THE ROYAL
SOCIETY

Measuring biodiversity for conservation

Summary

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The reality of ongoing biodiversity loss

The living world is disappearing before our eyes. Around a tenth of all the world's bird species and a quarter of its mammals are listed by the World Conservation Union (IUCN 2002) as threatened with extinction. For less studied groups such as fish, mussels and crustacea, the proportion of threatened species could be as high as one or two thirds (IUCN 2002). This information is available in the public domain, but a systematic framework for assimilating data on the loss of biodiversity and for assessing its impact on society, does not exist.

Losses of biodiversity have accelerated over the last two centuries as a direct and indirect consequence of human population growth, unsustainable patterns of resource consumption and associated environmental changes. Effective methods of measuring biodiversity are urgently needed to monitor changes in the state of the living world and to measure progress towards the target, set by the World Summit on Sustainable Development, of achieving 'a significant reduction in the current rate of biodiversity loss by 2010'. No sound basis currently exists for assessing global performance against this target. Without internationally agreed measures of biodiversity it will be impossible to determine whether the rates of loss are declining or accelerating. It will therefore be impossible to assess the success of mitigating actions.

The aim of this report is to clarify the scientific basis for measuring biodiversity in order to contribute to an international consensus on how it can be monitored. Such a consensus will be vital if significant progress is to be made – and measured – by 2010.

This summary report has been prepared by the Royal Society Biodiversity Working Group and has been endorsed by the Council of the Royal Society. The full report, which contains a more detailed description of the framework and provides case studies to demonstrate how it can be used, will be available in June 2003. We are grateful to the representatives from national and international conservation bodies, scientists, individuals, companies, governmental and non-governmental (NGO) organisations who provided valuable input into this study, through responding to a call for written evidence and through various stakeholder meetings.

The significance of biodiversity

Human dependence on biodiversity is absolute: without it we would not be able to survive. Apart from direct benefits of biodiversity from the harvest of domesticated or wild species for food, fibres, fuel and pharmaceuticals, humans also benefit from its influence on climate regulation, water purification, soil formation, flood prevention and nutrient cycling (i.e. ecological services); and the aesthetic and cultural impact is obvious (Table 1) (Daily 1997; Balmford *et al. 2002*).

Conserving biodiversity is essential to sustainability. Biodiversity provides substantial socio-economic, scientific, technical and socio-cultural opportunities. The perspective on sustainability adopted in this report requires that these benefits continue to be available to future generations. However, we recognise the fundamental tension between intergenerational equity and the humanitarian imperative of equality here and now.

Challenges

In broad terms enough is already known of the distribution and causes of biodiversity loss to indicate the scale of the problem and to guide conservation efforts. However, there are also major areas of ignorance. For example, knowledge of the earth's species is incomplete. Even for most of those species that have been formally described, little or nothing is known of their distribution, ecology, population size or evolutionary history. Knowledge is most limited and patchy for the very geographic areas and habitats where species diversity is greatest – principally in the tropics; and very little is known of the deep sea. The fate of organisms that have not yet been recognised by science cannot be measured. Understanding of trends in biodiversity, in both time and space, is further hampered by the absence of reliable baseline data for most groups and habitats, as well as by inconsistencies in methods. Likewise, how ecosystems function cannot be fully understood until more is known about the organisms that they comprise. Knowledge is also lacking on how much an ecosystem can be simplified but still provide the ecological services upon which humans depend.

Important information on historical status of habitats, species and ecosystems resides in museums, libraries and informal records. Synthesis of this information, and making it available as a basis for assessing trends and establishing time series, would greatly increase the value of data being collected now. Good data sets are essential to provide a sound basis for policy development and management action.

Conservation efforts could be enhanced greatly by transferring taxonomic information into more accessible and useable forms, for example through the use of the Internet, appropriate information technology or the development of user-friendly guides. Up-to-date lists of taxonomic experts, who are able to respond either remotely or directly, could also support situations where advice is required urgently.

Addressing the Johannesburg biodiversity commitment by 2010 will require striking a balance between synthesis of information that is already available and the collection of new data using sampling methods that are improved in efficacy and scope. This balance is important if future global biodiversity assessments are to rest on a firmer and broader foundation than current knowledge permits.

Table 1 Examples to illustrate the meaning of the terms interested party and valued attribute as applied to the value of biodiversity. Direct use benefits are valued through the market, whereas indirect use is valued by observation.

Object	Interested parties	Valued attributes	Type of value
Diversity of life on Earth	Evolutionary biologists	Global species richness and the location, abundance and range of species as resources for documenting and understanding the evolutionary process	Option value i.e. conservation allows time for new science and information to be discovered
	People who like wild nature	Global species richness and the abundance, range extent and viability of species	Existence value or non-consumptive use value
A forested river catchment	Local people whose health and livelihoods depend upon a reliable fresh water supply	Volume and reliability of streamflow (in part controlled by the moisture collection and retention properties of forest vegetation) as a determinant of water availability to people.	Forest vegetation – direct use value

Flood protection benefits in terms of costs avoided – indirect use value |
	Commercial foresters	Volume of timber that can be extracted	Direct use value
Coral reef	Local fisheries	Reliable ongoing source of protein and income	Direct use (consumptive) value
	Marine ecotourists	'Beautiful' and abundant coral and fish species	Direct use non-consumptive use (amenity) value
The world population of an arctic-temperate migratory goose species	Conservationists	Range and population size (desired state – at least maintained well above the minimum viable level)	Existence value
	Farmers in the winter range	Range and population size (desired state – below the level that results in significant damage to crops and grass by grazing)	Negative value above a given population size

Progress in improving the knowledge of status and trends for certain species and groups of species has already been made at a national scale, and has been aided in many countries by their biodiversity action plans. This information has the potential to inform policy development and conservation priorities. However, attempts to further improve the quality, extent, coverage and coordination of biodiversity assessment and analysis will cost money, and there is no large-scale mechanism in place to support such initiatives. The problem is exacerbated by the extent to which actions of the Convention on Biological Diversity focus within national boundaries, which makes it difficult to organise global databases and overviews.

A framework for measuring biodiversity

One problem in the measurement of biodiversity is that existing measures are often not well suited to the purposes of those wishing to make decisions about policy, or measure the effect of policy. To address this issue we have developed a framework consisting of a set of linked activities that comprise the assessment of some aspect of biodiversity (Figure 1).

The framework does no more than make explicit best science practice, but it is intended to be useful to scientists who measure biodiversity as well as those who commission and use the information generated. Routine use of the framework will ensure that measures are appropriate to the purpose to which they are being

applied. As a result each biodiversity assessment would clearly identify: i) interested parties; ii) the attributes that those parties value and are seeking to measure; iii) the extent of existing knowledge relevant to the assessment; iv) the assumptions used in the assessment and the limitations of the measure in addressing the valued attributes; v) precisely how each measure is defined; vi) the nature of the sampling strategy used; and vii) the data gathering and analytical methods to be employed. Applying this framework would also help to identify weaknesses in current approaches, as well as highlight major science and information gaps. In the main report (Royal Society 2003) a series of case studies demonstrate how the framework can be used for terrestrial, freshwater and marine systems, and at the ecosystem, species and population levels.

The framework can be regarded as a conceptual process that can be applied just as well to a long-term monitoring programme, as to an emergency situation, such as an oil tanker disaster. The quality of the assessment will be enhanced, as each stage is made more explicit.

Scoping stage
At the outset an assessment needs to define who the interested parties (stakeholders) are and what attributes of a particular element of biodiversity they are interested in. Combined with a review of existing knowledge, this will establish the aims and objectives of the assessment and inform decisions on what measure of biodiversity to use and the effort and precision required. Stakeholders' interests may have different timescales, which must also be identified at this stage, for example, commercial fisheries may be interested in the viability of next seasons' catch whereas conservationists may take a longer term view. Further examples of valued attributes and objects are provided in Table 1. Currently, many aspects of biodiversity, including some of those of greatest interest to local stakeholders, are scarcely being assessed at all.

The next step is to develop a conceptual model, based upon whatever is known about the system, that will force assumptions to be recognised and made explicit. It is essential that interested parties are clear about what the assessment can and cannot provide.

Project / study / design stage
No one measure of biodiversity is best for all purposes. A broad suite of measures is necessary to meet specific needs as they vary in scale and purpose and may focus on anything from entire habitats and ecosystems, through to the details of populations and genes of individual species. Many existing measures are well designed and informative, but overall, efforts to measure biodiversity do not provide an adequate assessment of its condition.

Selecting appropriate measures depends crucially on the object of the assessment and the attributes of interest. Choice of measures also requires careful consideration of the tradeoffs between their usefulness and the effort required to develop them, in terms of time and resources. There is often the temptation to gather the data that are easiest to obtain despite their limited bearing on the issue, or to gather new data when strategic additions to existing data could be more efficient.

Detailed measures of many key aspects of biodiversity are limited by resources, but effective sampling strategies and the application of new technologies could increase their cost effectiveness and thereby greatly enhance knowledge of changes in habitat extent, patterns and rates of delivery of ecosystem services, distributions of specific taxa, and changes in population abundance.

Careful design of the sampling strategies is crucial. A fundamental decision is whether to extrapolate from a sample, or to develop a comprehensive survey or measure. The precision of an extrapolated sample can be greatly improved by using stratified random sampling based on prior knowledge and a realistic model. Any sampling strategy should make clear when to survey and how often, and estimates should be made of the sources of uncertainty and their impact on the findings. Where there is time, testing the strategy, for example by conducting a pilot study, would help ensure that the sampling is appropriate.

Implementation and reporting
Data gathering and analytical techniques should aim to provide biodiversity information that is both relevant to interested parties and usable by other similar assessments. Reporting of the study should follow recognised protocols and contain as much information as possible about dates, methods and assumptions, to allow others to use and interpret the data. Enhancing the quality of the baseline knowledge will facilitate future use of the framework presented here and the development of more effective measures with greatly expanded scope. Clear reporting of the results of scientific assessments of biodiversity, with explicit reference to the steps taken in following the framework, will minimise the scope for misinterpretation.

Any repetition of an assessment should reconsider the original valued attributes, aims and objectives in the light of the new knowledge that has been created. However, it is important that measurements of changes over time are consistent to provide valuable time-series data. If the measurements cannot be replicated precisely, the new measurements will need to be calibrated against the old ones.

Figure1 *Framework for biodiversity assessment, showing the various conceptual stages necessary for assessing an element of biodiversity*
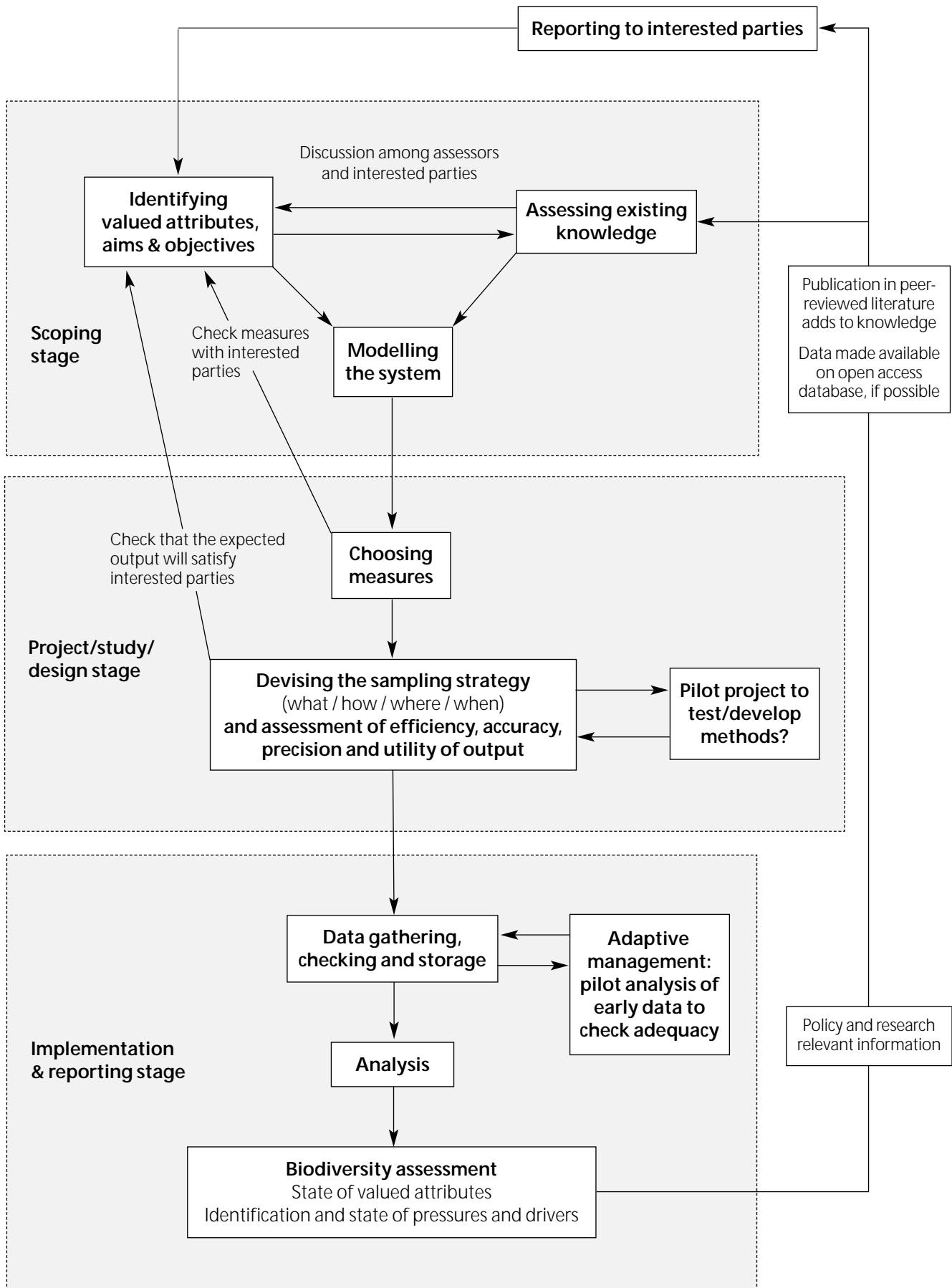
Recommendations

Despite the difficulties of measuring biodiversity, enough is known about the state of global biodiversity to say with confidence that unprecedented rapid losses of biodiversity are occurring. As a step towards halting these losses, better measures of rates of loss are needed, together with information on the geographic areas, habitats and groups of organisms where these losses are concentrated. Better measures, based on sound science, will help assess success in managing biodiversity. A full explanation of these recommendations, and the conclusions from which they are drawn, can be found in the main report (Royal Society 2003).

We make the following recommendations:

1   The framework for biodiversity assessment presented in this report should be applied routinely by those commissioning, funding and undertaking biodiversity measurements. It can be used for terrestrial, freshwater and marine systems, and at the ecosystem, species and population levels. We also believe it is applicable to situations ranging from large, long-term studies to instances where a rapid response is required, and can accommodate differences in the timescales of stakeholder interests. Application of the framework would ensure stakeholder involvement and that measures are fit for the purpose to which they are being applied. It would also help to identify weaknesses in some current approaches as well as major science and information gaps.

2   The scientific community needs urgently to emphasise synthesis that makes otherwise scattered data more readily available and more useful. This needs to be accompanied by a more favourable attitude towards such projects by funding bodies and more widespread use of web-based technology for more effective dissemination of information. Synthesis will also reveal key gaps in knowledge, which should then be addressed by the development of realistic new programmes capable of delivering substantial improvements in knowledge of otherwise poorly understood geographic areas, habitats and groups of organisms. Such programmes must be implemented urgently with realistic goals for completion in the course of the next three to seven years.

3   The scientific community should focus on the development of data gathering and analytical techniques to provide biodiversity information that is both relevant and organised for efficiency. This will involve consideration of sampling strategies (both sample sizes and appropriate stratification); assessment and integration of the relevant drivers of change, including input from the social sciences; better information on the values ascribed to biodiversity by different stakeholders; effective deployment of new techniques from molecular genetics, bioinformatics, remote sensing and e-science; as well as consideration of the role of volunteers and informal methods of data gathering.

4   We recommend enhancing levels of taxonomic training and linking such training more directly to the ongoing measurement and management of biodiversity. Increasing scientific and technical capacity in countries with high biodiversity is crucial. It is especially important to increase the number of professional taxonomists for key groups of organisms, and to ease the problems of identifying a broad range of organisms in the field by the more effective use of appropriate information technology. Low cost approaches to facilitate identification can also be extremely effective. Maximising the efficiency with which the information generated by systematists is transferred and made useful to biologists and non-experts in the field is crucial.

5   The international community and intergovernmental organisations should undertake a review of current programmes for biodiversity status assessment, especially at a global level. Existing monitoring programmes that are already contributing to, or delivering, robust, global assessments of biodiversity must continue. Where possible they should be enhanced and extended. Across both new and existing programmes, there should be a particular focus on establishing a baseline and rates of change so that progress towards reducing rates of biodiversity loss by 2010 can be measured. Expanding existing monitoring programmes and developing new assessments will require a marked increase in funding as well as a degree of co-ordination and co-operation among NGOs, academics, and governmental and intergovernmental agencies.

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