Support to Building the Inter-American Biodiversity Information Network

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Role and Use of Biodiversity Indicators at the Regional Level

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Support to Building IABIN (Inter-American Biodiversity Information Network) Project

Role and Use of Biodiversity Indicators at the Regional Level

Project Background

The World Bank has financed this work under a trust fund from the Government of Japan. The objective is to assist the World Bank in the completion of project preparation for the proposed project Building IABIN (Inter-American Biodiversity Information Network) and for assistance in supervision of the project, once and if it is approved. The work undertaken covers three areas: background studies on key aspects of biodiversity informatics; direct assistance to the World Bank in project preparation; and assistance to the World Bank in project supervision. The current document is one of the background studies.

The work has been carried out by Nippon Koei UK, an independent consulting company with substantial environmental experience, and the UNEP World Conservation Monitoring Centre.

Table of Contents

Annexes

Table of Tables

Table of Figures

Report Summary

Biodiversity indicators are essential information tools for summarising data on complex and sometimes conflicting environmental issues to show the overall status and trends in biodiversity and the factors that affect it. They are used both to support policy and decision making, and to communicate key issues of change. This report reviews the role and use of indicators at the regional level in the context of both national interests and activities, and the broader international policy agendas. In doing so the report draws on examples of various approaches around the world, particularly outside the Americas.

CHAPTER 1 INTRODUCTION

Biodiversity indicators are the information tools needed to summarise data on complex and sometimes conflicting environmental issues to show the overall status and trends in biodiversity and the factors that affect it. They are needed to support policy and decision making in many contexts and at several spatial and geographical scales, ranging from local and national to regional and global. The indicators that address biodiversity issues at broader geographical scales are particularly important because species and ecosystems are not confined to single political units and therefore the actions required for their management and conservation must be identified and implemented across political boundaries.

Providing biodiversity indicators and/or access to data that can be used to formulate them is a fundamental function of a network such as IABIN. This paper summarises first the basic concepts of indicators and their development and some of the policy contexts requiring biodiversity indicators. It then presents some basic frameworks for organising information and indicators and documents some successful international initiatives. Finally, it reviews some of the most important indicators of biodiversity status, the pressures that affect biodiversity and responses to them, and discusses their application at broad geographical scales.

What are indicators?

Indicators are measurements that are intended to convey information about more than just themselves. They provide means for quantifying and simplifying information on complex issues. They are purpose-dependent, almost always open to various interpretations, and never tell the whole story. Indicators are needed because assessing and monitoring everything is impossible and because what ***is*** known needs to be conveyed to non-experts in policy-relevant form.

Good indicators are:

- *scientifically valid*, i.e. they relate appropriately to what they are meant to represent;
- *based on easily available data*;
- *responsive to change*;
- *easily understandable*;
- *relevant to focal issues and users' needs*;
- *subject to target or threshold setting*.

The development of indicators is one of the crucial areas in conservation and sustainable development where science and policy meet. The major function of environmental indicators is to support assessment of the effectiveness of environmental policies and management practices by making relevant information available to decision-makers and managers in an intelligible form. The challenges in developing indicators are (1) to identify the key questions that affect policy and management, and (2) to confine development to measures that are feasible.

Biodiversity indicators can help in measuring and achieving tangible progress towards the conservation and sustainable use of biodiversity, progress towards the many national and international environmental goals and targets and progress in the implementation of the Convention on Biological Diversity (CBD) and other international and national policy instruments.

CHAPTER 2 POLICY CONTEXT AND SPECIFIC NEEDS FOR BIODIVERSITY INDICATORS

2.1 International

2.1.1 Earth Summit

The United Nations Conference on Environment and Development (UNCED) in 1992 recognised the need to develop indicators to enable countries to make informed decisions regarding sustainable development (Chapter 40 of Agenda 21). During the decade following UNCED, many initiatives, including the UN Commission on Sustainable Development, have sought to identify indicators of sustainable development and have recognised the importance of biodiversity as one aspect they should address.

2.1.2 Millennium Development Goals

In September 2000, the member states of the United Nations unanimously adopted the Millennium Declaration, which stated a set of shared values and identified a series of key objectives for translating those values to action. The General Assembly later recognised the eight Millennium Development Goals as a framework for implementing the Millennium Declaration. The first seven goals are directed at reducing poverty in all its forms, and the last goal -global partnership for development- is about the means to achieve the first seven. Goal seven is to ensure environmental sustainability. The goals have been commonly accepted as a framework for measuring development progress, and a series of targets and indicators have been developed for each goal. Progress towards these targets needs to be measured globally, regionally, and nationally.

2.1.3 Convention on Biological Diversity

The Convention on Biological Diversity (CBD) provides a more explicit international policy context for indicators of biodiversity. Article 7 of the convention requires parties to identify and monitor "components of biological diversity important for its conservation and sustainable use" and to identify processes or activities likely to have adverse effects on biodiversity. The text of the convention also recognises the role of indicators in assisting parties with monitoring the status of biodiversity and the effects of measures taken for its conservation and sustainable use.

To date, the CBD has sought to encourage parties and governments to identify appropriate biodiversity indicators, and to increase regional co-operation and capacity building for the development and use of indicators, as tools for managing biological diversity at the local and national levels and for assessing implementation of the convention. Most recently, the Conference of the Parties at its 7^{th} meeting recognised the importance of indicators for assessing progress towards policy targets.

In discussing the implementation of the 2010 target (see below) the CBD Conference of the Parties emphasised that the goals and targets adopted in Decision VII/30 should be viewed as a flexible framework within which national and/or regional targets may be developed. It invited Parties and Governments to develop national and/or regional goals and targets, and to incorporate them as appropriate into relevant policies and initiatives, including national biodiversity strategies and action plans.

The COP also encouraged the establishment of national and regional indicators, using the tools referred to in decision VII/8 (and UNEP/CBD/SBSTTA/9/10) on monitoring and indicators, to assess progress towards the Parties' national and/or regional targets.

The COP decided to develop a framework to help evaluate achievements and progress and to begin immediate testing of a limited set of indicators for use at global level, as well as to promote further development of additional indicators (CBD COP Decision VII/30). It also stipulated that as far as possible the same indicators should be used at global, *regional* and national levels.

2.1.4 2010 Target

The 2002 World Summit on Sustainable Development acknowledged the loss of biodiversity as one of the major problems facing humanity at the start of the 21st century and committed the world's countries to achieving a significant reduction in the rate of loss of biodiversity by 2010. This effectively endorsed the mission set out in the Strategic Plan of the Convention on Biological Diversity, and the statement made by Ministers responsible for the implementation of the Convention on Biological Diversity, in The Hague Ministerial Declaration (April 2002), who themselves committed to move from dialogue to action in the implementation of the Convention and resolved to strengthen their efforts to put in place measures to halt biodiversity loss at the global, regional, sub-regional and national levels by the year 2010. This demonstrates a global consensus establishing a major biodiversity target and setting a date – 2010 – by which that target should be met. The world is faced with the twin challenges of achieving the target and evaluating progress towards it. It will therefore need assessments of:

- The extent to which, by 2010, measures are in place to halt biodiversity loss at all levels, including the global level.
- Current rates of biodiversity loss at global, regional and national levels and mechanisms in place to measure rates of biodiversity loss in 2010, to allow assessment of the change in that rate between now and 2010.

2.1.5 Global Plant Conservation Strategy and targets in other CBD programmes of work

The Global Strategy for Plant Conservation (GSPC) was adopted by the Conference of the Parties of the Convention on Biological Diversity in April 2002 (Decision VI/9), with the long-term objective of halting the current and continuing loss of plant diversity. The GSPC comprises 16 broad outcome-oriented targets relating to the conservation of plant species and includes recognition that it will be necessary to monitor progress towards them at several scales. Consultations on the various targets have generated a number of observations on the information that will be needed to monitor progress towards them:

- *An international overview will be needed for most targets:* As the goals of the GSPC are aimed at global conservation of plant species and because most species distributions transcend national boundaries, global and regional overviews will be necessary in addition to assessment of national progress.
- *A diverse range of background data of several different types is needed*: Each target requires different data to verify whether it has been achieved, and the evolution of sub-targets and milestones will increase the range of data and the complexity of their combinations still further. Among other topics, data will be required on: taxonomy and state of knowledge; distribution of species and habitats; magnitude and distribution of threats; species use and economic importance; protected areas; and legislation, among other topics.
- *It will also be necessary to monitor actions taken nationally and internationally that could contribute to the achievement of the targets*, including: policy development; training and capacity building; production of educational materials; and establishment of protected areas.
- *Monitoring data will come from many different, and not always official sources,* including: academic literature and research; indigenous and local stakeholders' knowledge; a range of governmental sectors; and non-governmental organisations.

The Strategic Plan of the CBD now incorporates a framework for setting quantitative outcome-oriented targets and milestones, and other programmes of work have built on the approach adopted by the GSPC and set quantitative targets and milestones. These include the programmes of work on forest biological diversity, marine and coastal ecosystems and inland waters. Tracking progress towards these various targets will require the same kinds of monitoring efforts at national, regional and global scales as those needed for the GSPC, though in many cases useful indicators for several different targets may be derived from the same basic data.

2.2 Regional policies and indicator needs

Throughout the world regional bodies and processes develop policies that are important to biodiversity and need to be informed by appropriate indicators. The European Union is an example where policies on everything having impacts on biodiversity, from agriculture to trade and human health, as well as the environment, are made at the regional scale. Other examples include regional scale processes to promote and monitor sustainable forest management, for example in Africa, and regional bodies for economic cooperation such as ASEAN.

A number of international efforts that have developed at regional scales within the Americas will require biodiversity indicators to help track progress in their implementation. These include the Regional Biodiversity Strategy of the Andean Pact countries, which was adopted by the Andean Council of Foreign Ministers in July 2002, and the regional processes to promote sustainable forest management, the Lepaterique

Process in Central America and the Tarapoto Process of the Amazonian countries. Also in Central America, regional processes to develop environmental policy and resources such as the Comisión Centroamericana de Ambiente y Desarrollo (CCAD) and the Consejo Centroamericano de Bosques y Areas Protegidas (CCAB/AP) are potential users of regional scale indicators. International donors and multilateral agencies also require regional overviews to enhance coordination of the actions in which they are involved. The Meso-American Biological Corridor is a particularly good example of a programme that will potentially both generate and require biodiversity information at the regional scale.

Countries also have significant needs for biodiversity indicators. These include evaluating and reporting on progress in implementing their international commitments. Multilateral environmental agreements are built on national action, and their signatories are obliged to report on the steps taken to implement these agreements at national level. They also need to be able to assess the effectiveness of these actions in order to determine whether additional action or modifications are needed. Therefore, biodiversity indicators that permit national governments to assess the impacts of their policies and legislation on key components of biodiversity are vital. The audiences for these indicators include international bodies, national governments and agencies, and the general public. The latter two of these audiences often usefully evaluate progress on environmental issues by examining 'State of the Environment' (SOE) reports, which present a range of environmental indicators at regular intervals. Biodiversity indicators are increasingly vital ingredients of SOE reporting at both national and regional scales.

Such biodiversity indicators have a high potential to enable countries to base their decisions on a sound scientific foundation so as to place scarce resources strategically where the threats to significantly important biodiversity are highest. If countries do not have such tools at hand to enable them to prioritise their needs and to judge the progress of their actions towards the conservation and sustainable use of biodiversity, scarce resources will not necessarily be allocated to areas where action is needed most. Indicators link the fields of policymaking and science and therefore, the exercise of selecting a core set of indicators must be a consultative effort between scientists and policy makers.

IABIN and its member institutions can and should play a crucial role in ensuring that the necessary information is readily accessible and understandable. In some cases this will involve identifying a need and generating indicators directly. In other cases it will be a matter of ensuring that appropriate data for use in indicators are clearly identified and well documented so that other agencies can make use of them as they develop biodiversity indicators.

CHAPTER 3 ORGANISING BIODIVERSITY INFORMATION AND INDICATORS

Biodiversity indicators serve two principal purposes:

- They help identify priority areas for, and components of, biodiversity, and
- They help to evaluate the impacts of policy and management on biodiversity, so that negative impacts can be minimised.

Thus they are required both for *assessing* biodiversity in space and at a particular point in time and for *monitoring* changes in biodiversity status that may result from particular policies or management actions (Kapos and Jenkins 2002).

3.1 Biodiversity-relevant data

Information for biodiversity indicators can be drawn from many different types of data, which are likely to be held by many different types of institutions and to be relevant both individually and in combination to a broad range of policy and management questions. These data types include:

- Spatial, or mapped, data on ecosystem extent and on the distribution of ecosystems and species;
- Structural and other data on ecosystem condition, such as those derived from forest inventory;
- Data on species composition, from inventory plots and other forms of survey of plants and animals;
- Data on species abundance, acquired using various census techniques;
- Data on ecosystem management regimes;
- Data on human activities that affect biodiversity.

3.2 Models and frameworks

The wide range of data types on the one hand, and of policy and management questions on the other, means that the development of meaningful indicators requires some form of framework or conceptual model (Holdgate, 1996), which makes explicit both definitions and the relationships among the phenomena of interest and the indicators. Frameworks can also usefully be seen as tools for organising the key questions that indicators need to address and making clearer the relationships between the indicators and the questions, as well as the relationships among the questions.

3.2.1 Pressure-State-Response and related frameworks

The most widely used indicator framework is the “pressure-state-response” (PSR) framework, which was developed by the Organisation for Economic Co-operation and Development (OECD, 1993) on the basis of the “stress-response” model developed by Friend and Rapport (1979). The PSR framework is built on the idea that human activities (such as clearance of forest for agriculture) exert pressures on the environment, 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 programmes intended to prevent, reduce or mitigate pressures and thereby reduce environmental damage. Indicators provide tools for elucidating PSR relationships, both at the reporting stage and during policy analysis.

The PSR framework has been widely applied to indicator development; for example, it is explicitly recognised by the CBD (CBD, 1997a). The CSD has used a variant of this approach, namely the “driving force-state-response” (DSR) (CSD, 2001). This framework uses the term “driving force” instead of “pressure” to accommodate social, economic and institutional indicators more accurately and to acknowledge that their impact on sustainable development may be both positive and negative. The European Environment Agency (EEA, 1998) further expanded the PSR scheme to include drivers and impacts, forming the DPSIR framework.

3.2.2 CBD and 2010

Most recently, the CBD expanded its recommendations on indicators to adapt the Pressure-State-Response framework to take account of focal areas of interest to monitoring the progress and impact of the Convention, especially in relation to halting biodiversity loss by 2010. The framework includes as focal areas (CBD COP Decision VII/30):

(a) Reducing the rate of loss of the components of biodiversity, including: (a) Biomes, habitats and ecosystems; (b) species and populations and; (c) genetic diversity;

(b) Promoting sustainable use of biodiversity;

(c) Addressing the major threats to biodiversity, including those arising from invasive alien species, climate change, pollution, and habitat change;

(d) Maintaining ecosystem integrity, and the provision of goods and services provided by biodiversity in ecosystems, in support of human well-being;

(e) Protecting traditional knowledge, innovations and practices;

(f) Ensuring the fair and equitable sharing of benefits arising out of the use of genetic resources; and

g) Mobilising financial and technical resources, especially for developing countries .

3.2.3 GEF programme evaluation

The Global Environment Facility (GEF) has also attempted to develop a framework for indicators that would help evaluate the impact of its biodiversity programmes. This framework takes explicit account of the three objectives of the CBD and the three levels of biological diversity to identify the kinds of questions that should be addressed by indicators of its programmatic impact:

	Conservation of biodiversity	Sustainable use of the components of biodiversity	Equitable sharing of the benefits arising from the use of genetic resources
Ecosystems			
Species			
Genes			

Within this broad framework, the GEF found that a full appraisal of its work in biodiversity entails analysis of indicators belonging to three principal types: *coverage*, *impact*, and the wider global *context*.

Coverage indicators reflect what the GEF is doing (or has done) and where it is doing it. They are a measure of GEF efforts or activities (usually at the project level), and are therefore important as components of response indicators under the CBD. Important aspects of this are the kinds of activities that are being undertaken and the areas where these activities are intended to have an impact on biodiversity.

In themselves coverage indicators provide little information on whether progress has been made towards meeting the GEF's objectives. *Impact* indicators are used to measure the outcomes of interventions, rather than their existence. These indicators may be based on measures of biodiversity status and trends or on measures of human behaviour that may affect biodiversity.

Context indicators are used to track general trends in biodiversity and related issues. They provide a backdrop or baseline against which the results of GEF efforts can be measured. In general terms, these context indicators should not be used to measure **directly** the accomplishments of the GEF given that the GEF is only one element (the major parties are the members of the CBD) in the fight against biodiversity loss and degradation.

3.2.4 Other frameworks for biodiversity indicators

A number of other indicator frameworks have been proposed. Hyman and Leibowitz (2001) suggested that a conceptual model based on ecological principles could make it possible to evaluate the relationships between proposed indicators and assessment "endpoints", such as biodiversity. Noss (1990) presented a hierarchical framework for development of biodiversity indicators, recognising that three attributes of biodiversity –

composition, structure and function – can be considered at a number of different scales or levels of organisation. The framework of Stork *et al.* (1997) is based on a conceptual model of the relationship between anthropogenic activities affecting forests and the processes that influence biodiversity.

3.3 Indicators at different scales

Since decisions affecting biological diversity are made at a variety of scales, biodiversity data and indicators need to be aggregated across different scales for monitoring and reporting purposes (Noss, 1990).

If national conservation objectives are to be met, it is important to know (i) whether conservation projects reach their goals - and hence what lessons can be learned and replicated where relevant; and (ii) the cumulative impacts of development activities and projects, so that these impacts and their mitigation can be taken into account in decision-making. Thus indicators of biodiversity are needed at local or project levels, and these should ultimately form part of the monitoring and evaluation activities of individual projects or programmes.

Furthermore, countries need tools to assess the status and trends of their overall biodiversity, based on impacts that have accumulated over a much longer term from a variety of cross-cutting environmental and development activities. The resulting knowledge of biodiversity status and trends would enable them to decide where action is needed most and where activities may need to be modified in order to advance national conservation priorities. Such national scale indicators may be derived either from national scale data or, with care, aggregated from local or project-scale information. When monitored continuously, they can help ensure that actions taken at country level in one sector do not adversely impact the country's long-term goal in the sector responsible for ensuring the conservation and sustainable use of biodiversity.

Despite the fact that much action in relation to the conservation and sustainable use of biodiversity takes place at a national scale, it is vital to recognise that evaluation of biodiversity status and trends must also be done at broader geographical scales. This is principally because species and ecosystems are distributed independently of national boundaries. Actions in one part of the range of a component of biodiversity can affect its status locally, nationally, regionally and globally, depending on its distribution and abundance. Therefore, except for components that are nationally or locally endemic, a real understanding of the status and trends in biodiversity can only be obtained from indicators assembled at supranational scales. Furthermore, such international overviews can be assembled directly from national indicators only in some cases, and the process requires great care. In other cases, supranational indicators need to be assembled from supranational scale data (e.g. landcover classified using a single regional approach) or from the basic or raw data that underlie national scale indicators, i.e. data accessible through networks like IABIN.

CHAPTER 4 REVIEW OF RELEVANT INITIATIVES AND EXPERIENCES

Limited progress has been made in generating specific biodiversity indicators at both national and international scales. Among the international and regional initiatives reviewed below, none as yet provides a comprehensive set of biodiversity indicators at truly regional scale. The approaches taken tend rather to assemble national data (e.g. ARCBC), including those available from international sources such as FAO and UNEP-WCMC, or to focus on particular ecosystem types (EEA). Nonetheless they represent significant progress and include useful examples that will form the basis for broader indicator portfolios in the future.

4.1 Europe

The European Environment Agency (EEA) is the principal source of regional scale environmental data in Europe. Its current biodiversity indicators focus principally on grasslands and combine data from national reporting processes with remote sensing overviews, data from NGOs and some regional scale assessments (http://themes.eea.eu.int/Specific_media/nature/indicators). Presentation is a mixture of regional-scale international statistics and data by country. The EEA plans to adopt further indicators based on trends in populations of species associated with each of the major habitat types in Europe. The European Statistical Agency, Eurostat, compiles data for some sub-regions, and especially works with economic data on expenditure on environmental protection.

Recently, the EEA has begun working the Pan-European Biological and Landscape Diversity Strategy, with UNEP-WCMC and others, to develop indicators for assessing progress in achieving the 2010 target. In doing so they have adopted the framework previously adopted by the CBD Conference of Parties, and will be reviewing both the CBD-proposed indicators and a number of others. This work is currently being planned, and will begin in earnest in September of this year.

4.2 Baltic States

The Baltic countries have produced a second combined Sate of the Environment Report (http://www.bef.lv/baltic/baltic2/content.htm), which has a section on biodiversity. Many of the indicators are pressure-based, and all are reported on a country basis. The report includes data on internationally threatened species, on age and composition of forest stands, and on protected areas and legal protection of species. As this is the second report, many indicators have become monitoring tools showing change over time.

4.3 Asia and Southeast Asia

The ASEAN Regional Centre for Biodiversity Conservation (ARCBC: http://www.arcbc.org.ph/) is the hub of a wide network of biodiversity-relevant organisations in Southeast Asia. It aims to provide a range of ASEAN-wide summary data, but as yet provides protected area statistics on a country-by-country basis and links to the national biodiversity data and agencies within the region.

4.4 North America

The North American Commission for Environmental Cooperation (CEC) is an international organisation created by Canada, Mexico and the United States to address regional environmental concerns, help prevent potential trade and environmental conflicts, and to promote the effective enforcement of environmental law. Drawing on information resources such as those provided by NABIN, the North American Biodiversity Information Network, it produces periodic summaries of the state of the environment in the region (http://www.cec.org/files/PDF/PUBLICATIONS/soe_en.pdf), including statistics on endangered species and protected areas.

4.5 CSD

The Commission on Sustainable Development provides national reports on a number of key themes in sustainable development. Within its framework the environmental theme (http://www.un.org/esa/sustdev/natlinfo/indicators/isdms2001/isd-ms2001isd.htm#environment) includes area and protection of selected key ecosystems and abundance of selected species as biodiversity indicators and provides substantial documentation as to how they might most usefully be calculated at national level.

4.6 Criteria and indicators of sustainable forest management

In response to Agenda 21 and the "Forest Principles", a large number of national, regional and international initiatives, including the ITTO, Pan-European (or "Helsinki"), Montreal, Tarapoto, Lepaterique, Near East, Dry Zone Asia and Dry Zone Africa processes, have each generated sets of criteria and indicators for assessing forest management (Grayson and Maynard, 1997; FAO, 2001a). All of the ten major processes have identified the conservation of forest biological diversity among the criteria for sustainability, and many of the numerous indicators that relate specifically to the biodiversity criterion are common to more than one process (CBD, 1997b).

Of these processes only the Montreal Process (http://www.mpci.org) and the Ministerial Council for the Protection of Forests in Europe (MCPFE, formerly the Helsinki Process: http://www.mcpfe.org) have yet completed any national reporting cycle, and only the MCPFE has presented some of its indicators in aggregated form at regional scale. Some indicators, such as area of different forest types and protected forest area, are common to all of the criteria and indicator processes (Kapos and Newton 2002). Most processes also include indicators relating to forest composition, principally in terms of species richness and the presence of species of particular conservation concern (threatened or endemic species). Other indicators, such as forest fragmentation and rate of forest conversion, are less commonly included, while forest structure and area affected by disturbance are recognized by few of the processes.

The data requirements for these indicators include both spatial data on forest cover and ground-based inventory data, which help to define forest types and generate species lists that can be cross referenced to national and international assessments of species status such as Red Lists and CITES appendices. Spatial data on forest cover at the landscape scale are also required to generate fragmentation measures such as size, shape and connectivity of forest patches, or indices that combine these attributes (*e.g.* Kapos, Lysenko and Lesslie, 2000). Measures of forest conversion require reiteration of area measures over time using consistent or intercalibrated methods and baselines (Veldkamp and Lambin, 2001).

Kapos and Newton (2002) highlight the importance of appropriate summary and presentation of data in the generation and use of effective indicators. They suggest that it is possible to aggregate results of forest inventory at the local scale for reporting at national (and potentially regional) scale, and for monitoring change over time, by summarising in terms of forest area belonging to categories for each measure.

4.7 OECD

The Organisation for Economic Cooperation and Development (OECD) has been a leader in the development of environmental indicators in general. It developed the pressure-state-response framework as a way to identify important indicators for environmental issues and clarify the relationships between them. This is now fundamental to much of the work on environmental indicator development.

OECD has reviewed biodiversity indicators in several contexts. A review focusing on the Natural Capital Index approach was published in 2000 (RIVM 2000). An ongoing expert consultation process is also working on developing agribiodiversity indicators for use by OECD countries. The OECD regularly publishes compendia of environmental statistics, of which the section on wildlife (http://www.oecd.org/dataoecd/53/45/2958180.pdf) includes data on the threat status of species, on fisheries catches and on areas of international importance and protected areas.

4.8 CBD and other biodiversity-related conventions

The CBD Secretariat is working with the UNEP World Conservation Monitoring Centre and others to review and develop the indicators called for in CBD COP Decision VII/30 for assessing progress in achieving the 2010 target for significant reduction in the rate of biodiversity loss. This work is currently under way, with draft papers on the first indicators to be developed being reviewed as this report is being drafted. Full information on this process can be found on the CBD website at http://www.biodiv.org/2010-target.

It is worth noting that at the same time the Ramsar Convention's Scientific and Technical Review Panel is developing indicators for assessing the extent to which that convention's objectives are being met, and indicators being developed in this process will contribute directly to assessing achievement of targets by both the Ramsar Convention and the CBD. In addition, the Convention on Migratory Species is also reviewing this issue with a view to developing migratory species indicators.

CHAPTER 5 POTENTIAL APPROACHES FOR REGIONAL SCALE BIODIVERSITY INDICATORS

5.1 State indicators

Both the experience of the various regional initiatives and the recent CBD COP decision on indicators have identified as the highest priorities and most feasible areas for indicator development those 'state' indicators that supply information on trends in the extent and protection of ecosystems and habitats and in the abundance and distribution of species. Accounts follow of several different approaches that have been used successfully to generate such indicators, the data required for them, and considerations for applying them at regional scales using data held at various locations in a distributed network.

5.1.1 Extent of ecosystems

Measures of ecosystem extent are increasingly based on data from remote sensing. Though costly and potentially technically demanding, these data have the advantage of providing the potential for frequent updating and of being highly credible among a range of audiences. Some of the issues associated with using such data to develop indicators are:

Resolution: Both spatial and temporal resolutions vary among remote sensing products. Coarse resolution products provide little insight into ecosystem configuration and dynamics at scales that are relevant to most components of biodiversity. However, as spatial resolution increases, costs of acquiring imagery and of processing and storing the resulting large volumes of data increase substantially.

Classification: Not all ecosystems or types of landcover can be easily identified in remotely sensing imagery and different approaches to classification are appropriate for different ecosystems (e.g. forests vs. wetlands). Furthermore data from remote sensing alone are usually inadequate to distinguish very specific ecosystem types, so ancillary data and ground observations are usually required to aid the classification process, adding to the potential for variation among sources and iterations of data on ecosystem extent. Individual agencies processing remote sensing data for landcover assessment tend to use individual approaches to classification determined by the needs of their own users. This limits the potential for combining classified data from different sources to provide broader scale overviews. Nodes of a distributed network should be encouraged to harmonise their classification approaches to the extent possible, while recognising that they may have real needs for applying different approaches. Careful and accessible documentation of the approach and classification used will increase the value of the data sets for regional scale applications, and cross referencing to existing regional scale efforts such as the CCAD programme on ecosystem mapping are particularly useful.

Availability/sustainability of time series: Single remote sensing assessments of land cover are common, but the programmes that produce them often have difficulty obtaining the financial resources needed to update the entire data set. This can reduce the feasibility of generating robust national and regional indicators of trends in ecosystem extent. However, carefully designed sampling and analytical approaches (including some discussed below for species trends) can help to make the best of partial reassessments of land cover.

Consistency and comparability of data through time: The greatest problem in establishing indicators of trends in ecosystem extent is that of comparability among data sets generated for different time periods. This arises because of technical advances both in remote sensing and in data classification and analysis. Networks need to encourage their members to cross-calibrate new methods with old ones and to provide full documentation on the comparability of different assessments. The users need to be helped to recognise incompatibilities between different data sets and to be provided with tools for comparing or combining them when appropriate.

5.1.2 Species trends

One approach to monitoring trends in global biodiversity that has been discussed in a number of fora, including the CBD, is the use of indices derived from trends in species' populations. A recent paper commissioned by the World Bank (Jenkins et al. 2004) evaluates the potential of one such approach, the Living Planet Index, and related approaches to monitoring the state of biodiversity as tools for reporting at national level on progress towards meeting the 2010 target.

(1) Living Planet Index

The Living Planet Index (LPI) was first developed in 1997 by WWF (Worldwide Fund for Nature) and WCMC (World Conservation Monitoring Centre) and published in 1998 in the *Living Planet Report* (Loh et al. 1998). It was originally conceived as a rough indicator of biodiversity change that would help address the question, "how fast is nature disappearing?" through effective and quantitative use of the imperfect data that are available.

The LPI is based on data on population trends of a large number of animal species from all around the world drawn from published research and 'grey' literature. To generate the index, the geometric mean change in all populations is calculated by averaging the logarithm of all data points for each five-year interval and then finding the anti-logarithm. This approach avoids unequal weighting due to population size and the asymmetry associated with using percent change (i.e. a change from 100 to 5 is a 95% decrease, but change from 5 to 100 is a 2000% increase). An arbitrary baseline at the start of the period analysed is then set (in the case of the LPI the baseline is set at 100 for year 1970) and the population change calculated for each successive five-year interval. In effect, the trend line represents the average change within the entire collection of population samples within the study period, giving equal weight to each species, whether common or rare, and to small and large populations.

For presentation of the LPI (Figure 1), a trend-line is drawn between the geometric mean population values for each period (despite the fact that the composition of the population sample is not entirely constant across periods). This graph illustrates trends in the population samples. If it is assumed that this sample is representative of trends in a significant proportion of the species in some given area or habitat, the graph becomes a powerful means of communicating information about trends in ecosystem condition.

The global LPI is itself an aggregation of three separate indices, each of which relates to a different biome – forest, freshwater and marine – and each of which is given equal weighting. The three biome-based indices show average changes in abundance of forest, freshwater and marine species over the period 1970 to 2000. In the most recent *Living Planet Report* (Loh 2002), the forest species population index measures the average trends in populations of 282 bird, mammal and reptile species living in forest ecosystems around the world. The freshwater species population index comprises populations of 195 species of birds, mammals, reptiles, amphibians and fishes from lakes, rivers and wetland ecosystems. The marine species population index includes 217 bird, mammal, reptile and fish species found in marine and coastal ecosystems.

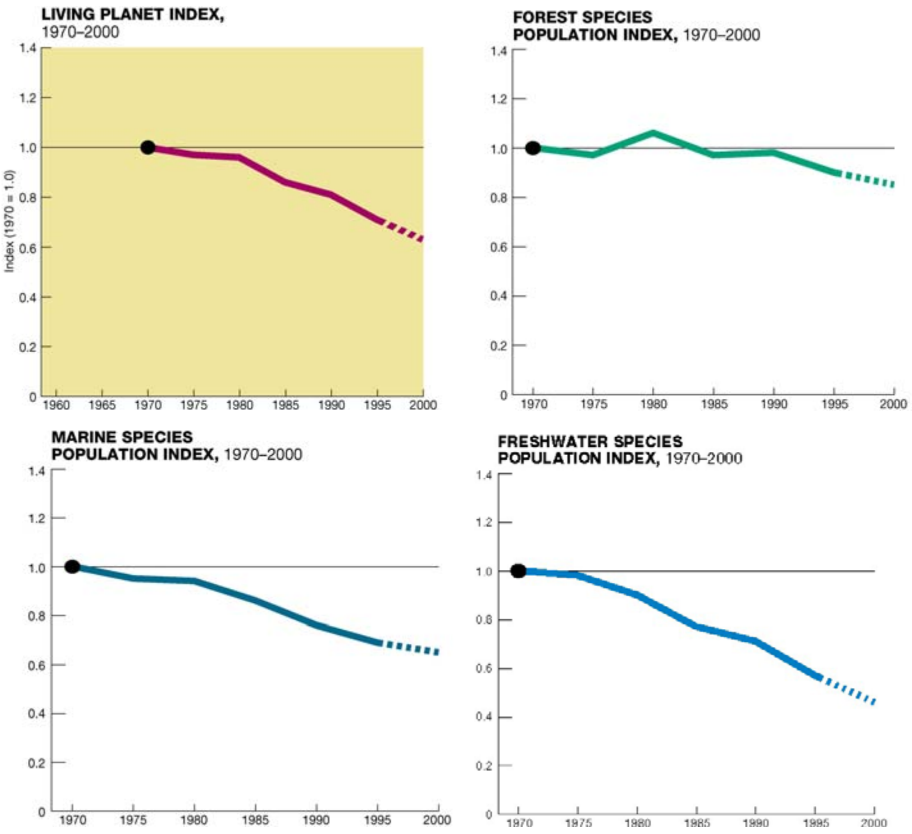

Figure 1. The global Living Planet Index. Dotted lines show trends over the most recent five-year period, 1995-2000. Because of the lag between collection and publication of census data, there are always relatively few data available for the most recent time interval.

The wider application of species population trend indices like the LPI is a promising avenue for national and regional monitoring of biodiversity trends and potentially one of the most useful ways of monitoring progress toward meeting the 2010 biodiversity target, at national, regional or global level. They have been applied at national scales in a number of developed countries and a few developing ones, and will form the basis or regional scale indicators in Europe. The advantages of such indices include:

- The ease with which they can be understood by and communicated to a non-scientific audience. They simply show the average change in the abundance of a number of species over time, and are analogous to well-known stock market indices.
- Their transparency. Listing the species populations included in them makes any biases clearly visible.
- Their flexibility. In addition to representing the state of the species in the index, they can serve as proxies for the healthy functioning of the ecosystems the species live in. Therefore they can be used as biodiversity indices in a broader sense.
- Their suitability at different scales. Species population trend indices can be constructed as indicators of biodiversity at any level: national, regional or global; for any ecosystem large or small. The only constraint is the availability of sufficient time-series population data for the area or ecosystem of interest.
- The ease with which they can be aggregated and disaggregated. Species population trend indices can be combined into big-picture "headline" indicators or presented as a series of biologically meaningful component indices.

There are a number of constraints on the ability to generate species population trend indices owing principally to the uneven availability of data across geographical, taxonomic and ecological foci. For example:

- Apparently more species population data are available for North America than for the rest of the IABIN region. Data availability is generally patchy (see below).
- More population data are available for birds, mammals and some marine fish species than for other species groups. Good time-series population data exist for those species that have been subject to long-standing monitoring efforts, whether because they are commercially important, of conservation interest, or simply easier to count.
- Among terrestrial ecosystems more population data are available for grassland species than forest species (very largely because they are easier to count), and among aquatic ecosystems more data are available for marine than freshwater species, with the exception of water birds.

These data constraints have important implications for the application of species population trend indices in some of the most biodiverse regions of the world, particularly tropical moist forests, where high levels of diversity mean that almost every species is rare, and animals are hard to count. Other constraints on the successful implementation of these approaches include: clear identification and representation of the trends of interest; data availability; data quality and stakeholder buy-in.

1) Choice and Representation of Focal Trends

At a national level there may be a number of related questions that can be addressed by species population trend indices, and it is important to match an index and its composition to the focal question very carefully. In many contexts, the data availability constraints discussed below could limit the degree to which an index is in fact a balanced representation of trends in overall biodiversity. There are likely to be taxonomic, geographic and trophic biases that need to be recognised, adjusted for if possible and taken into consideration when using the index. These problems are likely to be of greater magnitude in countries with high biodiversity and highly complex ecosystems such as humid tropical forests or coral reefs.

In some cases, an index focused on a particular ecosystem type might be more appropriate for monitoring in relation to particular policy interventions, and it may also be necessary to adjust the time intervals over which the index is calculated to maximise it sensitivity. In all cases, the composition of the index has important implications for which uses are appropriate.

2) Data availability

The availability of data on population sizes of wild species is the largest constraint in developing population trends indices to evaluate progress towards biodiversity targets at national or regional level. In most countries, there is an urgent need to establish monitoring programmes for wild species. Equally however, there may be existing data sets that are appropriate for use. In many developed countries with strong traditions of field studies and wildlife census, there are extensive data on populations of species of conservation interest. Sometimes these are associated with particular interests such as hunting.

Globally, by far the greatest monitoring effort is devoted to marine fishes of economic importance and to birds. Probably 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. The bird species that are surveyed regularly by networks of mainly amateur ornithologists are by far the best-known large terrestrial group. This is especially the case for breeding species in developed countries and for migrant and wintering water birds at wetland sites in the developed and to some extent the less developed world. 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. Other sources of data on population trends include academic studies and long term forest inventory programmes.

Many developing countries, however, have few monitoring programmes and as a result can only draw upon much smaller data resources than those of many developed countries. For example, of more than 2600 separate data sets accumulated over four years of compilation of the Living Planet Index, only 540 (20%) are from non-OECD countries. In the same database, the Americas are represented by 307 data sets from North America and a total of 90 from the countries of Latin America and the Caribbean (Table 1). Search effort in accumulating data sets for the LPI has been relatively intensive but more data sets than those above undoubtedly exist, albeit of variable quality, widely dispersed and often in grey literature.

Sensitivity analyses for the global LPI suggest that in this case – that is a very heterogeneous data set intended to provide a wide-scale picture – a minimum of around 45 populations is needed to produce an index with an acceptable associated variance. Smaller samples may still be useful if these represent a high proportion of the total number of species in the set being sampled, or if all the species in the sample show similar trends and therefore the overall trend has low intrinsic variance.

Table 1. Numbers of species population trend data sets currently included in the global Living Planet Index database

Antigua and Barbuda	1	Guatemala	1
Argentina	1	Guyana	1
Bolivia	1	Cayman Islands	2
Brazil	8	Saint Lucia	1
Bahamas	1	Mexico	15
Chile	7	Panama	1
Costa Rica	5	Peru	10
Dominica	1	Puerto Rico	13
Dominican Republic	1	Paraguay	1
Ecuador	6	Suriname	7
Falkland Islands	2	Venezuela	2
French Guiana	1	US Virgin Islands	1
Total Latin America and Caribbean:			**90**
Total North America			**307**

Within the Americas there are certainly other sources of data that have not yet been tapped due to problems of access including the location of publication, non-publication and language limitations in the searches that have been conducted to date. Participants in IABIN are well placed to identify, document and mobilise appropriate datasets. Among the candidates are data on Amazon river dolphins and fish populations, data on migratory bird populations within Latin America, and data on reptile populations on Caribbean islands. Such data mobilisation, and indeed calculation of trend indices would represent a major contribution to understanding the status and trends of global as well as regional biodiversity.

3) Data quality

The range of potential sources and types of population trend data means that it is important to take into account both the quality and representativeness of each data-set before considering how to use the data. Basic criteria for data quality include:

- location and area represented by the population estimates should be clearly specified or ascertainable;
- the methods used should be specified;
- the time series should be as long as possible;
- compatible methods should be used through the time series;

Clearly in almost all cases there will be a trade-off between data quality and data availability. Too stringent an application of data quality criteria will mean that the number of usable data-sets may become vanishingly small. Too relaxed an approach will mean that the indicators produced will be difficult to defend and therefore lose much of their force.

4) Ways forward

The increasingly widespread uptake of the Living Planet Index as a communications tool and the adoption of species trend indices at national level demonstrate that such indices are a resonant and potentially influential tool for capturing changes in biodiversity and communicating these changes to a wide audience. Exploiting them to the full however, particularly at the national or local level, will require urgent increased effort at a number of levels, including:

- increasing the availability of data;
- ensuring that there are mechanisms in place to manage these data and generate the indices;
- ensuring that there is as much stakeholder buy-in as possible, and that there are mechanisms in place to disseminate the indices and associated information in a form that resonates with a wide constituency.

Steps towards these improvements include:

Identifying and improving access to more existing data: Extending access to academic and scientific literature is fundamental, and it is particularly important that 'grey' literature such as national government documents be fully searched and exploited. Improved outreach to amateur and academic networks is another mechanism for identifying unpublished data. Other sources that should be examined in both national and international efforts include hunting records and protected area records. The utility of such data, and especially those collected over the longer term can be vastly improved by making use of institutional memories to assess and document their quality. **Owners and custodians of existing time series data on species populations are encouraged to publicise the**

existence of the data so that support can be provided for their use in developing regional and national monitoring programmes.

Several other possibilities exist for developing indicators based on species abundance data:

Making use of small data sets - At the simplest end of the spectrum, data on the abundance of one or two species can be a useful indicator, especially where the fate of the species is closely and clearly tied to the status of the ecosystem of interest, or if the species itself is in some way emblematic. Such species are also likely candidates for indicators because there is often a greater availability of data on their population status

Semi-quantitative/expert approaches - Expert knowledge can also be used to generate qualitative data on species trends. In this approach, a panel of experts is asked, either jointly or independently, to assess the population trends for each species in an identified set as increasing, declining or stable. The challenge in this case is to identify an appropriate set of species that are representative of the phenomenon or ecosystem of interest and also well enough known for such evaluations to be reliable. There is a potential danger of circularity as expert assessments are reasonably likely to be based on the experts' knowledge of changing habitat extent and quality and of other pressures that may affect species abundance.

Perhaps a more convincing approach is to use expert knowledge to provide semi-quantitative assessments of species abundance. In this approach, experts are asked to assess a species' abundance at several specific points in time relative to their abundance at another specified point or to their present abundance. Thus a given species may be judged to have been twice as abundant 30 years ago as at present, but to have peaked at slightly higher abundance 10 years ago. Such a pattern might be represented in chronological order as values of 100, 110 and 50. This sort of assessment has the advantage of generating more detail in the species trends and providing a basis by which trends in many species may be combined to generate a synthesised temporal pattern rather than just a statistic. On the other hand, there is a danger that it may generate spurious detail.

Increasing the amount of monitoring - Most crucial and urgent of all is the need to increase the effort devoted to biodiversity monitoring. This requires both increased financial resources and recognition of the many different groups that can potentially be active in biodiversity monitoring, and the value of the data they can generate. There is a need to explore further the potential of integrated scientific and participatory methods and other simple and cost-effective approaches such as amateur networks. Guidance should be provided to help these groups enhance the quality and utility of the data they collect. The guidance would not be to develop more complicated or sophisticated programmes, but rather to ensure consistency between time periods and careful documentation of the methods and sampling regime used. In fact, simpler approaches are often better, as they are more likely to be sustained over long time periods

Similarly, resource managers such as game wardens, park managers and forest guards can and should be encouraged to conduct basic biodiversity monitoring as part of their routine activities. Monitoring should also be a fundamental part of biodiversity conservation and sustainable use activities.

Ensuring mechanisms are in place to manage data and generate indices: Any data that exist will be of very limited use unless mechanisms are in place to ensure that they are collected, maintained and analysed appropriately so that indicators can be produced at appropriate intervals. This is as much an institutional problem as a technical one: it requires data-holders to be willing to share their data, and one or more institutions at whatever level (national, regional, global) to be prepared to manage these data with the agreement of all data-providers. As well as the willingness on the part of all stakeholders, this undertaking will require ongoing commitment of resources (people, equipment, time), albeit not necessarily very large ones. It is vital to emphasise that the major value of these indicators (and of the monitoring on which they are based) will only be realised over quite long time periods and that therefore their production should not be seen as a once-off process. Commitment to funding over long time frames will require the education of funders of all complexions. The successful production and uptake of indicators should in itself help in this process.

Ensuring that there is as much stakeholder buy-in as possible, and that the indices and associated information are disseminated in a form that resonates with a wide constituency: A further constraint on the use of LPI-type approaches at national scale is the difficulty of ensuring that both scientists and decision-makers support their use. This difficulty can be overcome at least in part by ensuring maximum transparency in the way the indices are calculated, and especially with respect to which populations and species are included. Involving a range of stakeholders in selecting the species and populations included in the index using both scientific and value-based criteria is likely to generate greater support and credibility for the resulting index.

(2) Natural capital index

The Natural Capital Index (NCI) approach is based on the idea that species extinction is (only) the last step of a long process of ecosystem degradation and biodiversity loss. This trend has two main components:

a) loss of habitats, or ecosystem quantity, resulting from the conversion of natural areas to agricultural or urban use.

b) loss of ecosystem quality as a result of change in environmental conditions such as climate change, pollution, habitat fragmentation and over-exploitation.

The NCI framework has defined the natural capital (Figure 2) as the product of the size of the remaining area of a given habitat (ecosystem quantity) and its quality. The quantity is expressed as a percentage of a baseline extent. The quality is defined in terms of the ratio of the current abundance of a core set of ecosystem-characteristic species and their baseline abundance, also expressed as a percentage. Ideally the baseline represents a low-impact, 'natural' ecosystem, but it may also be an arbitrary point in the past for which appropriate data are available.

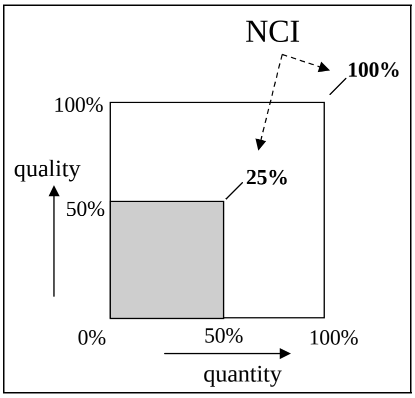

Figure 2. Schematic representation of the NCI

Ecosystem quality, ecosystem quantity and the resulting NCI range from 0 to 100%. A quality of 100% means that the abundance of all species is equivalent to the baseline. A quality < 100% means that one or probably more species have an abundance below their baseline abundance. Thus, for example on a national basis, if 50% of a country still consists of natural area and the quality of this area has been decreased to 50%, then the $NCI_{\text{natural area}}$ is 25% (figure 2). An $NCI_{\text{natural area}}$ of 0% means that the entire ecosystem has deteriorated either because there is no area left, or because the quality is 0%, or both. An $NCI_{\text{natural area}}$ of 100 % means that the entire country consists of natural area of 100% quality.

5.1.3 The NCI method

To construct the NCI a country or region is divided into a number of basic units, usually combinations of geographical units with habitat types (e.g. mixed forests, seasonal wetlands). For every unit, the area of remaining habitat is assessed. Then a set of characteristic species of flora and fauna is selected, and the abundance of each one in both the current and the baseline situation is determined. This results in a quality index per species per unit. The species indices are averaged into one quality value for each unit.

Multiplying the quality vales by the quantity values gives an NCI value per unit. These values can then be added together to give aggregated results for habitats or geographic units, at local, national or regional scales. The results can either be expressed as trends, where the data exist for a number of years, or as a state assessment, representing the cumulative effect of previous trends.

5.1.4 Baselines

Baselines are “starting points” for measuring change from a certain date or state (Figure 3). Setting a baseline can be a complex and rather arbitrary process. Many alternative baselines are possible. Each alternative generates a different result and different information for policy makers. For the Natural Capital Index framework various options have been considered, including:

- at the time that the CBD was ratified
- before *any* human interference
- before *major* interference by industrial society.

Since there is no unambiguous natural baseline point in history, and all ecosystems are also transitory by nature, a baseline must be established at an arbitrary but practical point in time. Because it makes most sense to show biodiversity change due to human influence, a postulated “baseline set in pre-industrial times", often referred to as “natural” or “low-impact” baseline, would appear to be most appropriate. However, for many regions and ecosystems it is difficult to establish such a baseline with any degree of confidence or comparability with other areas. Therefore the NCI approach is more likely to be applied with an arbitrarily selected modern baseline that relates to the availability of data. It then becomes more similar to the LPI approach.

It must be stressed that baselines serve as a calibration point or benchmark to quantify the extent of change due to human activities in modern times. The baseline is *not* necessarily the targeted state. Policy makers choose their targets on ecosystem quantity and ecosystem quality somewhere on the axis between 0 and 100% (Figure 3) depending on their balance of social, economic and ecological interests. Natural fluctuations are considered to be part of the baseline and not as loss or gain of natural capital. Any “natural” baseline is therefore defined as the lower limit of the abundance range of the species in natural ecosystems.

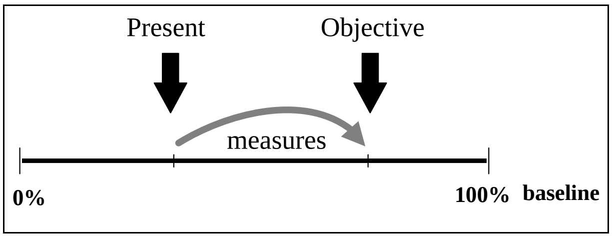

Figure 3: Ecosystem quality is calculated as a percentage of the baseline state.

5.1.5 Spatial Indicators

Spatial indicators can be used to summarise or augment information from a map or set of maps. Both a map of an indicator, and an indicator that summarises a map or other spatial data, can be thought of as spatial indicators. They can be useful in visualising which part of a country contributes most to a national trend, or in obtaining a statistically significant conclusion from existing geographical data. Each indicator should have a reference point so that two areas or time periods can easily be compared with one another, and should simplify a larger set of information in a way that is relevant to the question at hand (UNEP 1997).

Any indicator can be mapped if spatially disaggregated data are available. A *whole-map statistic* gives a summary of the pattern or set of data seen within a map or maps. Finally, indicators that rely on the spatial characteristics of the data can be mapped or summarised. These include measures of *distance*, *fragmentation* (or its opposite, *connectivity*), *spatial autocorrelation* (contagion), and *flow*. When using any of these approaches it should be remembered that the outcome is likely to vary with map resolution and extent as well as through time.

(1) Whole-map statistics

Whole-map statistics give a summary measure over the mapped area. Their uses include assessment of a trend through time, and validation of estimated versus observed data for a satellite classification or an environmental model.

Since these indicators give a single value for a map, they are easy to understand but may be difficult to interpret, as the spatial characteristics of the data are ignored. They can also be criticised because the map extent affects the metric outcome. This is less problematic when a particular extent (e.g. within a country's boundaries) is of intrinsic interest.

Agreement between maps of the same variable can be assessed using traditional methods of correlation or regression analysis. For presence-absence data such as forest presence, an index of agreement based on the number of positive and negative differences with the reference map is often used.

(2) Mapping spatial measures

Discussions of spatial indicators often focus on landscape metrics such as measures of size, shape, perimeter, fragmentation, slope orientation and land cover variability. For ease of analysis, these are usually based on a gridded map (rather than one composed of vector polygons). Landscape ecologists value these metrics in characterising landscape types and patterns. They can also be useful in developing indicators of naturalness and conservation status.

Spatial data on forest cover extent and distribution are increasingly assembled as a matter of routine. Maps of other ecosystem types are less commonly available, but are valuable resources where they exist. The principal limitations to the use of these approaches are resources for cover data acquisition and GIS capacity

(3) Mapping distance

Spatial distance to a resource or pressure is a basic measure, which may also be used to calculate other spatial pattern metrics. In wilderness mapping, weighted distance from infrastructure is used as an indicator of absence of human pressures (Lesslie et al. 1988, Sanderson et al. 2002). Distance from modified landscapes can have surprising impacts on biological communities (Laurance 2000). For example, the invasion of an exotic shrub into the Pasoh reserve in Malaysia was traced to the intrusion of wild pigs, whose populations had increased due to the replacement of native forest with oil palm plantations outside the reserve.

The *Globio* approach to mapping impacts associated with infrastructure is to compile studies relating species population abundances to distance from roads (Nelleman and Newton 2002). The impacts are classified according to habitat type and mapped as buffers to a road network, with weightings applied to different types of road and other infrastructure. Unexpected impacts on particular species can only be captured through individual study, but this approach does **summarise large quantities of data in a simple form**.

(4) Mapping habitat fragmentation

Forest fragmentation is frequently evaluated, but these methods could be applied to any land cover type. Fragmentation indices combine measures of distance, autocorrelation, shape, and area.

Fragmentation indices rely on the data definition for the habitat under consideration, distinguishing it from the surrounding matrix of other land cover types. In some circumstances there are sharp boundaries between habitats, but, for example, forest areas that have been altered but not transformed are more difficult to classify. Techniques for classifying patches from continuous surfaces include *local* methods, where variance or rate of change is calculated within a moving window over the map and allocated to cells in a new map. Areas of high variance or rate of change are used to define patch edges. Alternatively, a spatial constraint can be added to a standard clustering algorithm so that only adjacent land units are included in each cluster (Legendre and Fortin 2002).

At UNEP-WCMC, global forest fragmentation was analysed using remotely sensed presence-absence data. Single indices of patch size, localised forest density and connectivity were combined to give a 'forest spatial integrity' index (Kapos et al. 2000). This was intended as an indicator of forest capacity to retain a full biodiversity complement, taking the assumption that forest biodiversity is affected by area effects, edge/gradient effects, and isolation effects. Secondly, a wilderness approach was taken to give a forest naturalness metric.

Patch size was ranked, localised forest density was effectively calculated as an autocovariate and connectivity was defined as distance to a large patch of high forest density. These three indicators of forest integrity were mapped separately and also combined to give an index, which weighted connectivity more highly than patch size or density. These techniques could equally well be used to consider fragmentation as an indicator of human impact in any terrestrial system.

The freely available program Fragstats (McGarrigal et al. 2002) works with grid and vector data in various formats and will calculate a variety of spatial pattern indices, such as patch size and connectivity.

5.2 Pressure Indicators

It is important to recognise that the classification of individual indicators as pressure, state or response indicators relates much more to the questions they are used to address than to the indicators themselves or the data used to calculate them, and is always somewhat arbitrary. The same indicator can serve more than one of these functions. It is of far greater importance to ensure that the correct questions are asked.

As discussed above, a number of factors add to the difficulty of developing and implementing indicators of the state of biodiversity. Chief among these is the scarcity of appropriate data and inconsistencies among those data that are available, which make aggregation from data to indicators problematic. This is particularly true for indicators at broad geographic scales, where methods are more likely to vary among potential component data sets, and a broader diversity of habitats and/or species may need to be incorporated.

Because of these difficulties, the reality of biodiversity indicators is that many of the indicators that are already operational and in use relate more to pressures on biodiversity than to the state of biodiversity. In the case of pressures, this is largely because the data required are often relevant to other aspects of sustainable development and therefore already form part of environmental monitoring and reporting at national level. Thus data relevant to pressure indicators are more readily available and often are collected by relatively standardised methods. These factors increase the ease of assembling and aggregating data to produce indicators.

Equally important are the questions that users ask of indicators. Many key questions are about the processes causing biodiversity loss (pressures). Though the ultimate question is about the impact of these factors, tracking pressure indicators can also serve some important functions more effectively than state indicators. Pressure indicators can be used to construct scenarios and forecasts of future trends in biodiversity, even when detailed information on its state is unavailable. They are also important potential components of prioritisation processes as they can be used as measures of risk.

The pressures acting on the environment and natural resources are often considered from a policy perspective as the starting point for tackling environmental issues. Identifying the pressures acting on any resource of interest is fundamental to making informed decisions, and effective indicators of those pressures are vital to ensuring that appropriate information is available and accessible.

In managing biological diversity, the choice of pressure indicators will depend upon the components of biodiversity of greatest interest and the degree to which direct forces (e.g. exploitation rates) or underlying factors (e.g. population growth) are of interest. The latter are often presented as 'driving forces' in expanded indicator frameworks.

Pressures that directly affect biodiversity and its components include exploitation activities (e.g. logging, fishing) and their collateral impacts (e.g. forest damage, by-catch, trawling impacts). In many cases, direct measurements of real levels of activity are rare, so that it may be necessary to use proxies, such as data on the outputs of these activities, to build a complete picture of the magnitude of the pressure. For example, timber sales figures may be more readily available than direct measures of area logged or intensity of exploitation.

Other pressures on biodiversity are the results of human activities that do not relate to the direct exploitation of biodiversity. These include agricultural expansion and its effects on landscape configuration or siltation rates, various forms of pollution and wildfire resulting from human intervention. Data on some of these are readily available while others are more problematic. Other pressures such as climate change result from human activities still further removed from direct contact with the components of biodiversity of interest.

In many cases, the compounding effects of natural processes complicate development, use and interpretation of pressure indicators. For example wildfire and catastrophic disturbances due to tropical storms negatively affect forest biodiversity without human intervention.

Indicators of underlying causes or driving forces may relate to population growth or to consumption, among other factors.

In many cases the data required for pressure indicators will come from socio-economic monitoring rather than biological data. As for other biodiversity indicators, their calculation can be based on statistical or spatial data, or a combination of the two, and their presentation can be in statistical, graphical or spatial form according to the needs of the user and the issue addressed.

5.2.1 Statistical indicators of individual pressures and underlying causes

Data on individual direct pressures are often outside the scope of what is usually considered biodiversity information. They come from a wide range of sectors and are generally compiled for reasons having little or nothing to do with biodiversity policy and management. Nonetheless, they provide vital information on cross-sectoral responses needed to ensure conservation and sustainable use of biodiversity.

Which pressures are of interest depends on which components of biodiversity are of interest. More pressure indicators apply specifically to ecosystem types (and the species within them) rather than to individual species. These include measures of exploitation, conversion, and contamination, which tend to come from different activities and sectors for each ecosystem type. Statistical indicators of pressure on individual species are usually related to their direct exploitation (hunting or harvest) and for some species can be usefully derived from trade statistics. Otherwise, pressures on species can be inferred from pressures on the ecosystems and areas in which they occur.

One of the challenges in implementing pressure indicators is in identifying specific pressures and locating the data, which may come from quite different sectors and be in quite different units. For example, Table 3 shows a set of potential indicators of pressure on biodiversity in tropical forests. The indicators listed potentially require data from the forest sector, the conservation sector, the energy sector and agencies dealing with nutrition and household economies. While managing such information is outside the scope of the agencies involved in IABIN, identifying the sources of such data and, where possible, providing structured links to them are vital functions that can facilitate the construction of indicators at national and regional scales.

A second challenge of pressure indicators in a biodiversity information management context is to express information that is socio-economic in origin in biodiversity-relevant terms. This can mean re-expressing data in terms of the ecosystem they affect or the number of species influenced by the particular activity. It also means that aggregation of data, for example from national to regional scale, should be done using measures that are biodiversity-relevant in the first place. For example, combining national data on total timber harvest would be far less meaningful than expressing timber harvest relative to the total forest area that is currently subject to exploitation and/or relative to the total forest area in the country. This approach weights the data appropriately before combining them at supranational scales and ensures that locally intense pressure on a small resource neither outweighs nor entirely disappears in combination with data on limited pressure on large resources. Expressing such data by forest (or other habitat) type is still more useful. Thus, a useful regional indicator might summarise logging pressure as the area or percentage of a particular forest type that is subject to logging annually, perhaps expressed by type or intensity of logging operation.

Updating such statistics to produce genuine time series is often more straightforward than for state indicators of biodiversity, because economic sectors tend to maintain such data on an annual basis. However, it is important to recognise that there may be significant problems of data quality, and that certain types of data such as the issuing of licenses and concessions may bear only the most tenuous relationship to actual activities on the ground.

As with other indicators, effective presentation and careful consideration of the underlying assumptions and potential interpretation of pressure indicators is vital. Thus, for example, many of the indicators in Table 2 are predicated on the idea that granting of timber licenses represents a direct increase in pressure on forest biodiversity and an increased probability of forest disturbance, which can have significant impacts in adjacent forest areas. If this is valid, then from a biodiversity conservation perspective, rises in these indicators should prompt policy review and management guidelines to minimise impacts beyond the boundaries of the concession.

Table 2. Potential national-scale indicators of pressure on tropical forest biodiversity. Feasibility of their implementation in short to medium-term ranges from easy to implement (4 stars) to very difficult (1 star). (adapted from Kapos & Jenkins 2002)

Indicator	**Feasibility**
Area of forest per capita	****
Area of each forest type within areas of global biodiversity priority allocated to commercial concessions	***
Area of each forest type adjacent to protected areas allocated to commercial concessions	***
Area of each forest type with populations of species of conservation concern allocated to commercial concessions	**
Annual timber harvest in relation to total forest area	****
Annual timber harvest in relation to forest area allocated to production	****
Annual timber harvest from forest areas within areas of global biodiversity priority or by forest type	***
Annual fuelwood production in relation to total forest area	*
Annual fuelwood production in relation to forest area within areas of global biodiversity priority or by forest type	*
Area of each forest type converted annually	***
Area of each forest type within areas of global biodiversity priority converted annually	***
Amount of bushmeat from forest sources consumed annually	*
Per capita annual consumption of bushmeat from forest sources	*
Percentage annual protein needs supplied by bushmeat from forest sources	*
Value of non-timber forest products exported annually	**
Percentage of annual export earnings provided by export of plant non-timber forest products	**

Statistical data from socio-economic and sectoral sources can also be used to address underlying causes of biodiversity loss more generally at a range of geographical scales. An example of this is the development of consumption pressure indices within the Living Planet Reports issued by WWF (Loh et al. 1998-2002). In these reports pressure on global biodiversity is linked to rising consumption of natural resources by mankind. Consumption of grain, fish, wood, fertiliser and cement are reported (e.g. Figure 4), as are carbon dioxide emission rates, and these are linked to specific pressures on biodiversity such as agricultural expansion (grain consumption), urbanisation (cement) and eutrophication (fertilisers). These data are based on production and trade data that were collected by national and international agencies and are readily available, but compiling them on a global basis and linking them to trends in biodiversity has turned them into effective indicators of underlying pressures on biodiversity.

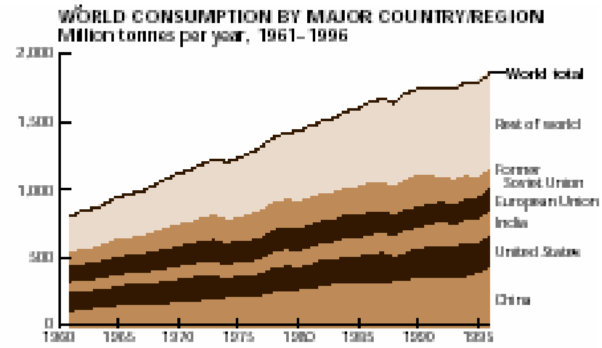

Figure 4. Global consumption of grain since 1961, an underlying force contributing to the pressure of agricultural expansion on global biodiversity (from Loh et al. 1999)

The most recent Living Planet Reports (Loh et al. 2000 and 2002) have taken this kind of analysis a step further and expressed consumption pressure in terms of the land area required to supply it, resulting in a global 'ecological footprint' (Figure 5). In theory this approach can be applied at either national or regional level, but the assumptions involved in their calculation can be quite sweeping and are more easily challenged at finer geographical scales.

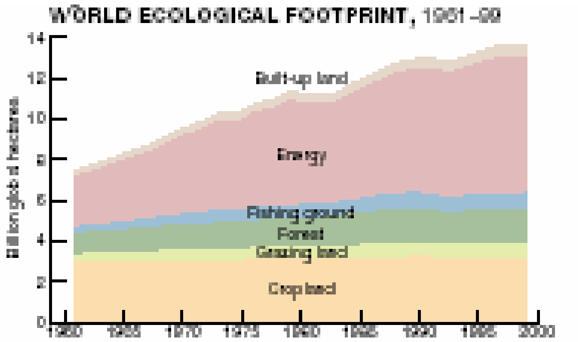

Figure 5. Global ecological footprint based on land area equivalents needed to supply global consumption of crops, meat, wood, fish, energy and building land (from Loh et al. 2002).

5.2.2 Using maps to identify pressures

Mapped data are an important basis for identifying pressures and the areas where they act. These can be maps of particular kinds of activity or exploitation, such as timber concessions, which can be used in combination with mapped data on ecosystems or species distributions to identify components of biodiversity potentially subject to the highest impacts.

Spatial distance to a resource or pressure is a basic measure, which may also be used to calculate other spatial pattern metrics. One strategy for this is based on measuring isolation from generalised human activity in the landscape. In one such 'wilderness mapping' approach, weighted distance from human activity is used as an indicator of absence of human pressures (Lesslie et al. 1988, Sanderson et al. 2002). Human activity in the landscape can be represented unambiguously in terms of:

- **settlement** - permanent human occupation, ranging in scale from single dwellings to conurbations which may extend over thousands of square kilometres.
- **infrastructure -** the built fabric which provides the physical means for accessing, distributing and transforming resources.
- **land use** - any resource procurement or transformation activity that can be spatially delimited on the land surface.

This type of approach underpinned the Australian government's National Wilderness Inventory (Lesslie & Maslen 1995) and the production of similar remote and natural lands databases elsewhere (e.g. Husby 1995), which emphasise measuring the extent to which points in the landscape are remote from, and undisturbed by, the influence of modern technological society. These approaches are usually based on measurements of Euclidean distance between each point in the landscape and ordered classes of settlement and infrastructure, with weighting schemes applied so that more prominent feature types (such as highways or commercial centres) are accorded greater influence than less prominent types (such as vehicle tracks or residences).

Wilderness indexing procedures provide a useful visualisation of the accessibility or vulnerability of ecosystems to human interference. They are measures of generalised human pressure on biodiversity that take no account of specific activities or their outcomes. In general, they have the important limitation of excluding resource manipulation techniques that rely on naturally occurring physical or biotic phenomena, such as fire or specific plants and animals, commonly associated with indigenous societies.

While their generality limits these methods' utility in predicting specific local pressures and their outcomes, it makes a broad scale comparison among areas feasible and makes it possible to include a standardised measure of vulnerability in the decision-making process. If wilderness values decline appreciably, it is likely that biodiversity is at increasing risk and policy action needs to be taken to limit the development of new access routes and or the spread of population. Reductions in ecosystem cover will tend to generate a reduction in the average wilderness of remaining areas, except where the loss is by total elimination of low-wilderness fragments.

The indices can be scaled to local conditions so that they reflect relative wilderness within an appropriate range. They are potentially very useful tools for scenario testing and planning as new roads or population centres can be provisionally "constructed" within the infrastructure data set and the magnitude of their likely impacts evaluated.

The utility of such generalised analyses is greatly enhanced by the application of empirical knowledge of the impacts of access. These can either be incorporated into the analysis or provided as accompanying material to aid in their interpretation. Therefore, access to both quantitative data and narrative examples of the relations between human activity and biological impact would be a useful output from IABIN.

Such data would also facilitate the application of the *Globio* approach to mapping infrastructural impacts (http://www.globio.info/). This approach is to compile studies relating species population abundances to distance from roads (Nelleman and Newton 2002). The impacts are classified according to habitat type and mapped as buffers to a road network, with weightings applied to different types of road and other infrastructure. Unexpected impacts on particular species can only be captured through individual study, but this approach does **summarise large quantities of data in a simple form**.

This type of approach has a number of advantages. Of particular relevance to the question of periodic assessments and monitoring is the fact that the analysis is quantitative and repeatable. Estimates of isolation or exposure to human activity produced by the analysis are a direct expression of the data and the modelling that is applied. This means that the scale of the analysis can be explicitly matched to the accuracy and precision of data inputs. GIS-based application of the model, which effectively automates the analysis, also promotes flexibility so that new primary attribute data can readily be introduced and the analysis repeated or manipulated in a variety of ways. However, especially in developing countries, there may be significant difficulty in obtaining data of sufficient quality on infrastructure and settlements that is updated with adequate frequency. A baseline analysis can be performed based on Digital Chart of the World, but providing a dynamic view is more difficult.

5.2.3 Mapping combinations of pressures to identify areas of high risk

Spatially distributed data on pressures are also useful tools for combining information on different pressures. This requires the establishment of some form of common denominator for adding different pressures. The ecological footprint approach discussed above is one way of doing this. A rather less contentious approach is to convert the data on each pressure to categorical form (e.g. high, medium, low) and to examine categorical combinations resulting from intersecting different pressure data sets.

When presented in map form, spatial patterns and hotspots in indicator data can easily be identified, particularly by those with knowledge of the region.

In a recent example, mountain areas under pressure from six causes were identified as follows: a high-risk category was defined for values from each of a set of pressure maps. The pressures were: global climate change, agricultural conversion, seismic activity, fire, war and conflict, and infrastructural development. The number of pressures in the high-risk category for each grid cell was then counted to produce a single global map (Figure 6). Areas of high value for different biodiversity elements can be treated in the same manner, and the resulting value surface can be intersected with a pressure surface to identify areas of high value at high risk.

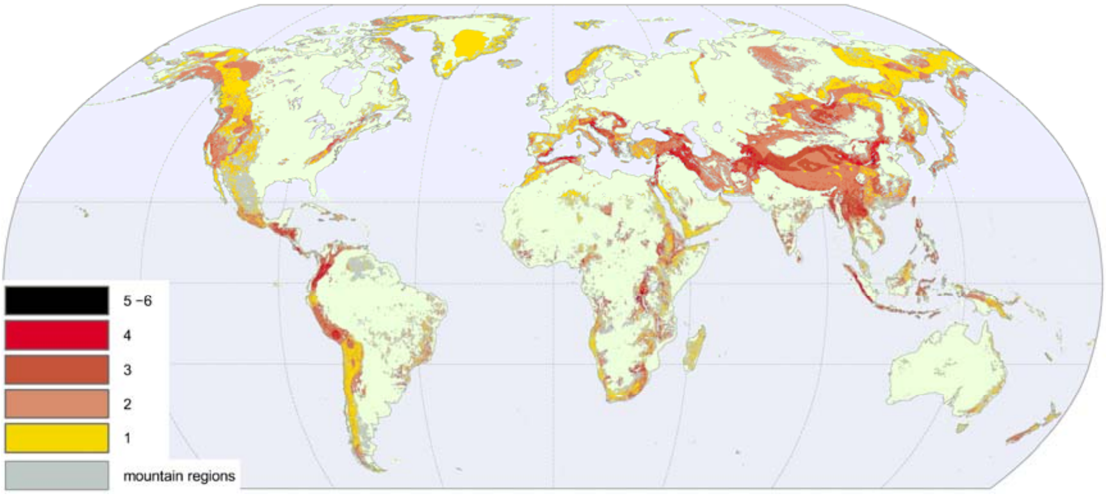

Figure 6: Synthesis of six pressure indicators for mountain areas (global climate change, agricultural suitability, seismic hazard, fire, human conflict, infrastructural development) (UNEP-WCMC 2002)

5.3 Response Indicators

Indicators of the actions taken by society to counteract the pressures on biodiversity are fundamental to charting progress towards conservation and sustainable use of biodiversity. They are particularly appropriate for examining progress at supranational scales and many of the data are generated as a result of national reporting to Multilateral Environmental Agreements.

As for other indicators, the selection and use of response indicators depends very much on the questions being asked. It may be relatively straightforward to generate measure of the steps taken to respond to pressures on biodiversity, but evaluating their influence or effectiveness is much more problematic and merges into state indicators.

The response indicators identified by the CBD for monitoring progress towards the 2010 biodiversity target include coverage of protected areas and official development assistance provided in support of the Convention. These are examples of a much wider range of responses that may ultimately need to be tracked, and careful consideration is needed to identify the most appropriate forms that indicators should take and how they can best be related to biodiversity conservation and sustainable use.

(1) Policy and legislation

The adoption of policies and enactment of legislation relevant to biodiversity are important societal responses, which are relatively easily tracked, and commonly reported to the CBD. It is important that clear access to this information is provided. The compilation of quantitative indicators on this subject is problematic for at least two reasons. One is the question of the units that would be meaningful and the other is how to track progress towards the adoption or enactment of such instruments. For these and other reasons most indicators of policy and legislative responses are likely to be qualitative, tracking the existence or absence of particular types of policy and legislation.

(2) Protection

The CBD's recommendation on coverage of protected areas needs to be considered at the very least in terms of both ecosystems and species. Thus data on protected areas need to be combined with data on ecosystem cover and species distributions. While these analyses are important at national scale, their validity is even greater at supranational scales that can encompass the entire distributions of the species and ecosystems of concern. At both scales data availability is problematic but improving through the work of IABIN and similar networks. Regional scale efforts to agree ecosystem classifications and maps, such as that undertaken by CCAD, are especially important.

In order to ensure that such indicators are meaningful for monitoring, the results of coverage analysis should be expressed in terms of absolute area or numbers of species protected rather than, or in addition to percentages. Changes in percentages may represent changes in the amount protected or in the total amount, whereas changes in total area protected or area protected relative to potential cover are much less ambiguous.

(3) Management

A further important consideration is the effectiveness of protected areas in protecting the biodiversity they cover. For this reason, the CBD and other processes have identified management effectiveness as an important parameter to track. While this is still rather difficult, the WCPA adoption of a framework for assessing protected area management effectiveness and the subsequent development of several different scorecard schemes hold promise for the future availability of such information.

An indicator based on their application is likely to take the form of a number or percentage of protected areas in which management effectiveness is improving. This could be developed on national or regional scales or applied to protected areas encompassing particular habitat types or groups of species.

As the application of such scorecards increase, IABIN may wish to consider whether and how it can direct users to their results.

Management of biodiversity is important outside protected areas as well as inside them, and relates closely to issues of sustainable use. It is likely to be some time before analogous scorecard approaches are applied in the wider landscape. Meanwhile, the most likely information for indicators in this field is likely to be based on certification schemes such as those for sustainable forest management and organic agriculture and the areas they have certified. IABIN may wish to develop links to this information for its region.

(4) Restoration

Habitat restoration is increasingly important in some areas, and efforts in this respect are and important part of society's response to the loss and degradation of biodiversity. A useful response indicator will therefore be related to the area of habitat under restoration (restoration success requires such long-term evaluation that it is unlikely to be practical). A number of programmes and internet sites document restoration efforts (e.g. the Forest Restoration Information Service), and IABIN may well wish to link to these and to consider developing data resources about such efforts and their progress.

(5) Investment

As the CBD's proposed indicator on overseas development assistance relating to biodiversity suggests, the investment of financial resources in biodiversity conservation and sustainable use is also an important indicator of response. Although the DAC database has been suggested by CBD as the principal source for this information, there are a number of sources of investment that it does not cover. These include multilateral donors, especially the GEF and non-governmental organisations. One way to track this is through the recipient countries and through resources that compile information on project activity, such as the Rainforest Alliance's Eco-Index (http://www.eco-index.org). IABIN could usefully provide access to these resources as important representations of response and potentially key tools in helping donors coordinate their efforts and support (discussed elsewhere).

Chapter 6 Conclusions and Recommendations

Although the importance and potential utility of biodiversity indicators to support policy and management at many different scales has been widely recognised, there are as yet no fully accepted and established standard indicators. However, the CBD's recent adoption (decision VII/30) of a framework for evaluating progress towards the achievement of the 2010 target gives significant guidance on the way that indicators should be developed and the need for access to relevant data.

The first indicators to be developed are those referring to ecosystem extent and to trends in the populations of selected species. Both are applicable at scales ranging from local through national and regional to global. Indicators of pressures on biodiversity and societal responses to those pressures are also recognised as critical by the CBD.

Developing meaningful indicators at regional scales requires a more complex approach than simply aggregating national indicators, and IABIN should develop its data management strategies accordingly.

Given the history of ecosystem mapping in the region and the degree to which species trend data are dispersed and frequently inaccessible, it is likely that map-based indicators will be the first to be fully operational at the regional scale. *IABIN can and should facilitate this by:*

- *making mapped data on ecosystems accessible;*
- *ensuring that adequate documentation is available to enable users to evaluate the appropriateness of comparing or combining different data sets;*
- *providing guidance or lexicons to elucidate the relationships between different ecosystem and land cover classification systems.*

The potential for developing species trend indicators in the Americas is high and will increase as the participants in IABIN mobilise more relevant data resources. *This objective should be pursued by:*

- *making species population trend data easily accessible and providing guidance on their use;*
- *providing linked documentation on species distributions, ecological requirements and habitat associations;*
- *enhancing access to data included in grey literature;*
- *improving outreach to amateur and academic networks as a mechanism for identifying and documenting unpublished data;*
- *making use of institutional memories to assess and document data quality;*
- *(potentially) providing access to on-line index calculation, allowing users to choose focal ecosystems and select species for inclusion.*

Also high priorities for development are spatial indicators that give some measure of habitat quality (e.g. fragmentation metrics), although it is likely that these will only be developed for some easily mapped ecosystems such as forests. For aquatic systems and those for which mapping is more problematic, the species based approaches will need to be followed up sooner.

IABIN can facilitate the development and use of indicators of pressure on biodiversity by:

- *recognising the importance of data from outside the biodiversity and conservation sector;*
- *identifying important pressures on ecosystems and species at local, national, regional scales;*
- *establishing collaboration with relevant organisations that may hold data on such pressures;*
- *where possible, providing well-documented links to relevant data on these pressures, which are likely to be held outside the IABIN network.*

In the area of response indicators, IABIN potentially has a key role to play in:

- *facilitating access to data on protected areas and ecosystem and species distributions;*
- *mobilising information on the assessments of management effectiveness that are taking place under a number of different initiatives and providing access to their results as they become available;*
- *identifying and facilitating links to other data, including:*
    - *data on certified ecosystem management within the region;*
    - *information on ecosystem restoration activities;*
    - *data on investments by donors (bi-lateral, multilateral and NGOs) and the private sector in conserving, managing and restoring biodiversity.*

Above all, it is vital for IABIN to consider the potential for use in biodiversity-related indicators of the data it delivers and to ensure that the user is clearly and transparently directed to data that are important for the focal areas for indicators outlined in this document. *A clear structure showing how different kinds of data relate to these focal areas and to key policy questions will be critical. Clear and comprehensible documentation of data and the relationships among them are also vital.*

The connection between indicators and key questions of interest for policy and management is also vital. *It will be important for IABIN to take account of (and participate in) regular review programmes to assess the value of existing indicators in supporting decision-making, and to adjust indicator development and implementation programmes accordingly.*

ANNEX 1 - Acronyms and Abbreviations

ARCBC	The ASEAN Regional Centre for Biodiversity Conservation
ASEAN	Association of Southeast Asian Nations
CBD	Convention on Biological Diversity
CCAB/AP	Consejo Centroamericano de Bosques y Areas Protegidas
CCAD	Comisión Centroamericana de Ambiente y Desarrollo
CEC	North American Commission for Environmental Cooperation
CIFOR	Centre for International Forestry Research
CITES	Convention for International Trade in Endangered Species
COP	Conference of the Parties
CSD	Commission on Sustainable Development
DAC	Development Assistance Committee
DPSIR	Driving Force – Pressure – State - Response
DSR	Driving Force-state-Response
EEA	European Environment Agency
GEF	Global Environment Facility
GIS	Geographic Information System
GSPC	Global Strategy for Plant Conservation
IABIN	Inter-American Biodiversity Information Network
ITTO	International Tropical Timber Association
LPI	Living Planet Index
MCPFE	Ministerial Council for the Protection of Forests in Europe
NABIN	North American Biodiversity Information Network
NCI	Natural Capital Index

NGO	Non-Governmental Organisation
OECD	Organisation for Economic Co-operation and Development
PSR	Pressure – State - Response
SOE	State of the Environment
SBSTTA	Subsidiary Body on Scientific, Technical and Technological Advice
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
WCPA	IUCN World Commission on Protected Areas
WWF	Worldwide Fund for Nature (formerly World Wildlife Fund)

ANNEX 2 - Bibliography

RIVM. 2000. *Natural capital indicators for OECD countries*.

Boyle, T.J.B & Sayer, J.A. 1995. Measuring, monitoring and conserving biodiversity in managed tropical forests. *Commonwealth Forestry Review*, 74: 20-25.

Commission on Sustainable Development (CSD). 2001. *Indicators of sustainable development: guidelines and methodologies*. New York, USA.

Convention on Biological Diversity (CBD). 1997a. *Recommendations for a core set of indicators of biological diversity*. UNEP/CBD/SBSTTA/3/Inf.13 Montreal, Canada, Secretariat of the Convention on Biological Diversity.

CBD. 1997b. *Indicators of forest biodiversity*. Working document prepared for the meeting of the liaison group on forest biological diversity. UNEP/CBD/SBSTTA/3/Inf.23 Montreal, Canada, Secretariat of the Convention on Biological Diversity.

Dallmeier, F. & Comiskey, J.A. 1998. Forest biodiversity assessment, monitoring, and evaluation for adaptive management. *In* F. Dallmeier & J.A. Comiskey, eds. *Forest biodiversity research, monitoring and modelling. Conceptual background and Old World case studies*, p. 3-16. Man and the Biosphere Series Vol. 20. Paris, France and Carnforth, UK, UNESCO and Parthenon Publishing Group.

European Environment Agency (EEA). 1998. *Europe's environment – the 2nd assessment*. Luxembourg, Office for Publications of the European Communities.

FAO. 2001a. *Criteria and indicators for sustainable forest management: a compendium.* Forest Management Working Papers No. 5. Rome.

FAO. 2001b. *State of the World's Forests 2001.* Rome.

Ferris, R. & Humphrey, J.W. 1999. A review of potential biodiversity indicators for application in British forests. *Forestry*, 72(4): 313-328.

Ferris-Kaan, R., Peace, A.J. & Humphrey, J.W. 1998. Assessing structural diversity in managed forests. *In* P. Bachmann, M. Köhl & R. Päivinen, eds. *Assessment of biodiversity for improved forest planning*, p. 331-342. Forestry Sciences Vol. 51. Dordrecht, the Netherlands, Kluwer Academic Publishers.

Grayson, A.J. & Maynard, W.B. 1997. *The world's forests – Rio +5: international initiatives towards sustainable forest management.* Oxford, UK, Commonwealth Forestry Association.

Hawthorne, W. & Juam Musah, A. 1993. *Forest protection in Ghana*. Kumasi, Ghana, ODA.

Holdgate, M. 1996. *From care to action: making a sustainable world.* London, UK, World Conservation Union (IUCN) and Earthscan.

Hyman, J.B. & Leibowitz, S.G. 2001. JSEM: a framework for identifying and evaluating indicators. *Environmental Monitoring and Assessment*, 66: 207-232.

Iremonger, S., Ravilious, C. & Quinton, T. 1997. A statistical analysis of global forest conservation. *In* Iremonger, S., Ravilious, C. & Quinton, T. (eds.) *A global overview of forest conservation. Including: GIS files of forests and protected areas, version 2.* CD-ROM. Cambridge, U.K., CIFOR & WCMC.

Kapos, V. and Jenkins, M.D. 2002. *Development of effective indicators for monitoring biodiversity in tropical moist forest ecosystems*. Final Technical Report Project R6515. London, U.K., DFID Forestry Research Programme.

Kapos, V., Lysenko, I. & Lesslie, R. 2000. *Assessing Forest Integrity and Naturalness in Relation to Biodiversity*. 60 pp. FAO FRA 2000 and UNEP-World Conservation Monitoring Centre.

Legendre, P. & Fortin, M-J. 1989. Spatial pattern and ecological analysis. *Vegetatio* **80**: 107-138.

Lesslie, R.G., Mackey, B.G. & Preece, K.M. 1988. A computer based method of wilderness evaluation. *Environmental Conservation* 15(3): 225-232

McGarigal, K., Cushman, S.A., Neel, M.C. & Ene, E. 2002. *FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps. Computer software program*. University of Massachusetts, Amherst, USA. Available from: http://www.umass.edu/landeco/research/fragstats/fragstats.html

Nelleman, C. & Newton, A.C. 2002. *The Great Apes - the road ahead. A Globio perspective on the impacts of infrastructural development on the Great Apes*. UNEP, Nairobi, Kenya

Newton, A.C. and V. Kapos. 2002. Biodiversity indicators in national forest inventories. *Unasylva* 210: 56-64.

Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology*, 4(4): 355-364.

Noss, R.F. 1999. Assessing and monitoring forest biodiversity: a suggested framework and indicators. *Forest Ecology and Management*, 115: 135-146.

Organisation for Economic Co-operation and Development (OECD). 1993. *OECD core set of indicators for environmental performance reviews*. Environmental Monograph No. 83. Paris, France.

Sanderson, E.W., Jaiteh, M., Levy, M.A., Redford, K.H., Wannebo, A.V. & Woolmer, G. 2002. The Human Footprint and the Last of the Wild. *BioScience* 52(10): 891-904

Stork, N.E., Boyle, T.J.B., Dale, V., Eeley, H., Finegan, B., Lawes, M., Manokaran, N., Prabhu, R. & Soberon, J. 1997. *Criteria and indicators for assessing the sustainability of* *forest management: conservation of biodiversity*. CIFOR Working Paper No. 17. Jakarta, Indonesia, CIFOR.

UNEP. 1997**.** *Recommendations for a core set of indicators of biological diversity*. [online] UNEP/CBD/STBSTTA/5/12, and inf. 13, inf.14, Montreal. Available from: http://www.biodiv.org/doc/meetings/sbstta/sbstta-03/official/sbstta-03-09-en.pdf. Accessed 27 Feb 2004.

Vanclay, J.K. 1998. Towards a more rigorous assessment of biodiversity. *In* P. Bachmann, M. Köhl & R. Päivinen, eds. *Assessment of biodiversity for improved forest planning*, p. 211-232. Forestry Sciences Vol. 51. Dordrecht, the Netherlands, Kluwer Academic Publishers.

Veldkamp, A. & Lambin, E.F. 2001 Predicting land use change. *Agriculture Ecosystems and the Environment* 85:1-6