.xml)

Conservation International (CI) created the Rapid Assessment Program (RAP) in 1989 to fill the gaps in regional knowledge of the world's biodiversity 'hotspots'. The RAP

process assembles teams of experts to conduct preliminary assessments of the biological value of poorly-known areas. RAP teams usually consist of experts in taxonomically well-known groups such as higher vertebrates (eg. birds and mammals) and vascular plants, so that ready identification of organisms to the species level is assured. The biological value of an area can be characterised by species richness, degree of species endemism (ie. percentage of species that are found nowhere else), special habitat types, threatened species, degree of habitat degradation, and the presence of introduced species. RAP teams use standardized methods to survey the diversity of plants, mammals, birds, reptiles, amphibians, and selected insect groups. The RAP methodology is not a substitute for more in-depth inventories or monitoring, but it is designed to provide critical scientific information quickly.

6. HOW SHOULD A PARTICIPATORY BIODIVERSITY ASSESSMENT BE CONDUCTED?

What is a participatory approach?

Participatory assessment, monitoring and evaluation of biodiversity (PAMEB) involves non-scientists in observing, measuring or assessing biodiversity or its components. 'Participatory' is a word that has gained much currency in the last 15 years, so much so that it can mean all things to all people. It is often understood to mean assessment by rural communities, but can also involve other stakeholders such as students, policy makers, conservationists or volunteers. It can refer to scientists and local people working *together* to assess biodiversity, so that they understand each other's perspectives better; so that local people contribute to national biodiversity monitoring processes; or so that scientists support local people in managing biodiversity. Participatory monitoring is a powerful approach that can improve effectiveness of information gathering, transparency of decision-making and implementation of policy, as well as achieve some human development objectives. It is an approach that is increasingly being used to support biodiversity conservation and management. This chapter draws on shared experience from an internet conference (Lawrence 2002) and published case studies. It is a new field, and much of the experience is from developing countries, where a participatory approach is particularly appropriate, but the processes would be similar in other contexts.

Participation ranges from passive participation, where people are only told what is going to happen and their responses are not taken into account, to self-mobilisation, where people take initiatives independent of external institutions (Pretty 1994). To date, most examples of participatory biodiversity assessment and monitoring reach only the halfway point in this range: people participate by providing labour so that data can be gathered more quickly and cheaply. Interactive participation where people contribute to decisions in biodiversity management or self-mobilisation where they have the full rights and responsibilities in biodiversity management are still very rare. This chapter highlights the possible steps in participatory biodiversity monitoring at this interactive part of the spectrum, where we take local communities, protected area (PA) staff and policy makers to be the main stakeholders and hence participants.

Despite its popularity, participation is not an end in itself, but a route to *either* more efficient biodiversity monitoring, *or* empowerment of local communities – or both. To choose the approach it is important to decide on the objectives, and to negotiate those objectives with the participants before proceeding. Practitioners of participatory approaches talk about the importance of *process* and *product.* Without due attention to process (*how* the work is conducted), the product (*what* is achieved) will be meaningless because it will have been produced by people without understanding or motivation to contribute. This is a particular challenge in participatory approaches, not only because different stakeholders have different livelihood goals and education levels, but also because of different knowledge systems, culture, worldviews, values and beliefs.

Both process and product combine to improve resource management because decisions are made by stakeholders who are both :

a) better motivated (through the participatory *process*)

b) better informed (by more relevant and meaningful *data*).

Therefore, the process approach becomes more important towards the active end of the participation scale, i.e. in interactive participation and self-mobilisation.

Why conduct a participatory biodiversity assessment?

Local people are valuable actors in assessing and monitoring biodiversity, because:

1. They may have knowledge about wildlife, plants and resources derived from generations of use.
2. Most monitoring systems within, and many outside, protected areas (PAs) focus on protected species of wildlife and plants. Monitoring local resource use is a neglected but crucial dimension in planning sustainable harvesting by local people.
3. It is internationally acknowledged that involving local people in the planning and management of biodiversity and resources can increase their awareness and motivation for conservation. It can enhance an exchange of local and outside perceptions on the relationship between biodiversity and use patterns, leading to feedback on how to change unsustainable resource use practices.
4. Decisions on biodiversity management, especially in protected areas, are often non-transparent for local communities depending on those resources. The involvement of local people in the gathering and analysis of biodiversity data will enhance the transparency of management decision-making.
5. Communication among stakeholders is often limited, as is the recognition by management staff that local people can be valuable partners in such management activities. Interactive participation by various partners, including nearby communities and PA staff can to improve relations (Fabricius and Burger 1997; Van Rijsoort and Zhang 2002), and resolve conflict (Bliss et al. 2001).
6. Particularly in developing countries, resources for biodiversity assessment are limited - human capacity, money and time are all scarce (Danielsen et al. 2000). A monitoring and management system for biodiversity and resources should be based on locally available capacity and resources to be sustainable.

Finally, local perspectives can be an invaluable contribution to the scarce evidence for or against success of Integrated Conservation and Development Projects (ICDPs) (Kremen et al. 1994; Salafsky and Margoluis 1999).

An interesting illustration of the role of PAMEB in conflict management is provided by Steinmetz (2000). Officials in Southern Laos declared an area to be a core zone, because of the presence of mineral licks, an important source of salt for protected wildlife like elephant and gaur. Through a PAMEB, the local people showed that the large mammals concentrate their use of the salt licks in the rainy season, thereby resolving questions of resource conflict with intensive human use of the area, which is mainly in the dry season. Establishment of an all-year round core zone would have ignored the seasonal movements of the protected wildlife.

Steps in the process

One important difference from conventional procedures for biodiversity assessment, is the diversity of stakeholders, objectives and information needs that form the starting point for the process. Another is that these stakeholders are also involved in the selection of targets, developing methodology, and data analysis. The steps of the process are as follows (see also figure 1):

1. Who are the stakeholders?
2. What are their objectives?
3. Therefore what are the information needs of each stakeholder?
4. Are the information needs of different stakeholder groups compatible?
5. Which representatives of each stakeholder group will take part in the monitoring?
6. What is the available budget?
7. What are the benefits of and obstacles to participation in monitoring?
8. Which variables should be monitored?
9. Which indicators and methods to use?
10. How to analyse, validate and use the results?
11. How to document and disseminate the results?
12. How to use experiences to improve the participatory system?
13. Is all of this feasible within the budget? If not, revise steps 7 to 12.

Before starting

As with any biodiversity assessment, the process should begin with a compilation of secondary information – maps, reports, aerial photographs etc. which will help in planning and stakeholder selection. Successful case studies also point to the need to recognise any existing monitoring systems (which may be informal and not named as such) in order to build on established practice (Danielsen et al. 2000; Van Rijsoort and Zhang 2002).

Facilitating a participatory process

The *time* needed to facilitate a participatory process in biodiversity monitoring must not be underestimated. The process may take much longer than a non-participatory approach, but this is essential for mutual understanding and therefore useful data and / or local empowerment. It is also important that the facilitator recognises his or her privileged position as a stakeholder who, despite striving to leave bias and subjectivity on one side, will nevertheless have personal objectives and motives for becoming involved. This will help the facilitator to be more self-aware and protect against undue bias.

Before entering into a participatory process of biodiversity monitoring, an enabling environment is needed – i.e., favourable policy and institutional factors. In cases where PAs are strictly protected, the possibilities for interactive participation by surrounding communities may be limited, since the benefits perceived by these communities may not be high. In cases where the rules and regulations of the PA enable sustainable use of resources and even joint management of (parts of) the PA, incentives for local communities to participate in biodiversity and resources monitoring will be higher. Furthermore, in most developing countries, the forestry sector has a history of top-down management. When there is no room or even positive

attitude towards decentralised management and involvement of local communities, PAMEB in the most participatory sense will be difficult. This move from a teaching to a learning style, where the focus is less on *what* we learn, and more on *how* we learn and *with whom,* has profound implications for conservation institutions (Pimbert and Pretty 1995).

The facilitator will also need to be aware of any obstacles perceived by stakeholders before entering into the process, in order to address misunderstandings or justified fears. For example, in Yunnan, China, villagers were initially reluctant to join in, fearing that the monitoring process would lead to further restrictions in their resource use. This fear appeared to be justified during the analysis phase, when most of the proposed solutions involved banning resource use. More constructive solutions that provided benefits for all stakeholders had to be thought of, including sustainable resource use and enrichment planting (Van Rijsoort and Zhang 2002).

Stakeholders

A whole range of people is involved in PAMEB. In the context of protected areas, these are likely to include: local communities, protected area staff, government staff as policy makers, NGO staff, and biologists. A useful participatory process cannot begin until the stakeholders understand and respect each others' objectives and values. Usually a facilitator will be needed to help begin this process.

Objectives

Each of these stakeholders has a distinctive perception of whether and why the area should be managed. For some, maintenance of livelihood will be most important, for others, protection of culturally or spiritually important places, while others are motivated by a concern to protect rare species for all humanity. As indicated above, the purpose of participatory monitoring may involve:

a. Conservation of biodiversity
b. Protection of cultural/spiritual places
c. Sustainable use of resources
d. Capacity building among stakeholders in conducting monitoring and analysing reasons of change
e. Planning for local resource management and monitoring its success
f. Awareness building towards conservation and sustainable use
g. Empowerment / mobilisation of local communities through taking management decisions
h. Enhanced communication / mutual understanding between stakeholders
i. Enhanced efficiency and sustainability of monitoring by using local capacity
j. Assessing and monitoring national biodiversity (CBD reporting)
k. Other objectives to be defined with stakeholders

It is important that all stakeholders remain aware about each others' monitoring and management goals, and that they are given feedback and adjusted if necessary throughout the PAMEB process.

Information needs

Each stakeholder works with a set of assumptions, or values, about what is important, and it is these that influence both decisions about what to monitor and evaluations of whether management has been successful or not. Different value-laden needs can also exist *within* stakeholder groups, including conservationists (Callicott et al. 1999) and local communities (Salim et al. 2001). Facilitators need to recognise what is important to each stakeholder, to help them define their information needs. Ways in which information needs can vary are:

a. Content: species, subspecies, habitats, land use, wildlife damage
b. Quantity: population sizes, abundance, stock volume, basal area, uses
c. Quality: importance, trends in uses, trends in abundance
d. Location: distribution; relationship between place and cultural value
e. Value: economic, conservation, aesthetic etc.

If information needs of different stakeholder groups are compatible, stakeholders can work as a multi-disciplinary team. It they are not, it is advisable to either:

- Develop parallel systems, and share findings, or
- Encourage those stakeholders who need the information to pay other stakeholders who are able to obtain the information.

One approach to resolving these differences in objectives and information needs, and at the same time creating opportunities for stakeholders to learn from each other, is illustrated by Van Rijsoort and Zhang (2002). Working with staff of a nature reserve, and neighbouring communities in Yunnan, China, they supported the development of three *parallel* monitoring systems. The scientists conducted a detailed biological inventory and used permanent sample plots to explore changes in the ecosystem; park wardens recorded observations of priority wildlife on their routine patrolling routes through the park, and communities monitored land use, wildlife damaging their crops and selected resources through indicators such as 'effort required to collect them'. The project facilitates exchange of results between the different monitoring systems. Different groups of stakeholders changed their own perceptions of resource abundance and ecological health as a result. This also prompted park staff to seek further training in ecology, in order to be able to answer community members' questions.

Selection of partners

Even within each stakeholder group, biodiversity is valued differently. For example, within a local community different people have different interests in and knowledge about resources and biodiversity. Ideally, such heterogeneity should be understood before selecting a team of appropriate monitoring partners.

Resource user groups may be taken as a basis for selecting partners (for example, farmers, herbalists and hunters may form different stakeholder groups); alternatively more natural groups may form according to age, gender and income. The team should include representatives of the selected groups, as well as recognised local experts in plant or animal identification, any relevant local officials such as forest guards, and perhaps someone who is good at motivating the rest of the village.

Drafting a preliminary budget

PAMEB cannot be done without financial support. Although participatory biodiversity monitoring *can* be cheaper than more conventional scientific monitoring, this is not always so, and in any case funds should be carefully defined and secured. A preliminary budget should be defined at this stage of the process since there is no point in involving people in a complicated process without the funds to implement it. The items of the budget should at least include costs for organising discussion and analysis meetings, transportation costs, stationery, and other operational costs. Funds for publicity and dissemination are important as well. Training may be needed in specimen preparation and storage, data analysis and photography by villagers, depending on which methods are defined.

The budget may need to include payment to participating stakeholders, particularly villagers. For local communities, especially in the case of poor farmers, being involved in biodiversity monitoring is extra work which takes time and money. It is fair to offer a fee to take account of these costs borne by local people, keeping in mind that this will be temporary.

After developing the rest of the methodology, i.e. after determining how many targets to monitor, which methods to use, and how to document and disseminate, the budget should be finalised.

Monitoring targets

It is impossible to assess the whole of biodiversity, and decisions must be made about *which* components are to be measured and what they tell us about the whole (or the part that we are interested in). Different stakeholders will have different views on and monitoring targets should be selected on the basis of stakeholders' interests. For example, scientists might be most interested in (globally) rare and endangered species or habitats, PA staff in protected species and vegetation, and local communities in resources for trade or domestic use. Additionally, in Yunnan, villagers chose to monitor wildlife damaging their crops, wild animals they consider as having an important function in the ecosystem, and some land uses.

Choosing indicators

Variables are often measured using indicators. The use of indicators is a concept that has been introduced from project management frameworks, and one which is not always easily grasped by local communities (Lawrence et al. 2003). The purpose of each indicator must be very clear to all participants, and linked to the targets already defined. Ideally, indicators of trends in biodiversity and resource use should be (Danielsen et al. 2000):

- Easy and cost-effective to collect, analyse and report
- Meaningful to local people
- Indicate as directly as possible changes in biodiversity and resource use
- Provide a continuous assessment over a wide range of stress (threats)
- Differentiate between natural cycles or trends (weather, climate etc.)
- Relate to human-induced stress
- Relatively independent of sample size
- Sufficiently sensitive to provide an early warning of change

- Applicable over a range of ecosystems.

For species indicators it is often important to determine the scientific name in order to ensure all stakeholders are referring to the same species. This may require training and preparation of identification guides.

Choosing methods

For many practitioners, the big question is whether to use quantitative or qualitative methods (Fuller 1998; Lawrence et al. 2000; Sheil et al. 2002). Because both have their strengths, they can often be fruitfully combined. On the one hand, quantitative measures of change are often more meaningful at the wider scale, and for planning. Biologists can contribute rigour to monitoring by introducing concepts of sampling and establishing plots. This does not preclude participation: scientific methods also have a role in participatory approaches, and we should not underestimate the abilities of local people to record detailed and complex data but note that analysis and generation of useful results can require much external support. However, the sustainability of highly technical methods based on detailed measurements of all species within quadrats is highly doubtful. Simplified methods may be more appropriate, such as the triangular plots used by the indigenous hunters of Finland, who regularly record observations of game along the three sides of triangular plots, enabling data to be linked to habitat (Linden et al., 1996). Other simple quantitative methods were used in the Yunnan case, for monitoring resource use, wildlife damage and land use. Market surveys and interviews with co-villagers are used to assess the amount of resources collected and marketed, and the market price. For timber, the number of houses built per year is used as well, and for fuel wood the number of households using alternative energy systems (Van Rijsoort and Zhang 2002).

Qualitative methods may however be sufficiently useful in those protected area management contexts where time, resources and capacities are limited and threats to biodiversity are high. Instead of spending the scarce resources on detailing exactly what is changing, in these contexts it may be sufficient to know the trends of change, why biodiversity is changing and what are the local perceptions of change in order to formulate management decisions. Moreover, in those areas where participatory monitoring is a new concept and involvement of villagers is based on their interests and capacities, it may be wise to start simple and grow slowly. In Yunnan where poor farmers and (hunter/)gatherers are the main monitoring partners, qualitative methods use forest walks and interviews with co-villagers to assess simple indicators such as 'easy or hard to see', 'quality' (of e.g. habitat, fruits or plantation condition).

Maps are a valuable start to combining species and landscape values, linking knowledge with place and quantitative data with qualitative information. There is often a strong correlation between detail on locally made maps and scientific data – even in distant sites visited infrequently by local informants (Obura 2001; Sheil et al. 2002; Stockdale and Ambrose 1996).

Data analysis, validation and use of results

Collection and analysis of the data is related to the objectives of the participants; these objectives also define the users of the results. So analysis and presentation of results

must be considered with these end-users in mind. Ideally, in a participatory process, the results are to be used by those who provided and analysed the data.

Local people, if given the opportunity to discuss findings, often provide interpretations and insights that otherwise may have been missed if the results had been interpreted solely by staff and advisors (Steinmetz 2000). Moreover, the drafted solutions emerging from participatory data analysis will be more practical and adjusted to the local conditions.

The results can be validated through feedback from more scientific monitoring systems, or even through a kind of triangulation with two complementary systems as in the Yunnan case. Biologists and conservationists are often concerned about the reliability and generality of local environmental assessments. They wonder how objective or rigorous data gathered by villagers are. The question however is not the extent to which participatory monitoring can fit into scientifically based (and therefore assumed reliable) formats, but, again, what the objectives and intended application of the assessment are (see above) (Abbot and Guijt 1998).

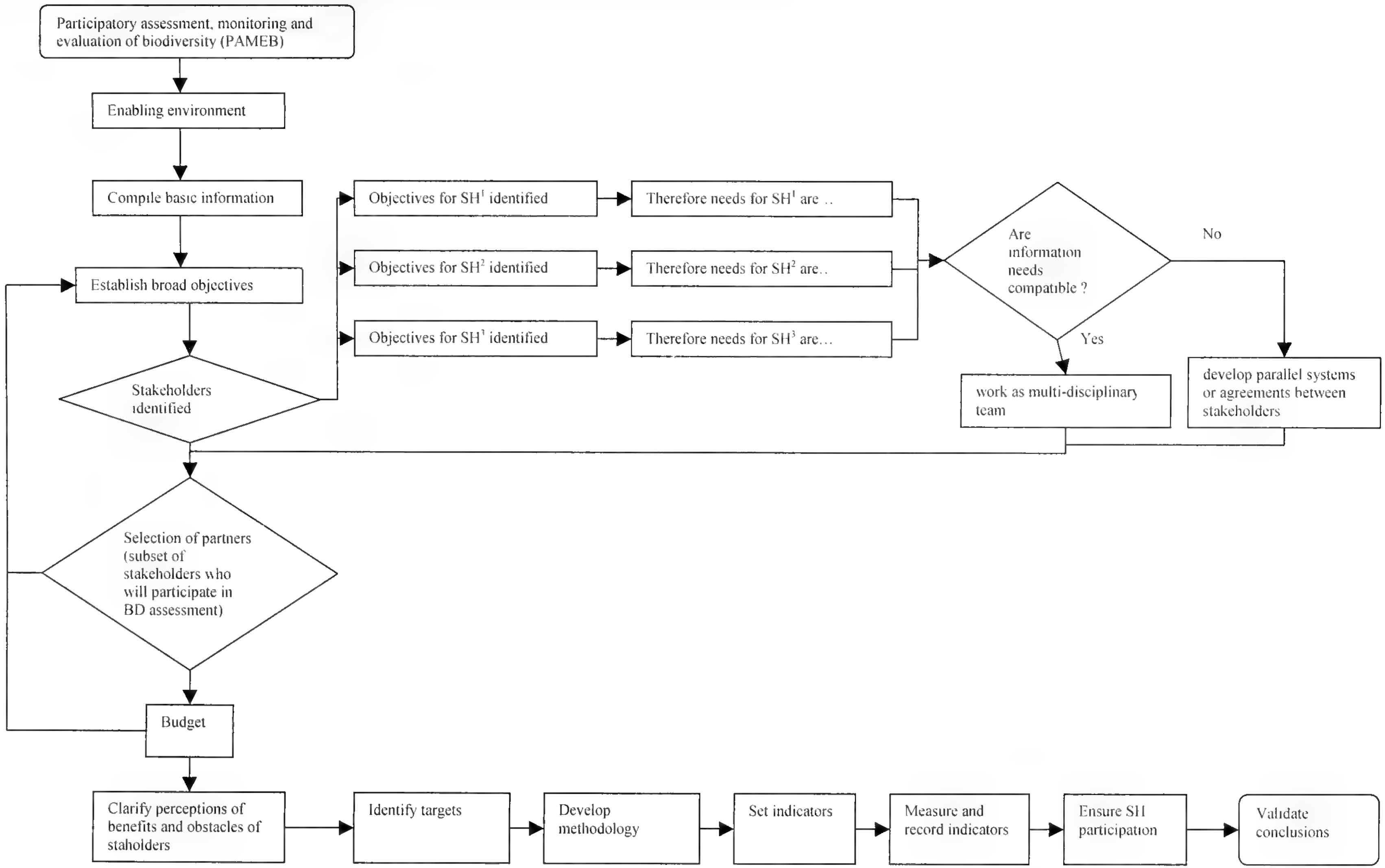
Follow up

Continuing support in analysis and decision-making is important. If PAMEBs are funded as a one-off event by a particular project, they are of little use in management unless they become integrated into regular decision-making activities.

The impact of PAMEB is greater if the result and methods are documented and disseminated. There are various ways to do this; the choice again depends on the objectives. Appropriate methods to disseminate at village level are through schools, village meetings, festivals, market days, local radio programs, etc. The media can also be valuable at national level: the People's Biodiversity Registers in India have gained attention in the national press (Gadgil 1998), and raised awareness of the existence, but erosion, of practical ecological knowledge.

Finally, in product as well as process approaches, the monitoring and evaluation of the process and the results are very important. PAMEB is often a new concept, which needs continuous feedback to optimise and adjust the methodology to local conditions. Increased attention to documenting the *impact* of PAMEB will help scientist and decision-makers to see the possibilities, and particularly to see where they can contribute and benefit from such an approach.

Figure x. Schematic diagram illustrating the process of undertaking a participatory biodiversity assessment or monitoring programme.


Participatory assessment, monitoring and evaluation of biodiversity (PAMEB)
Enabling environment
Compile basic information
Establish broad objectives
Stakeholders identified
Objectives for SH1 identified
Objectives for SH2 identified
Objectives for SH3 identified
Therefore needs for SH1 are ..
Therefore needs for SH2 are..
Therefore needs for SH3 are...
Are information needs compatible ?
No
Yes
work as multi-disciplinary team
develop parallel systems or agreements between stakeholders
Selection of partners (subset of stakeholders who will participate in BD assessment)
Budget
Clarify perceptions of benefits and obstacles of staholders
Identify targets
Develop methodology
Set indicators
Measure and record indicators
Ensure SH participation
Validate conclusions

7. WHICH IS THE BEST APPROACH?

Biodiversity assessment and decision-making

The approaches to biodiversity assessment described here each have strengths and weaknesses. Scientific methods have mainly been applied to conservation priority setting, even though they have much potential for broader applications. Local assessments capture what matters locally but are difficult to link – as may be required for local or national policy – to higher-level processes. Partly for this reason, assessments driven by national and international agendas, as well as those emerging in the private sector, almost invariably emphasise global biodiversity values over national or local values. The outstanding problem, then, is *exchange* among the different approaches to biodiversity assessment.

Biodiversity assessments need to provide information that is useful to those involved in policy implementation, as well as development. The most direct management decisions are made at local levels, and in this sense the most useful biodiversity assessments are those based locally. However, there are also a number of other levels at which decision-making affects biodiversity and livelihoods connected with it. National and local governments, land-owners and development or conservation organisations are some examples of others whose policies and activities are influential, and many of these agencies implement biodiversity assessments of their own. At both local and non-local levels, evaluation of biodiversity is part of broader cycles of land-use and natural resource management, either purposively or not (Figure 3).

Currently, most biodiversity assessments are poorly coordinated among different groups of decision-makers. This is only one component of a broader uncoupling among their respective management cycles – in short, a natural resource governance challenge that needs to be tackled on all fronts. Biodiversity assessment might be a relatively tractable part of this challenge, and offer a tool for broader progress towards pluralist decision-making, for example by providing empirical information that serves as a basis for dialogue, negotiation or cooperation among different groups.

By adopting the principles of the Ecosystem Approach as the primary framework for operationalising the Convention on Biological Diversity, a large number of governments have committed to locally driven biodiversity management. Although international statements do not of course guarantee national or local change, the Ecosystem Approach nonetheless provides a framework for natural resource management in which, while other interest groups have their say, local roles, values, priorities, knowledge and decision-making may take a lead. The CBD is an example of a broader trend of decision-makers in government, NGOs and the private sector recognising the utility of decentralised and democratic natural resource management, for reasons of efficiency if not equity. Trade-offs and synergies between global and local biodiversity values are increasingly on policy agendas at local, national and international levels. Conservation discourse is also putting more emphasis on conservation of biodiversity outside reserves, with integration rather than segregation of global biodiversity and local livelihoods (Vane-Wright 1996; Prendergast et al. 1999).

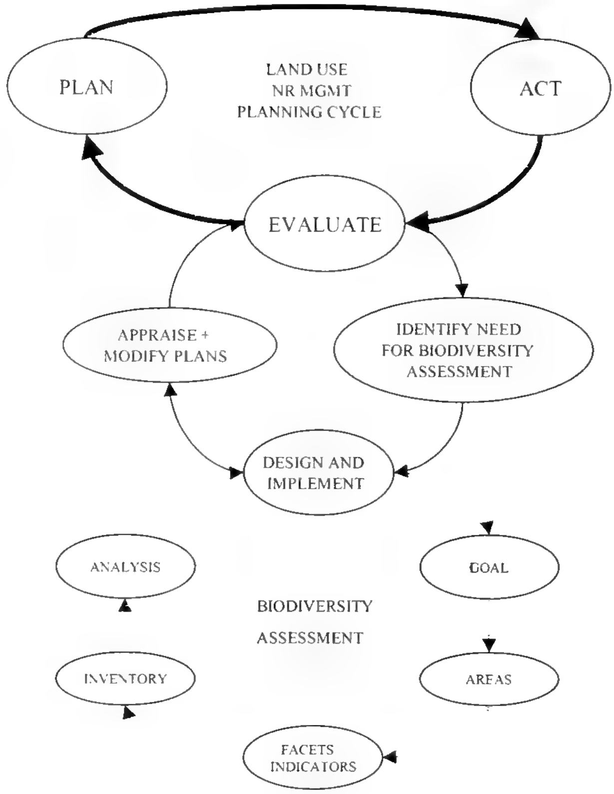


Figure 3. How biodiversity assessment fits as a sub -component of land use and natural resource management planning cycles

Devolved, pluralist and adaptive management of biodiversity has obvious implications for assessment. Fundamentally, all the details of choosing, planning, conducting and learning from biodiversity assessments (Figure 3) need to be decided locally, shared and flexible. In response to this, one of the most promising directions internationally is the growing interest in, and practice of, participatory biodiversity assessment (Lawrence and Ambrose-Oji 2001; Rodriguez and van der Hammen 2002). These kinds of approach take up the challenge of finding a broad middle ground between local and wider biodiversity values, not only through communication of local values to global audiences and vice versa, but by sharing ownership of both the responsibilities (e.g. planning, fieldwork) and the benfits (e.g. access to information, financial rewards) of biodiversity assessment.

Not all biodiversity assessments need to be joint activities. Often stakeholders see no benefit in mutual evaluations or understandings of biodiversity. Local users all over the world rely on independent appraisals. Sometimes biodiversity may not be an issue at all, even among a broad range of interest groups. Biodiversity assessments can be expensive, or even risky. There can be serious disadvantages to local people, especially disempowered or indigenous groups, in

becoming involved in biodiversity assessment: not only the obvious transaction and opportunity costs, but also the potentially negative impacts of sharing information with outsiders, such as biopiracy (Shiva 1997). Much is made in international circles of the need to mainstream biodiversity issues into the full spectrum of national and regional planning processes. Perhaps instead the emphasis should be on mainstreaming – at a decentralised level – the *option* of collaborative biodiversity assessment and management.

Improved governance and better information go hand-in-hand. The remainder of this section identifies some strategies and tactics for ensuring that the outputs of biodiversity assessments serve broader goals of integrated evaluation and decision-making among different stakeholders.

Lessons learned: some guidelines for biodiversity assessment

One of the most important messages for decision-makers at all levels is to approach biodiversity assessment with pragmatism and scepticism. Formal biodiversity assessment is expensive, sometimes to a degree that it detracts from management (Sheil 2001). The jargon of scientific assessments can hide a great deal of uncertainty, resulting in land management decisions based on spurious conclusions about local biodiversity (e.g. Homewood and Brockington 1999). Decision-makers require evaluations of biodiversity that answer specific questions as effectively as possible within the time and other resources available. Naturally, good assessment results are contingent on good processes, and decision-makers need to be aware, and take advantage, of the political and other contexts surrounding and implicit in biodiversity measurement (Box 22). Researchers have an associated role to play in developing assessment approaches that are relevant to the decision-makers who use the information generated.

Box 22. Putting biodiversity assessment into context

What decision-makers can do

- Rationalise biodiversity assessment – only assess biodiversity when there is good reason to do so, be explicit about the goals of assessment and base the methods used on these goals
- Be aware of the limitations of existing methods, and put more resources into developing integrated methods
- Identify relevant indicators rather than relying on internationally sanctioned conventional indicators (e.g. numbers of endangered species)
- Implement the CBD – ensure at an international level that a broad range of interests are reflected, especially those of local resource users and less wealthy countries, and nationally take advantage of the loose guidelines to set up a pragmatic and nationally specific programme of assessment
- Simplify requirements for biodiversity assessment in audits (e.g. forest certification and environmental impact assessments)

What researchers can do

- Provide more user-friendly evidence of the causal links between biodiversity and its ascribed indirect use values – e.g. Does biodiversity really offer environmental services such as watershed protection? Under what

circumstances?

- Work together (natural scientists, economists and social scientists) to design methods for measuring biodiversity in terms of the value that people derive from it – including measures of accessibility, substitutability, and the added value of variety and variability (capacity to change) over the sum of biological resource values
- Look into how the knowledge and equipment needed for specific scientific assessment methods can be transferred and used without significant cost to less wealthy contexts
- Act as "go-betweens" to link local managers of biodiversity to higher-level policy-makers

Examples from both researchers and decision-makers suggest some general guidelines for designing biodiversity assessments:

- <u>Start planning any biodiversity assessment by disaggregating values</u>. For practical purposes, biodiversity is not a feature of living organisms, but rather a catch-all term for all the types of variety that might be useful to people (e.g. the range of decomposers in the soil) or might not (e.g. the range of deadly viral diseases). Treating biodiversity as one composite property, then, is not helpful. An especially useful way of disaggregating biodiversity is in terms of the values we attach to it: the relevant direct, indirect and non-use values. These can be further broken down according to the relative values to different beneficiaries – the differences between local and global values have been stressed here, but other distinctions among stakeholders may be more relevant in other contexts. Considering biodiversity in terms of what people derive from it, rather than as an end in itself, helps us phrase much clearer questions and objectives for assessment.

- <u>Acknowledge trade-offs between biodiversity and other benefits, among different aspects of biodiversity, and among the values attached to biodiversity</u>. Biodiversity assessment could and should be a powerful tool for making difficult decisions about what aspects of conservation and management of biological resources to prioritise. As a start, separating biodiversity values from general biological resource values would overcome a lot of confusion (e.g. "biodiversity" is said to provide watershed protection, but it may be found that a monoculture does just as well). Other key trade-offs exist among direct use, indirect use and non-use values of biodiversity (e.g. maximising genetic variety in economic species versus maximising existence of unused species for future option values), between local and global values (e.g. conservation of all local bird species or concentrating on the one species that is rare globally), and among ecosystem, taxonomic and genetic levels of biodiversity (e.g. whether to maintain many different families of flowering plants versus many examples of a family deemed especially important).

- <u>In deciding what to measure, begin with a wide view of biodiversity and narrow down from there</u>. Measuring the wide array of different facets of biodiversity is a daunting proposition, and in practical terms an inefficient use of valuable expertise, time and finances. On the other hand, it is difficult to have a standard means of prioritising what should be measured

for all circumstances. Noss (1990) recommends starting with a coarse-scale, wide-reaching characterisation of a site, under the themes of composition, structure and function (alternatively other typologies such as structure/process/impact, state/pressure/response or ecosystem/taxa could be used), from which the key facets to measure are identified by comparing against data on "stress levels" (once again alternative criteria such as utility to local livelihoods, access, or rate of environmental change could be substituted). The underlying idea is to start by considering biodiversity in its broadest sense and then to use criteria to discard possible aspects to measure until a manageable set, based on the objectives and questions at hand, is reached. Even if the original characterisation of the site and the criteria are based on patchy evidence, a comprehensive checklist of possible factors is a very low-cost means of helping decision-makers to consider biodiversity more widely.

- <u>Measure the desired good or service rather than the associated biodiversity</u>. Links between biodiversity and provision of goods and services are poorly understood. Therefore it makes sense to assess the desired good or service rather than measuring biodiversity – evaluate seasonal availability of food, reduction in crop diseases, or landscape beauty, rather than the biodiversity that is considered to be providing it. Direct assessments of biodiversity are valid mainly for answering questions about non-use (option) values or questions of scientific interest, such as to provide baselines of genetic variation and variability in crop species, or to find out how many species there are in the world. Vanclay (1998) provides several other examples of where biodiversity is used as a surrogate and where biodiversity surveys are justified.

- <u>Design indices and indicators for specific land-use decisions and management processes</u>. There will never be a universal index of biodiversity that is generally accepted. The growing plethora of approaches and formats to express biodiversity is an encouraging rather than dismaying sign. Assessment techniques, indicators and indices need to be tailored to particular land-use or management decisions. For example, the certification audit for Stora-Ludvika recommended a "Rio index" of conservation value, based on a set of parameters that are available and relevant at the intended site, but would need to be adapted at other sites. What is transferable is the basic tool, in this case a composite index.

- <u>Accept imperfection – and be open to change</u>. Biodiversity assessments simply cannot be comprehensive. To carry out even a rough charaterisation of the biodiversity in a particular place is an expensive exercise if primary data collection is involved. Each stage of a biodiversity assessment – choosing values, choosing which facets of biodiversity reflect these values, designing and implementing field inventories, analysing data, relating data to land management options – involves compromises. No one approach is perfect, and the usefulness and relevance of techniques changes over time. Well established approaches to assessing biodiversity, such as the IUCN Red Data lists, accept (and, where possible, estimate) uncertainty, as well as updating the ranking system to reflect changes in, or refinements of, knowledge and values. The estimation and communication of the uncertainty associated with biodiversity assessments is currently one of the most significant scientific challenges facing the conservation research community.

- Be aware of multiple perspectives and the political context of biodiversity assessment. Practitioners have become so accustomed to indices and descriptions of biodiversity as a valuable end in itself that it is easy to forget that these portrayals of biodiversity are based on a view that the worth of biodiversity is in its non-use values (conservation for option, bequest and intrinsic benefits) to the whole of humanity. Criteria such as those used in selecting some protected areas appear to be based on some sort of global consensus over what is and what is not of "universal natural value". In reality, the global consensus is that of wealthy countries, and the most energetically promoted means of assessing biodiversity are those of wealthy conservation lobbies. This is not to say that poorer people would decline, given the opportunity, the opportunity to support biodiversity conservation based on non-use values – simply that practitioners should be aware that the views and values of less powerful groups are generally absent from prevailing national and international approaches to biodiversity assessment and management.

Sheil (2001) has provided a particularly valuable critique of biodiversity monitoring in tropical countries. He points out that monitoring activities can actually hinder, rather than improve conservation action, as limited resources are diverted away from practical management activities. Sheil makes the following recommendations, which should be considered whenever assessments are being planned:

- Monitoring and assessment activities must be allocated with sensitivity to local priorities and limitations, especially when local resources are involved
- Researchers should ensure that they are familiar with local management issues before they become general advisors on local conservation needs
- Care must be exercised whenever monitoring activities are promoted at the possible expense of important conservation actions
- Managers should only be required to collect data that are useful to them in ways that they understand
- High level monitoring is vital: information is needed on threats to biodiversity, and conservation priorities should be continually refined in the light of such information. However, the costs and responsibilities for generating such information must be allocated with care.
- Interventions should bolster, and not undermine, the attainment of conservation goals; case-by-case assessment is needed.

Combining multiple values into single indicators

Real life trade-offs in the management and assessment of biodiversity will be solved via political processes rather than through derivation of "objective" indicators that combine different sets of biodiversity values. Nonetheless, policy-makers at national and international levels need biodiversity assessments that assist planning and priority setting. If policy decisions are to depend on local as well as national or global biodiversity values, reliable and generalisable methods that contrast or combine different measures are required. Researchers have already designed several methods for integrating multiple measures:

- Category method. Different sites are placed in different categories according to clear criteria. Multiple biodiversity values can be included by a hierarchical system of classification or by categories having more than one criterion each. For example, the categorisation of biodiversity 'hotspots' combines parallel criteria for endemism and threat. A local value, for instance contribution to food security, could be substituted or added. The category method is applicable to both qualitative and quantitative data. It is perhaps the most commonly used system for combining multiple global conservation values, but has not been widely applied as a means of co-assessing local and global biodiversity values.

- Equation method. Multiple values are combined into a single index using an algebraic equation. Each term can be used to represent one facet or value of biodiversity. The different terms can be weighted according to their importance by using different factors of multiplication. For example, a formula developed for calculating biodiversity credits has weighting terms for abundance, uniqueness and vulnerability, the relative importance of which can be adjusted by increasing or decreasing their relative weightings. Any one of these terms could be substituted by a term expressing local value, which could be weighted according to perceived (or negotiated) relative importance. For example, an obvious substitute for "uniqueness" would be "substitutability", a measure of how many replacements people have for a species used for a specified purpose.

- Graphical method. Rather than lumping very different biodiversity values together, the graph method plots out different indices on opposite axes, to give a visual representation of difference. For example, a prioritisation of Canada's bird species plotted a measure of threat of extinction on one axis and the degree to which a species is concentrated in Canada (and therefore the responsibility of the Canadian government) on the other. Graphical means of combining more than one factor do not conflate factors that vary in different ways, without correlation, and therefore are more transparent than the category or equation methods.

Each of these three methods has associated strengths and weaknesses. To date, these methods have been applied mainly to integrating multiple conservation aims (e.g. endemism and threat of extinction). They could be just as easily used to combine multiple biodiversity values, such as direct, indirect and non-use values, or global and local values. Indeed, some planning processes have already integrated multiple values in this way.

More complex methods for integrating multiple values are also possible. Presentation of results of participatory biodiversity assessments, for example, often entail what might be called "scientification" of local knowledge, such as the application of formal statistical techniques, especially nonparametric rank-based tests, to information about local practice and perceptions (Hoft et al. 1999; Sheil et al. 2002). More broadly than biodiversity management, modern approaches to integrated natural resource management have begun to tackle how best to combine multiple values attached to natural resources, values based on different and sometimes conflicting stakeholder perspectives. Techniques include multivariate statistical methods such as principle components analysis, radar diagrams and canonical correlations (Campbell et al. 2001).

Integrated measures calculated in the above ways could be described as indices of "bioquality" (sensu Hawthorne 1996) rather than "biodiversity", in that sites that have the highest diversity of

beneficial taxa, biological processes or potential impacts might be different from the sites that have the highest overall diversity of taxa, biological processes or potential impacts. The usefulness of a term such as bioquality is that it places emphasis on the values that people derive from biodiversity.

Real consensus over measurement of biodiversity, with common vision and minimum compromise, cannot realistically be hoped for. Without consensus among stakeholders over how measures of biodiversity are derived (from which facets are chosen through to how they are recorded, weighted, calculated and combined), any uni-dimensional index of biodiversity will always be questioned. The fact remains that stakeholders with different values will always need space for dialogue. Measures of biodiversity, and more importantly the management decisions that are made on their basis, will continue to be determined, ultimately, by negotiation rather than through rational exercises based on state-of-the-art techniques.

Principle-based approaches to biodiversity assessment

Biodiversity is just one of many examples of a natural resource that is valued widely but managed locally, and therefore requires approaches that are locally adapted yet broadly applicable. A popular, and potentially very powerful, solution to achieving both ends is an evaluation system based on sets of principles that are agreed among a wide group of stakeholders, but allow substantial flexibility in decisions and actions taken locally. This is analogous to "loose-tight" models of business management that expect employees to work within core principles but to take most responsibility for local decision-making.

There are many working examples of principles applied to environmental and natural resource management. Some, such as the certification scheme overseen by the Forest Stewardship Council, rely on compliance from applicants in order to participate, but sets of principles that provide non-compulsory best-practice models for participants may be just as useful – the primary utility of principles is in their role as learning tools for organisations and alliances. Principles are usually succinct, and general enough to apply to many different types of stakeholders, which means that they are excellent tools for negotiation and collaborative management if they are supported by sufficient mechanisms for accountability.

A principles-based approach may be well suited to biodiversity assessment that needs to incorporate both global and local values. One of the big challenges of biodiversity assessment is the sheer amount of information that could potentially be gathered and evaluated. Principles provide the fundamental questions that need to be answered by assessment – a good starting point for choosing what to measure. Well-developed principles often include menus of potential indicators or targets within wider guidelines for implementation, which can be selected from or adapted to suit very different needs in different localities (e.g. in forest certification).

More importantly, principles-based approaches have a broader applicability to the process as well as the content of assessment and management procedures. The twelve principles of the CBD's Ecosystem Approach (see earlier) are a good example of a set that includes both principles for how the resource ought to be managed (e.g. Principle 6: Ecosystems must be

managed within the limits of their functioning) and principles for how management decisions ought to be made (e.g. Principle 2: Management should be decentralised to the lowest appropriate level). A biodiversity assessment based on this model would include questions on how close an ecosystem is to its limits (e.g. its state, rates of change, resilience, adaptability) and on how far management was decentralised (e.g. institutional rights and responsibilities, legal frameworks, budget control).

A global set of principles is only one of many potential ways forward – principles rooted in national or local realities could be just as useful for bringing multiple biodiversity values into more open debate. However, the principles of the Ecosystem Approach provide a valuable framework for collaborative approaches to biodiversity assessment, to support decision-making and adaptive management at local scales. As parties to the Convention of Biological Diversity place increasing emphasis on implementation of the various Work Programmes that have been developed, greater emphasis is likely to be devoted to practical implementation of the Ecosystem Approach. As noted in this report, this is likely to lead to increasing use of participatory methods for biodiversity assessment, and the explicit incorporation of local values into planning and management processes. Future development of biodiversity assessment and monitoring approaches will undoubtedly benefit from the experience gained in putting such methods into practice.

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Acronyms and abbreviations

AVHRR	Advanced Very High Resolution Radiometer
Bern Convention	Convention on the Conservation of European Wildlife and Natural Habitats
Bonn Convention	Convention on the Conservation of Migratory Species of Wild Animals
CBD	Convention on Biological Diversity
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CEOS	Committee on Earth Observation Satellites
CHM	Clearing House Mechanism
CITES	Convention on International Trade in Endangered Species
COP	Conference of the Parties
CPR	Continuous Plankton Recorders
CSD	Commission on Sustainable Development
CZCS	Coastal Zone Colour Scanner
DEWA	UNEP Division of Early Warning and Assessment
EROS	Earth Resources Observation Systems
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organisation of the United Nations
FFI	Fauna and Flora International
GEF	Global Environment Facility
GLASOD	Global Assessment of the Status of Human-induced Soil Degradation
GLCCD	Global Land Cover Characteristics Database
GOFC	Global Observations of Forest Cover
GTOS	Global Terrestrial Observing System
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme
IGO	Inter-governmental organisation
INPE	Instituto Nacional de Pesquisas Espaciais
ITTA	International Tropical Timber Agreement
IUCN	World Conservation Union
IUCN/SSC	IUCN Species Survival Commission
LME	Large Marine Ecosystem
MEA	Multilateral environmental agreement
NGO	Non-governmental organisation
NOAA	US National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Co-operation and Development
Ramsar Convention	Convention on Wetlands of International Importance
SBSTTA	Subsidiary Body on Scientific, Technical and Technological Advice
Straddling Fish Stocks	*The Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10th December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks*
TM	Thematic Mapper

TREES	Tropical Ecosystem Environment Observations by Satellite
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP-GEMS	Global Environmental Monitoring System
UNEP-GRID	UNEP-Global Resource Information Database
UNEP-WCMC	UNEP–World Conservation Monitoring Centre
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on Forests
WCMC	World Conservation Monitoring Centre (now UNEP-WCMC)
WCS	Wildlife Conservation Society
WHO	World Health Organisation
WRI	World Resources Institute
WWF	World Wide Fund for Nature

Appendix. Some internet resources relevant to biodiversity assessment and monitoring

A Bird Community Index of Biotic Integrity for the Mid-Atlantic Highlands - http://www.cas.psu.edu/docs/CASDEPT/FOREST/wetlands/BCI.htm -
Alberta Forest Biodiversity Monitoring Program - http://www.fmf.ab.ca/bm.html British Columbia's Resources Inventory Committee (RIC) - http://www.for.gov.bc.ca/ric/-
An Interactive Tool for Exploring Diversity in Digital Earth Images (Diversidad) - http://home.att.net/~podolsky/divcov.htm
Aquatic Environmental Effects Monitoring Requirements - http://199.212.18.79/eem/english/eemreg.htm
Bibliography on the Conservation of Biological Diversity: Biological/Ecological, Economic, and Policy Issues - http://osu.orst.edu/dept/ag_resrc_econ/biodiv/biblio.html -
BRD Expertise Page - http://www.nbs.gov/pubs/expert/ -
CB Forest Biological Diversity - http://www.biodiv.org/forest.html -
Chapman's Bibliography of Biodiversity Assessment Methodologies - http://www.environment.gov.au/life/general_info/biodiv_assess_intro.html
Conservation International Rapid Assessment Program - .http://www.conservation.org/web/fieldact/c-c_prog/science/rap.htm
Criteria and Indicators of sustainable forest management in Canada - http://nrcan.gc.ca/cfs/proj/ppiab/ci/indica_e.html -
CSEB - SCBE BioWeb - http://www.freenet.edmonton.ab.ca/cseb/b_listserve.html
Distance Sampling - http://www.ruwpa.st-and.ac.uk/distance/
Geographical ranges of species (http://www.gisbau.uniroma1.it/),
Interior Columbia Basin Ecosystem Management Project - Terrestrial Ecology Assessment - http://www.spiritone.com/~brucem/icbemp.htm -
Interior Columbia Basin Ecosystem Management Project (ICBEMP) Home Page - http://www.icbemp.gov/-
Internet Directory for Botany: Checklists, Floras, Taxonmic Databases, Vegetation - http://www.systbot.gu.se/mirrors/idb/botflor.html
Key Biodiversity Websites- http://www.icipe.org/environment/biolist.html
Landscape perspectives & biodiversity management of forest birds in Minnesota - http://www.nrri.umn.edu/nrri/land_bio.html
Molecular sequence (http://www.ebi.ac.uk/ and http://www.ncbi.nlm.nih.gov/Genbank/GenbankOverview.html), and data on phylogenetic position (http://phylogeny.arizona.edu/tree/phylogeny.html and http://herbaria.harvard.edu/treebase/
Monitoring and the Man and the Biosphere Program - http://www.mp1-pwrc.usgs.gov/fgim/calendar.htm#Biosphere -
NBII electronic gateway to biological data and information - .http://www.nbii.gov/biodiversity/index.html
Nongame Surveys and Population Monitoring - http://www2.state.id.us/fishgame/info/nongame/ngsurvey.htm
References - Arthropod Biodiversity Assessment Technology - http://res.agr.ca/ecorc/abat/refer.htm -

RIC Standards - http://www.for.gov.bc.ca/ric/standards.htm
Smithsonian Institution Monitoring & Assessment of Biodiversity Program http://www.si.edu/organiza/museums/ripley/simab/start.htm
Species Extinctions: Causes and Consequences - http://www.wri.org/wri/biodiv/extinct.html
Species Inventory Fundamentals Standards for Components of British Columbia's Biodiversity No.1 - http://www.for.gov.bc.ca/ric/Pubs/teBioDiv/sif/index.htm -
Stream Biological Monitoring Publications - http://www.wa.gov/ecology/eils/fw_benth/fwb_pubs.html
Terrestrial Ecosystems - Biodiversity Webpage - http://www.for.gov.bc.ca/ric/Pubs/teBioDiv/index.htm -
The Forest Transect Data Set of Alwyn H. Gentry - http://www.mobot.org/MOBOT/research/applied_research/gentry.html
The Instituto Nacional de Biodiversidad (INBio)- http://www.inbio.ac.cr
The Multi-Resolution Land Characteristics (MRLC) Consortium: An Innovative Partnership for National Environmental Assessment - http://www.epa.gov/mrlc/About.html -
The Nature Conservancy Home Page - http://www.tnc.org/
Use of Remote Sensing for Ecological Monitoring in Canada 1995 - http://www.cciw.ca/eman-temp/reports/publications/remote-sens/main.html -
USGS Patuxent Wildlife Research Center - http://www.pwrc.usgs.gov
Vermont Forest Ecosystem Monitoring (VForEM) - http://moose.uvm.edu/~snrdept/vmc/index.html
World Resources Inst. Global Forest Watch- http://www.wri.org/gfw/-