European Academies

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Science Advisory Council

A user's guide to biodiversity indicators

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Foreword

This report is intended to give policy-makers the tools to engage with debates about biodiversity. It comes at a timely moment. The Lisbon aspiration to make the European Union 'the most competitive and dynamic knowledge-based economy in the world' includes a commitment to deliver this in a way that is environmentally sustainable. The EU's 2001 strategy for sustainable development sets the more specific ambition to 'protect and restore habitats and natural systems and halt the loss of biodiversity by 2010'. And, at the global level, initiatives from the 1992 Rio Conference onwards are increasingly focusing attention on biological diversity. The 'Rio + 10' conference at Johannesburg in 2002, for example, endorsed the commitment to 'achieve by 2010 a significant reduction in the rate of biodiversity loss at the global, regional and national level'.

So there is a wide consensus that biodiversity is important and that its protection should be an urgent priority for policy-makers. But that consensus cannot effectively be translated into policy unless we have ways of measuring biodiversity. Only then can we monitor the impact of attempts to protect it and thus know whether our policies are having their intended consequences.

The measurement of biodiversity is not simply an issue for specialist scientists. It is also relevant to policy-makers. Biodiversity is a complex, many-sided concept, and its measurement is equally complex and many-sided. Information about the matrix of measurement tools currently available is an essential pre-requisite to understanding the basic phenomenon, so it is important that policy-makers should have access to such information.

We were therefore delighted that the Environment Committee of the European Parliament asked us to prepare this briefing on biodiversity indicators. EASAC is established by the national science Academies of the EU Member States to enable them to collaborate with each other in providing advice to European policy-makers. The national science Academies of Europe recognise that the scope of their policy advisory functions extends beyond the national to cover also the European level, and policies related to biodiversity are a strong example of this.

The bulk of our report consists of a systematic description of 17 different indicators related to particular aspects of biodiversity and an analysis of their current and potential utility. The introductory chapters address the concept of biodiversity and why it is now such a topical issue. An annex summarises current biodiversity policies and initiatives. Key points are brought together at the beginning of the report.

I should like to give my warmest thanks to Professor Georgina Mace and her colleagues for their energy and professionalism in delivering this report, and doing so within three months. Since the group was drawn from across the European Union and all the members were volunteers, giving their time freely in the midst of other professional commitments, this represents a substantial effort and augurs well for the cause of scientific collaboration in support of European policy.

Professor David Spearman
Chairman, EASAC

1 Summary briefing

1.1 Key points

(i) Biodiversity, or biological diversity, is important: it matters to people and is an indispensable part of a sustainable world. It describes the variety, quantity and distribution of the components of life whether they are species, ecosystems or genes.

(ii) Biodiversity can be measured: indicators and indexes are not perfect, but they are good enough to show which way some of the key components of biodiversity are heading. The crucial issue in developing biodiversity indicators or indexes is to be clear on the specific question about biodiversity that the measuring system is designed to answer. In particular there are biodiversity indicators that measure:
- population trends
- the extent of different habitats
- trends in the status of threatened species
- trends in the impacts of a specific pressure, for example the effect of fishing on fish stocks
- the coverage of protected areas, measuring the total area of natural habitats under protection

(iii) Where it is being monitored, most measures of biodiversity show that it is in decline. The exceptions tend to occur where intensive management action is now reversing recent declines, for example through species recovery plans, biodiversity action plans (BAPs) or in protected areas.

(iv) The European Union has set the challenging target of halting biodiversity loss by 2010, but since the indices/indicators needed for monitoring have only recently been agreed it is currently difficult to know if this is a sensible target or if it can or will be achieved.

(v) There are indicators of biodiversity that could be used right away for reporting to the Spring Council on Sustainable Development within the framework of the Lisbon Strategy. They are:
- European Wild Bird Index (a population trend measure)
- Coverage of protected areas

(vi) For implementation by 2010, the population trend index could be extended to include other well-studied taxa: mammals and butterflies for example. In addition to these, there is a further set of indicators that could be used in reporting at the 2010 target date for halting biodiversity decline. They are:
- Extent of habitats, a development of the EU CORINE Database
- The Red List index, which measures trends in threatened species
- The Marine Trophic index, which measures impacts of fishing on fish stocks

(vii) Although considerable progress is being made at European and International level in agreeing a set of indicators, problems remain. The problems have delayed progress in agreeing and implementing a suite of indicators. In essence the problems fall into three kinds:
- Lack of clarity about what is meant by biodiversity and therefore on how best to measure it. The term ‘biodiversity’ has become so wide in use that all available indices can seem to have drawbacks.
- Lack of political commitment to biodiversity monitoring in member states and an extended debate about cost effectiveness in relation to the monitoring of biodiversity. This is exacerbated by difficulties associated with economic valuation of biodiversity and the services it provides.
- Gaps in knowledge and in data

We believe that these problems can be overcome once they are recognised and incorporated into the process to develop and implement the indicators.

(viii) The IUCN Red List indicator should be immediately investigated for its potential to incorporate all species of Community interest, including those listed in the annexes to the Birds and Habitats Directives. Its relevance to species that are most threatened by extinction and to species on which Community legislation has a particular emphasis make this a high priority indicator for further development.

(ix) Although these current indicators are under vigorous development, in the longer term we need indicators that match more closely the concerns of Europe’s many and diverse communities. These should be designed to measure biodiversity that matters to people and policy-makers in Europe.

(x) In summary, it is perfectly possible to start reporting on biodiversity, using currently available indicators and indexes for the Sustainable Development Report to Spring Council. It would certainly be possible to use the European Wild Bird/Farmland Bird Index and an index based on the area under protection. In the longer term other indicators, of threatened species, extent of habitats and impacts of human pressure, are well on their way.

1.2 The EASAC process

This report has been prepared for a project group supported by EASAC. The membership of the group is given in Annex D. The report has been reviewed and approved for publication by the Council & EASAC. It was commissioned by the Environment Commitee of the European Parliament.

During a visit to the European Parliament on 17 September 2004, Peter Collins, the EASAC Executive Secretary, and John Murlis, the Secretary of the project group, met Officials and Members of the Environment Committee to confirm the scope of the work and the timetable for the report. It was agreed that the work would be in two main parts: a briefing for members of the Environment Committee and a more detailed report for members and advisors.

The project group held its first meeting in London on 23 September 2004 to agree a provisional structure for the report and to assign writing tasks to members. At a second meeting on 21 October 2004, the project group reviewed the work to date, produced a definitive structure for the report and developed outlines for the conclusions and recommendations. The final report was submitted in the European Parliament on 30 November 2004.

1.3 What is meant by biodiversity?

'Biological diversity', or biodiversity, means the variability among living organisms that derives from all sources including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part. This includes diversity within species (at a genetic level), between species and of ecosystems.

Biodiversity at each of these levels of complexity is characterised by:
- Variety, the number of different types
- Quantity, the number or total biomass of any type
- Distribution, the extent and nature of geographic spread of different types

In general terms, biodiversity conveys the biological richness of planet Earth.

1.4 Why is it important?

At the most basic level, biodiversity is important as an element of environmental sustainability.

We humans and our societies are completely dependent on an unknown number of species of animals, plants, fungi, and microbes that produce our food, substances that are needed for health care, and materials for clothing, manufacturing, construction and other purposes. We are also dependent on species that provide indispensable ecosystem functions, such as the biogeochemical processes without which waste would accumulate and productivity of ecosystems would decline. These products and functions have become known as ecosystem services. The economic valuation of these services is a topic of intense debate. Estimates exist on a wide range of scales, from the annual value to farmers of pollination services, to the annual value of well forested water catchments to a major city, and heroic attempts to estimate the annual global value of a number of specific ecosystem services. The estimates produced in these studies are impressive, rising from tens of thousands of Euros to billions of Euros to about the global sum of gross national products.

Apart from these many direct and indirect benefits of biodiversity, humans place existence values on biodiversity: that is, people value the existence of particular species or habitats, regardless of the services they provide, because of the pleasure or meaning they derive from them or the significance they have in cultural terms. Biodiversity is an essential part of humanity's natural and spiritual surroundings. Therefore, when a species disappears there is a feeling of irreversible loss.

Where ecosystems provide essential services for humanity, the existence of critical thresholds is of paramount concern: an ecosystem may become disrupted when a critical amount of biodiversity has been lost or a level of nutrient inputs exceeded. There are indeed well-defined extinction thresholds that characterize the long-term persistence of populations. When a critical amount of habitat has been lost species may decline to extinction rather abruptly.

1.5 Can biodiversity be measured?

Biodiversity it too complex to be fully quantified at the kinds of scale that are relevant to policy. However it is perfectly possible to characterise biodiversity through the use of surrogate measures and there is considerable experience worldwide in the development and application of biodiversity indicators.

Biodiversity measurement is needed because of widespread concern about the loss of biodiversity, the generally inadequate nature of the information on biodiversity currently available, the policy response to the loss of biodiversity, including the EU target of halting the loss of biodiversity by 2010, and the need to take effective action in response to these policies. This requires a much better knowledge of status and trends in biodiversity, of the impact of the main drivers and pressures that determine biodiversity loss, and of the success, or lack of success, of policies and practices designed to conserve and/or restore biodiversity.

This process is commonly referred to as biodiversity assessment, rather than biodiversity measurement, because the measurements are made to assess, for example, the state of biodiversity in relation to one or more of the following: a baseline, target, pressure or policy response.

1.6 What progress is being made at European and global levels?

Following the adoption of the 2010 target at global, regional and EU levels, progress has been made in agreeing core sets of indicators for reporting and to support the achievement of the 2010 target. Globally, within the Convention on Biological Diversity (CBD), eight biodiversity indicators are considered ready for immediate testing while another 13 require further development.

In the Pan-European region the Kyiv Resolution on biodiversity calls for the development of a core set of biodiversity indicators to monitor progress in achieving the European 2010 biodiversity target. A set, based on the CBD indicators, is proposed for approval by the Council of the Pan-European biological and landscape Diversity Strategy.

For the EU, a set of European biodiversity headline indicators was adopted at the Malahide stakeholder conference 'Biodiversity and the EU: Sustaining life, sustaining livelihoods' in May 2004. The European Parliament has expressed a particular interest in biodiversity reporting, and the outgoing European Environment Commissioner Margot Wallström has responded positively.

At each level, then, there is progress in developing the indicators of biodiversity that will assess progress towards the 2010 target of halting biodiversity decline.

1.7 What could be done now?

Our independent assessment of available indicators suggests that there is a range of indicators for which there is an established methodology, and for which data exist. Several of these can be implemented immediately, in particular, the following biodiversity 'state' indicators:

- *Measures of population trends*. Foremost among these is the Wild Bird Indicator, derived from annual breeding bird surveys from 18 European countries, obtained through the *Pan-European Common Bird Monitoring Scheme*. The survey covers 24 birds characteristic of either woodland or agricultural habitats in Europe, selected by experts. These, and similar data sets, can immediately be used to examine trends and provide comparisons between habitats, areas and management practices.

- *Measures of habitat extent*. The CORINE habitat classification is established and the database from 1990 is already being updated for 2000. This information could form the basis for an ongoing indicator reflecting the area and extent of ecosystem classes, and the way that this is changing over time. Further work will be needed to turn this into an indicator. The reassessment will have to be completed and a methodology will have to be developed to derive a composite indicator from the many classes of ecosystem that CORINE contains.

- *Measures of changes in threatened species*. The trend towards extinction is measured by the Red list index, and forms an indicator that is complementary to the population trends index above. Many of the assessments of species extinction risk that underpin this indicator exist, and where they do not exist already, there are networks in place to develop them. The methodology is already established.

- *Measures of fishing impacts on marine fishes*. The Marine Trophic Index, which measures the changing status of fisheries catches, has been shown to be an effective indicator of fishing pressure. It seems likely that this indicator could be adapted for freshwater exploitative fisheries too, thereby providing a means to balance the terrestrial systems that dominate most of the other indicators.

There is also one measure of the policy response to biodiversity loss that is available immediately:

- *Coverage of protected areas*. This information on the extent of protected areas in Europe is already available and highly relevant.

This set of indicators provides information on some key dimensions of biodiversity, and already exists for the EU area, or could be put together from existing initiatives. Importantly, these indicators are all also part of the set chosen by the CBD for their 2010 assessments. Hence we recommend their immediate adoption and implementation.

1.8 What is stopping it?

First, 'Biodiversity' has evolved into an umbrella concept that can include practically everything about the living world, from the genetic composition of populations to the viability of particular populations to the structure and species richness of communities to the structure of their habitats to the functioning of ecosystems. It is impossible to derive a simple and practical indicator that would reliably cover all these aspects simultaneously. Any suggested indicator can appear inadequate because it fails to reflect some particular aspect, and this aspect may be particularly important to some particular community, context or conservation concern.

Second, there has been insufficient political will to tackle the key issues about preserving biodiversity, because of the common perception that doing so would primarily mean additional costs and with the benefits being less easy to define in monetary terms and to assign to particular interest groups.

Finally, there are certainly important gaps in data and knowledge that limit indicator development. Poorly known habitats and ecosystems, and poorly understood dynamics within natural systems can appear to be obstacles to progress. Lack of expertise on particular groups of organisms and the decline in taxonomic expertise has also limited some initiatives.

However, once the political will is there to stop the decline in biodiversity, it is definitely possible for ecologists and other scientists to deliver relatively simple measures and indicators of biodiversity that would widely be considered as sensible approximations of the complex set of (ideal) indicators that would accurately reflect all possible aspects of biodiversity.

One particular way to address societal concerns would be to define the biodiversity that communities want and need for different purposes and to develop indicators that reflect these values.

1.9 Is this a problem?

Yes. European targets are not backed at present by an effective monitoring system. It is impossible to know if targets are feasible (there is, for example, no agreed baseline) nor what progress is being made to halt the decline in biodiversity.

1.10 What further needs to be done to produce a better framework for monitoring?

- Develop indicators that resonate with society's concerns. This will require studies to define the biodiversity that communities want and need for different purposes and the development of indicators that reflect these values.

- Improve data: we need large-scale inventories and to realise the potential for using NGO inputs of expertise and data. There is an urgent requirement for the development of common protocols for data collection across Europe.

- There are many initiatives in Europe; existing mechanisms for European coordination need to be enhanced.

- Get the message across by putting at least one biodiversity indicator in the in Structure Indicators for reporting to Spring Council.

- More support is needed for scientific programmes aimed at development of biodiversity indicators.

- Higher level of commitment for research. Setting biodiversity in a priority framework for European research funding. There is now a major opportunity to do this in the seventh framework programme.

1.11 Recommendations

(i) Adopt the following indicators now:
- European Wild Birds Index
- Extent of protected areas

(ii) Test the following indicators now:
- Corine Habitat Classification
- The Red List of threatened species
- The Marine Trophic Index

(iii) In our view these would make adequate proxy measures for current policy purposes, notably the assessment of the 2010 targets.

(iv) The questions being asked must be sharpened. In particular, more effort should be made to develop an understanding of the values attached to biodiversity by different public constituencies in Europe and to build indicators that are matched to these public concerns.

(v) The European Parliament should comment to the Commission that the two indicators/indexes that are ready now should be included in the sustainable development report to the Spring Council.

(vi) Encourage on DG Research of the European Commission to include the development, implementation and further refinement of biodiversity indicators explicitly within the framework of the European Union's Seventh Framework Programme.

(vii) Consider how the expertise and data of NGOs can be mobilised in support of European biodiversity indicators.

(viii) Support the work of European coordination initiatives.

2 Introduction

2.1 What is biodiversity?

Biodiversity is a common contraction of 'biological diversity'. Strictly speaking, according to the Convention on Biological Diversity, 'Biological diversity' means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems. In more general terms, biodiversity conveys the biological richness of planet Earth. It is the outcome of the long and elaborate process of evolution of life and includes all the products of that history, most of which is long gone. Contemporary species share common ancestors and represent the ability of life on Earth to renew and reform in the face of continuing environmental change. The populations of different species have unique and special adaptations to their place in the web of life, and people too are part of that web.

In the face of this elaborate complexity, biodiversity is most commonly measured at these three levels:
• Genes
• Species
• Ecosystems

At each of these levels measures may represent one of any of the following:

• *Variety*, reflecting the number of different types. For example, this could refer to different species or genes, such as how many bird species persist in an area, or how many varieties of a genetic crop strain are in production.

• *Quantity*, reflecting how much there is of any one type. For example this might include the population size of a species in a particular area, or the biomass of a fish species exploited by a fishery.

• *Distribution*, reflecting where that attribute of biodiversity is located. For example, having all the world's pollinators present but only in a single location will not meet the needs of the plants that depend upon them.

In practice the relevant measure and attribute depends upon the role being assessed. Broadly speaking, and according to our present level of understanding, variability is more significant at the genetic level and at the species level, whereas quantity and distribution are more significant at the population and ecosystem levels. For most ecosystem services, local loss of biodiversity is most significant; but for future option values, existence values and for certain services such as genetic variability and bioprospecting, global loss is the primary consideration.

Biodiversity conservation is often and inappropriately equated with the prevention of species extinction at a global level. This approach – ie the loss of one species from the biosphere – has a strong emotional appeal, but misses the important fact that losses of species or populations at local level are often more significant. At local levels they have been playing some ecological (or social) role.

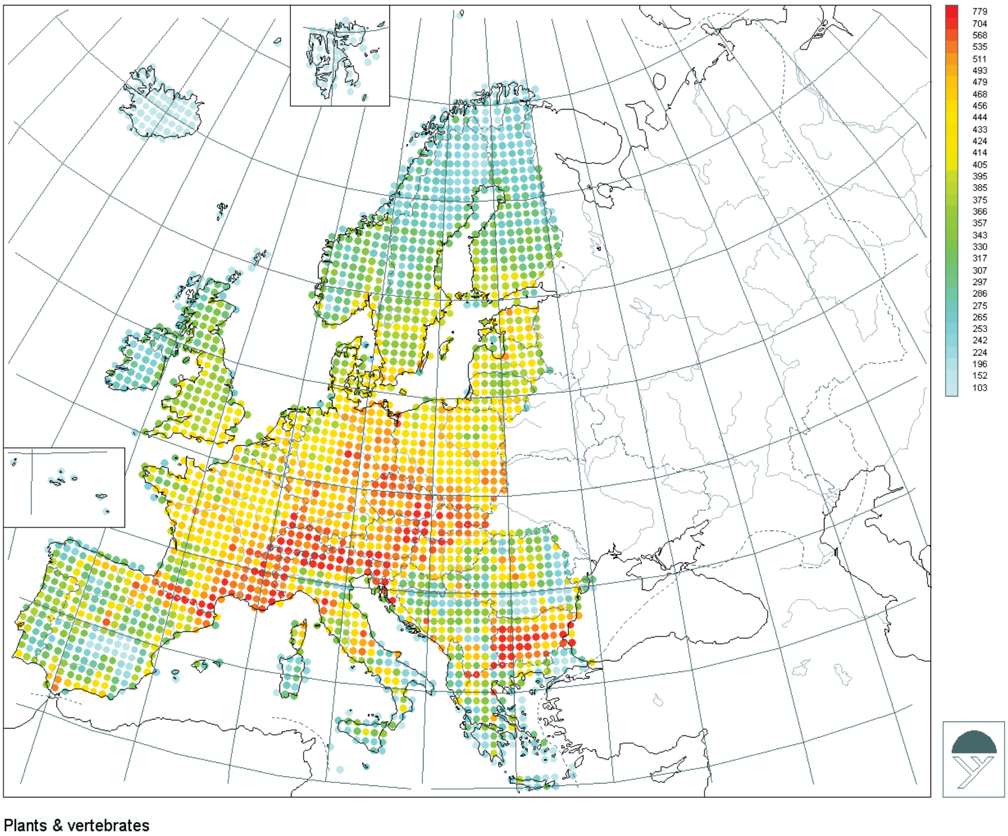
2.2 Biodiversity in Europe

In pre-agricultural times most of the lowlands of Europe were covered in closed or semi-closed forest or appeared as a park-like half-open forest (Vera, 2000). Whatever its original nature, the advent of agriculture dramatically changed vegetation patterns over much of the Continent, and the economic and technological revolutions starting towards the end of the nineteenth century have further changed the face of most of Europe. Now almost all areas are directly affected by human activities. In the North West, in areas with the highest economic development and human population density, natural ecosystems have mostly been lost and persist only as small and marginal zones amidst the extensive areas dominated by agriculture and urban development. Central and Eastern Europe, for example, still contain areas of natural and semi-natural habitats. The Mediterranean region retains a range of traditional agricultural and pastoral landscapes, with a rich biodiversity both in the mainland and islands (Garcia Novo 2003). For the most part, however, the pattern is of change. Here we have the opportunity to learn from the past and manage economic development more sustainably.

Compared to many areas of the world, especially the tropics, biodiversity in Europe is relatively low in overall richness. Yet within the continent many diverse habitats and species assemblages are found, sometimes restricted to particular small areas. On a global scale, the Mediterranean is the one eco-region that extends into Europe that is recognised as an area of exceptional species richness and threat (Myers et al 2000). The spatial pattern of biodiversity variation across Europe, a product of gradients in our climate, landforms and geology, and shaped by the rather recent glacial episodes, is the backdrop to cultural and economic development. Maintaining these spatial patterns is as significant as preserving the overall diversity of species and habitats.

This rich diversity is difficult to summarise. But consider the significance for people and local resources of Europe's wetlands, stretching from the sub arctic to the Mediterranean, and the extensive and diverse coastlines including marine areas, sand dunes, cliffs and coastal meadows. Heathlands, a product of human activities thousands of years ago, are valued for their distinctive fauna and flora, and for their cultural landscapes. Yet both are extremely vulnerable to changing environmental conditions and intrusion by human urban, recreational and transport infrastructures. Only about 2% of Europe's forest cover is natural, and sustainable management of forested areas remains a challenge across the continent. The natural and semi-natural grasslands, a distinctive European habitat resulting from extensive agricultural practices of the past are outstanding for their species richness, especially for flowering plants and invertebrates. These areas have been greatly impacted by intensive agriculture, husbandry and urbanisation, and face further threats from land drainage, re-afforestation and de-afforestation, fertilizer usage and land abandonment. Some of the most distinctive and diverse European habitats are the mountainous areas (see Figure 1). Here the altitudinal zoning is associated with many distinct species and habitats, yet these areas too are subject to a range of complex challenges, originally from agricultural and pastoral practices, and increasingly today as a result of competing recreational uses. Climate change is emerging as a potential major threat to mountain areas.

Figure 1 Map of species richness



Plot of combined records from atlas data for vascular plants, amphibians, reptiles, breeding birds and mammals among 50x50 km grid cells (total 3143 species, 2435 grid cells). Species richness counts are divided into 33 colour-scale classes (shown right) of approximately equal size by numbers of grid cells, with maximum richness shown in red and minimum richness in light blue. This option for an equal-frequency colour scale is used to maximize geographical differentiation of regions within a map. Svalbard and the Azores are shown displaced relative to the mainland and in boxes. (Source: WORLDMAP)

2.3 Why does it matter?

We humans and our societies are completely dependent on an unknown number of species of animals, plants, fungi, and microbes that produce our food, substances that are needed for health care, materials for clothing, manufacturing, construction and other purposes. We are also dependent on species that provide indispensable ecosystem functions, such as biogeochemical circulation of essential elements, without which waste would accumulate and productivity of ecosystems would decline. These products and functions are what have become known as ecosystem services (MA 2003, Daily 1997). Apart from these many direct and indirect benefits of biodiversity, people place existence values on biodiversity, that is they value the existence of particular species or habitats independently of the ecosystem services they provide (Balvanera et al 2001, Goulder and Kennedy 1997). Biodiversity is an essential part of humanity's natural and spiritual surroundings. Therefore, when a species disappears there is a feeling of irreversible loss that is felt by contemporary and future generations. Some authors will even go further and argue that biodiversity has an intrinsic value that cannot be analyzed from an utilitarian or anthropocentric point of view (Rosa 2004).

2.3.1 Biodiversity and ecosystem services

The Millennium Ecosystem Assessment classifies ecosystem services in four broad categories (Figure 2). Provisioning services are the products obtained from ecosystems such as food, timber and biochemical resources (eg medical substances). Regulating services are the benefits obtained from the regulation of ecosystem processes such as carbon sequestration and run-off regulation. Cultural services are the nonmaterial benefits obtained from ecosystems such as recreation (eg bird watching) and the cultural heritage associated with traditional or natural systems. Finally, supporting services are the services necessary for the production of all the other services, including soil formation, primary productivity and keeping the oxygen concentration of the atmosphere at a steady level.

Different components of biodiversity provide different ecosystem services. Consider for example the services provided by different ecosystems in a river basin (Heal et al 2001). A forest provides timber, water purification and flood control, farmlands provide food and wetlands provide flood control, water purification and recreation. Some services are associated with species diversity while other services are associated with the abundance of particular species. For instance, primary productivity increases with species richness (Tilman 2001, Hector 1999), and ecosystem resilience and stability can be highly affected by species loss (McCann 2000, Loreau et al 2001, Tilman and Downing 1994). In contrast, timber production depends on the abundance and distribution of highly-valued or productive timber species.

The existence of critical thresholds in ecosystems is of paramount concern: an ecosystem may become disrupted when a critical amount of biodiversity has been lost or a level of nutrient inputs exceeded. There are indeed well-defined extinction thresholds that characterize the long-term persistence of populations. When a critical amount of habitat has been lost species may plummet to extinction abruptly. The precautionary principle suggests that biodiversity losses should be minimized to minimize the risk of sudden loss of stability and ecosystem function.

Several studies have assessed the economic value of ecosystem services. For instance, pollination services from two forest fragments of a few dozen hectares were valued in approximately 50,000 per year for one Costa Rican farm (Ricketts et al 2004). The acquisition of forest in the Catskills watershed area and other protection efforts has saved New York City around $5 billion, based on the estimated cost of the alternative, a filtration water plant (Salzman et al 2001). An assessment of the value of 17 ecosystem services, including provisioning, regulating, cultural and supporting services, estimated the annual value of those services at the biosphere scale at US$16-54 trillion (Constanza et al 1997), which is of the same order of magnitude as the global gross national product. Another global assessment found that in many instances the overall benefit from ecosystem services of protecting remaining natural habitats is at least 100 times greater than conversion to human-dominated uses (Balmford et al 2002).

Figure 2 A classification of ecosystem services provided by biodiversity (MA 2003)

Provisioning services
Products obtained from ecosystems

- Food
- Fresh water
- Fuelwood
- Fiber
- Biochemicals
- Genetic resources

Regulating services
Benefits obtained from regulation of ecosystem processes

- Climate regulation
- Disease regulation
- Water regulation
- Water purification
- Pollination

Cultural services
Nonmaterial benefits obtained from ecosystems

- Spiritual and religious
- Recreation and ecotourism
- Aesthetic
- Inspirational
- Educational
- Sense of place
- Cultural heritage

Supporting services
Services necessary for the production of all other ecosystem services

- Soil formation
- Nutrient cycling
- Primary production

One may ask how much biodiversity can we afford to loose before it affects the quality of our lives? Though it is clear that ecosystem functioning is not equally affected by all species, ecologists have no way of reliably predicting which species are of no value now and in the future. History shows that new utilitarian values of biodiversity are constantly discovered, and species that were previously thought to be of no benefit at all have turned out to provide significant or even crucial benefits. These are also known as option values. Taking into account that the cost of protecting biodiversity at an adequate level is modest in comparison with many other expenses, protection of biodiversity is rightly seen as an essential component of sustainable development.

2.3.2 Existence and intrinsic values of biodiversity

Existence values of biodiversity can be seen as a cultural service provided by ecosystems. Existence values are often assessed by the Contingent Valuation Method. This method consists in asking a sample of individuals their willingness to pay for a given change not to occur, for instance the willingness to pay to protect a species from extinction. For instance, the existence value lost with Exxon Valdez oil spill was estimated to be $2.75 billion for the English-speaking households in the USA (Perman et al 2003). While the reliability of values estimated by Contingent Valuation has been under debate (Perman et al 2003), there is much evidence for existence values that people place on emblematic species or habitats. Environmental NGOs, natural history books, and nature television channels, are among the strongest manifestations of existence values placed on biodiversity by people at large. Another non-use value associated with biodiversity is option-values, the premium that an individual is willing to pay to guarantee that biodiversity will be available for future use by that individual, and bequest values, the value that an individual ascribes to preserving biodiversity for future generations (Bawa and Gadgil 1997).

In contrast to the utilitarian view of the world expressed above, Kantianism defends some things as priceless because they have an intrinsic value: 'Everything has a *price or dignity*. Whatever has a price can be replaced by something else as its equivalent; on the other hand, whatever is above all price, and therefore admits of no equivalent, has a dignity' (Kant 1959). Many cultures and religions consider that biodiversity has an intrinsic value (MA 2003). For instance, in the Judeo-Christian tradition, plants and animals are creatures of God, and St. Francis of Assisi taught universal brotherhood with all animals and plants. In the past few decades, several bio-ethicists have called for the need to consider both anthropocentric and biocentric perspectives of the conservation of nature (Rosa 2004, Goulder and Kennedy 1997). In the anthropocentric perspectives, only the interests of humans are important. This perspective is well represented in classical utilitarianism where aggregate human happiness is the goal of social policy (MA 2003). In the biocentric perspective all living creatures have interests and count independently of their interest for humans. Intrinsic values are a key component of the biocentric perspective.

One of the ethical issues raised is whether humans have the right to exterminate other species with whom we share the Biosphere. The diversity of life on Earth is the result of over 3 billion years of evolution. Humans are the species with largest impacts on biodiversity and at the same time are the only species aware of the consequences of their decisions on the fate of other species.

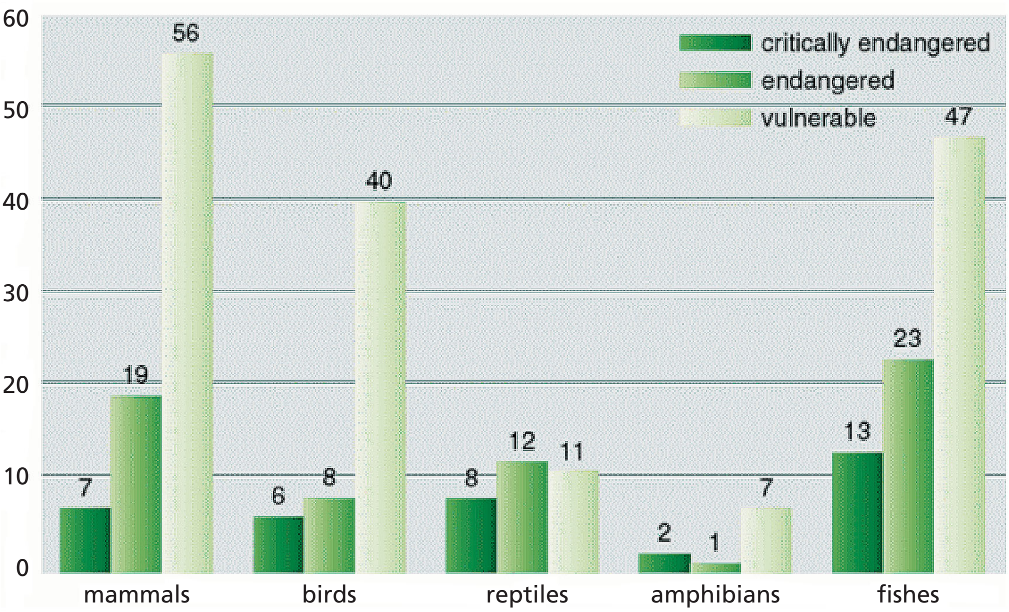
2.4 What is happening to biodiversity?

Habitats and ecosystems on Earth have always been in a state of change, which has led to evolutionary changes in the species and caused extinctions of species throughout the history of life. The rate of change has been very slow, excepting some catastrophic events such as the impact of asteroids that have collided with our planet. The long-term trend for the past 500 million years has been towards greater diversity.

The natural rate of species extinctions can be calculated for mammals, for which there exist comprehensive fossil data. The lifetime of mammalian species in the fossil record is roughly 2 million years, hence we would expect one extinction per species in two million years. Currently there exist about 5000 species of mammals, which puts the predicted natural rate of extinctions at one species per 400 years. In reality, about 50 mammal species have gone extinct in the past 100 years, and thus the current rate of extinctions is about 200 times higher than the natural rate. Other estimates based on other data suggest that the current extinction rate is 100 to 1000 times greater than the natural rate, and the rate of extinctions is accelerating (May et al 1995). For example, bird extinctions have been nearly twice as frequent in the past 100 years as in 1600-1900 (Groombridge 1992). The extinction rate will further accelerate rapidly in this century if the pressures from the main drivers of biodiversity loss are not reduced.

Globally, the best-known groups of animals are mammals and birds, of which 24% and 12% respectively are extinct, threatened, or near-threatened (IUCN 2003, http://www.redlist.org). At the European level 12% of the 576 diurnal butterfly species known to occur in Europe are regarded as threatened (Van Swaay & Warren, 1999). Our knowledge is much more limited about other groups of species, but their level of threat appears to be even higher. Among the species of reptiles, amphibians, fishes, and plants for which sufficient data are available to allow the assessment (<10% of all species), 40 to 70% of the species have been classified as extinct, threatened, or near-threatened (IUCN 2003, http://www.redlist.org). Figure 3 shows the numbers of globally critically endangered, endangered, and vulnerable species of vertebrates that occur in Europe. There are altogether 260 such species in Europe.

Figure 3 Numbers of critically endangered (extremely high risk of extinction in immediate future), endangered (very high risk of extinction in near future), and vulnerable (high risk of extinction in medium-term future) species of vertebrates in Europe (Source: GEO-3 2002)



Global extinctions are irreversible and hence most harmful for the intrinsic value and existence values of biodiversity, while local and national deterioration of biodiversity damages the many direct and indirect benefits that nations derive from species and ecosystems. It is hence not sufficient to work towards reducing the global rate of extinctions, it is important to halt the decline of biodiversity at local and national scales. Table 1 describes the current level of threat to the exceptionally well known fauna and flora of Finland in the boreal region in northern Europe, and to the less well-known fauna and flora of Portugal in southern Europe. These figures indicate that 19% of all the species in Finland are nationally extinct, threatened, or near-threatened, while the corresponding figure for vertebrates, butterflies, and bryophytes in Portugal is

31% (for the other species in Portugal no assessment has been made so far). Comparable or even higher figures are likely to apply to most European countries.

The above figures reveal that biodiversity is lost at all scales, from local to global, and that the level of threat preceding complete loss appears to be relatively uniform across different groups of species (Table 1). The similarity across spatial scales and different kinds of organisms is likely to reflect the fact that the major driver of declining biodiversity locally, nationally, and globally is habitat loss and fragmentation, which occurs everywhere and affects all groups of animals, plants, and fungi. Loss and fragmentation of natural habitats can be attributed to agriculture, forestry, urbanization, construction of infrastructure, and tourism (Delbaere 1998). For instance, by 1950 only about 30% of the Mediterranean forest biome remained, and since then an additional 2.5% has been lost (Mace *et al* 2005). Even higher rates of conversion of forest occur in the tropical biomes, where current annual rates of forest loss are about 0.6-0.8% (Achard et al, 2002; FAO, 2001). In some parts of Europe the trend in forest cover has been different. For instance, in Portugal forest cover has increased by more than 50% over the last century (Pereira et al, *in press*). Nevertheless, the increase in forest cover is essentially due to plantations of monocultures of pine and eucalyptus, which have low biodiversity (Pereira et al, *in press*). In the boreal forest region in northern Europe, forest cover is high and not declining, but intensive forestry has turned natural forests into intensively managed production forests with even-aged stands of single tree species. Such forests lose most of the ecologically specialized species of animals and plants (Hanski 2000). The disappearance of wetlands over the last century in Europe has been dramatic, ranging from 60% in Denmark to 90% in Bulgaria (EEA 2003). Another important change occurring in Europe is the decrease of low-intensity farming systems, which supports high level of biodiversity (Bignal et al, 1996; EEA, 2004a). For instance, in Finland the loss of habitats associated with traditional low-intensity agriculture is the second most important cause of threat to biodiversity following forestry (Rassi et al 2001).

Table 1 Nationally extinct (EXT), threatened (THR), and near-threatened (NTHR) species of plants, animals, and fungi in Finland and Portugal

	Finland			Portugal		
	EXT	**THR**	**NTHR**	**EXT**	**THR**	**NTHR**
Vertebrates	2.3%	14.5%	14.0%	0.2%	11.7%	3.6%
Invertebrates/butterflies*	1.2%	8.8%	6.7%	-	28.0%	24.2%
Vascular plants	0.6%	14.9%	7.7%			
Spore plants/bryophytes*	2.8%	15.8%	12.0%	13.8%	27.6%	45.1%
Fungi	1.0%	9.3%	5.8%			
Total	**1.4%**	**10.4%**	**7.4%**	**2.6%**	**15.8%**	**12.7%**

Note: Sufficient data to assess the level of threat were available for 35% of the estimated total of 43 000 species in Finland, and for 49% of the 1751 species in the assessed taxa in Portugal. The vast majority of species in Portugal belong to taxa that were not assessed.

** For Finland the figures in the table are for invertebrates and spore plants, for Portugal the figures are for butterflies and bryophytes.*

Sources for Finland: Rassi et al (2001). Sources for Portugal: (1) Almeida, P.R. et al (eds.), in preparation: Livro Vermelho dos Vertebrados de Portugal - Revisão. Instituto da Conservação da Natureza, Lisboa. (2) Magalhães, F. and L. Rogado (eds.), 1993: Livro Vermelho dos Vertebrados de Portugal: Peixes Marinhos e Estuarinos. Vol. 3. Serviço Nacional de Parques, Reservas e Conservação da Natureza, Lisboa, 146 pp. (3) Maravalhas, E. (ed), 2003, As Borboletas de Portugal. Vento Norte, Lisboa, 455 pp.(4) Sérgio, C., C. Casa, M. Brugués and R.M. Cros. 1994. Lista Vermelha dos Briófitos da Península Ibérica. Museu, Laboratório e Jardim Botânico da Universidade de Lisboa, Instituto da Conservação da Natureza. Lisboa.

Biodiversity loss also occurs through climate change, impact of invasive species, harvesting and persecution. Many of these factors are more specific to certain groups of species, and their impact varies geographically. Climate change has already caused significant changes in the geographical distribution of species (Parmesan et al 1999; EEA, 2004b) and in their seasonal occurrence (Parmesan and Yohe 2003, Root et al 2003). The predicted change in average global temperature by the year 2050 will cause such great changes in the habitats and ecosystems that an estimated 15 to 37% of species on Earth will become endangered (Thomas et al 2004a). No similar analysis has been carried out for Europe, but a comparable level of threat can be expected especially to those species that occur in distinct habitats on mountains and at extreme latitudes, from where the habitats and the species associated with these habitats cannot move to anywhere. Climate change will have particularly harmful effects anywhere where natural habitats have become highly fragmented, which hinders the movement of species' geographical ranges (Warren et al 2001).

Considering the temporal scale of biodiversity loss, it should be noted that populations and species respond to environmental changes with a characteristic time lag, and this time lag is likely to be long (decades or even centuries) at large spatial scales (Sala et al 2005). Therefore the full impact of current environmental changes will not be seen until some time in the future (Hanski and Ovaskainen 2002). This observation has the important corollary that we are likely to underestimate the long-term impact of habitat loss and other environmental changes to biodiversity, because we do not observe the changes in biodiversity immediately. Both the dynamics of biodiversity loss and the dynamics of climate change exhibit relatively slow response time.

2.5 The need for measurement and assessment

The measurement of biodiversity is needed because of widespread concern about the loss of biodiversity, the generally poor level of information on biodiversity currently available, the policy response to the loss of biodiversity, including policies with targets that oblige EU Member States and signatories to the CBD to halt or significantly reduce the loss of biodiversity by 2010, and the need to take effective action in response to these policies. This requires a much better knowledge of status and trends in biodiversity, of the impact of the main drivers and pressures that determine biodiversity loss, and of the success, or lack of success, of policies and practices designed to conserve and/or restore biodiversity.

This process is commonly referred to as biodiversity assessment, rather than biodiversity measurement, because the measurements are made to assess, for example, the state of biodiversity in relation to one or more of the following: a baseline, target, pressure or policy response.

Biodiversity assessment can only be done through indicators: biodiversity is too complex to be fully quantified at scales that are policy relevant. Complex, time-consuming approaches to biodiversity assessment also fail to deliver information quickly enough to aid decision-making by policy makers and other stakeholders.

Baseline values (for biodiversity) are difficult to set. We know very little about even recent trends in the abundance of most species apart from some insects in restricted parts of Europe (eg Southwood et al 2003) and, more generally, birds (eg BirdLife International 2004a). Information on habitat change is better: detailed maps of potential vegetation exist for Europe, some of them very detailed (Bohn 1995, Larsson et al 2001). However, these maps ignore evidence of significant shifts in the distribution of forest habitats from the pollen record (eg Bradshaw et al 2000). The pollen record also shows marked changes in plant species richness and composition (eg Hannon et al 2000). Consequently, the choice of baseline may be as much a political as an ecological decision. However, in the face of ecological uncertainty, it may be better to adopt a pragmatic approach and to set the conditions at the start of a monitoring programme or at the year an international treaty came into force as a baseline.

Although the definition of biodiversity baselines is problematical, it has not prevented the establishment of general and specific targets for biodiversity. In the UK, for example, targets for species and habitat action plans have been established. These targets rarely refer explicitly to a specified baseline but nevertheless implicitly relate to knowledge of, or assumptions concerning, historical trends in biodiversity. The issue of baselines is discussed in the CBD paper UNEP/CBD/SBSTTA/5/12.

Biodiversity indicators must supply significant/meaningful information to policymakers and others. For policymakers in general this information should provide an indication of how effective policy is – a lever for taking measures. The information must, therefore, be able to indicate cause-effect relationships and provide a reliable trigger for action. For high-level policymakers the information should provide a broad indication of the level of overall biodiversity – an indicator, index or proxy measure to bring the message across. The information must, therefore, bring across a message by communicating complex issues in simple terms. For other stakeholders the amount of information necessary varies according to the needs.

Information on status and trends in biodiversity is confounded by natural variation in the abundance of species, habitat succession and disturbance. Marked sudden change in the abundance of species may be of no long-term significance, but a long-term decline is clearly a cause for concern. Expert interpretation of indicator trends is therefore critical. The *State of the UK's Birds and Pan-European Common Bird Index* give good examples of meaningful presentation of indicator trends (eg Easton et al 2004, BirdLife International, 2004b).

Information on biodiversity is usually collected locally but biodiversity indicators report trends at local, national or international scales and are used in support of policies at all these scales. The level of detail and accuracy of policies increase from the global to the local scale and so does the level of detail in the measurement of biodiversity: for example, the management of a NATURA 2000 site will require detailed assessments of biodiversity. It is impossible to base policies at national level on such detailed assessments: aggregation of information collected at local scales or the collection of less complex information at national scales is necessary to support national and international policies. Aggregation of data to wider geographical scales may also help to solve the problem that natural variation in biodiversity may create misleading results, although this conclusion, in part, assumes that natural drivers act locally, rather than regionally, and this is clearly not always the case (Liebhold and Kamata 2000). However, aggregation of information may also mask significant changes in biodiversity at local scales.

2.6 Drivers of change

Drivers of change are the causal processes driving biodiversity change within Europe. Most important trends affecting Europe's biodiversity are due to agriculture, forestry, urbanization, infrastructure development and tourism (EEA 1998). Climate change is a more recently recognised driver that may have particularly significant consequences for northern, high altitude, coastal areas and for species with very restricted ranges and limits to dispersal.

Delbaere (1998) provides the following overview.

(i) *Agriculture*. The polarization of Europe into regions of intensive agricultural production and regions where the land is being abandoned is a major issue. The intensification of agriculture involves changes in crops, rotation rates, and grazing coverage and intensity. In the Central and Eastern European region in particular, changes in farm structure – privatization and an increase in scale – have a considerable impact on biological and landscape diversity. Abandonment is a major problem in the Less Favoured Areas (areas with poor soil and/or climate conditions), which are found mainly in the Mediterranean region, Ireland, Scotland and the Nordic countries (Baldock et al, 1996).

Although the primary objective of agricultural policies is still to raise yields, the rate of use of inorganic fertilizers and pesticides has decreased during the last decade, particularly in Western Europe. During the same period organic farming has expanded to cover about 6% of the agricultural land in the EU in 1995; and 10% to 15% of the arable land area has been brought under the EU set-aside regulation. Agricultural land in regions that in the past were farmed less intensively, because of the climate, soil or economic conditions, is now being abandoned. In some regions (eg mountains) this leads to reduced biodiversity, the impacts being more pronounced in areas where small-scale traditional farming methods predominate.

(ii) *Forestry*. The overall forest cover in Europe is increasing, but only a very limited percentage of Europe's forests retain some natural values. Many forests are managed primarily for the production of timber, but environmental concerns are increasingly being taken into account through sustainable forest management and certification schemes for environmentally sound timber production. These practices are mostly concentrated in Western and Northern Europe. In the Mediterranean region afforestation with exotic species is increasingly common and has a deleterious effect on biodiversity. The Mediterranean and Eastern European region are also confronted by the impacts of forest fires, most of which have non-natural causes.

(iii) *Urbanization and infrastructure*. Urban development and new infrastructure have a direct impact on habitat coverage and coherence, species populations and landscapes. The urban population in Europe has continued to increase and European cities continue to show signs of environmental stress in the form of poor air quality, excessive noise, traffic congestion and loss of green space. All these have a direct or indirect effect on animal and plant populations, weakening or driving them out. As regards urbanization the growing interest in Local Agenda 21 being shown by European cities is a positive development. The expansion of the Trans-European transport networks, in particular, is a major concern. Habitat destruction, habitat fragmentation, and barrier effects are direct impacts that lead to the isolation or extinction of populations. Indirect impacts include noise and light disturbance, emissions of air-borne pollutants and pollution from run-off. A positive development is the implementation of environmental impact assessments as a standard procedure in Europe, and the application of mitigation measures such as fauna passages (EEA, 1998).

(iv) *Tourism*. With over 60 million tourist arrivals per year (CIPRA, 1998) the Alps are one of the most heavily affected tourist destinations in Europe. Another region clearly under high pressure from tourism is the Mediterranean coast; but other European regions, particularly now in Eastern Europe, are also harmed by direct and indirect impacts of the tourism industry (construction of infrastructure, increased consumption of natural resources and increased pollution, high levels of disturbance). Tourism is likely to grow in Europe, and the World Tourism Organization foresees an increase of 3% per year in tourism arrivals in Europe in the next two decades. Fortunately, the major international tourist organizations are increasingly aware of their responsibilities and promote ecotourism and other methods of sustainable tourism, and in various regions projects to balance the needs of tourism and nature conservation are being implemented.

Most of the driving forces described here are related to another indirect driving force, that of climate change resulting from higher emissions from agriculture, industry and transport and from an increase in built area.

2.7 Progress in developing indicators

Following the adoption of the 2010 target at various levels (see Annex B for an overview of policy development), progress has been made in agreeing core sets of indicators to report and help achieve the 2010 target. The key sets that have been agreed are briefly described below. Annex B describes in more detail some of the initiatives towards implementing biodiversity indicators.

The Convention on Biological Diversity: the 7th Conference of the Parties (COP7) adopted in its Decision VII/30 a framework to:
- facilitate the assessment of progress towards the 2010 target and communication of this assessment;
- promote coherence among the programmes of work of the Convention;
- provide a flexible framework within which national and regional targets may be set, and indicators identified.

Eight indicators were considered ready for immediate testing while another 13 indicators required further development (see Annex B).

For the Pan-European region the Kyiv Resolution on biodiversity calls for the development of a core set of biodiversity indicators to monitor progress in achieving the European 2010 biodiversity target. A set, based on the CBD indicators, is proposed for approval by the Council of the Pan-European biological and landscape Diversity Strategy.

For the EU level a set of European biodiversity headline indicators was adopted at the Malahide stakeholder conference 'Biodiversity and the EU: Sustaining life, sustaining livelihoods' in May 2004, and subsequently endorsed by the European Environment Council in June 2004.

2.8 Why has it been so difficult to make progress?

Despite the popular appeal of biodiversity, the abundance of information, and the wealth of policy initiatives, progress in developing and agreeing a set of biodiversity indicators has been limited. There are several good reasons why progress has been limited, and recognising what these are may be an important step towards overcoming the obstacles of the past.

First, biodiversity encompasses everything about the living world, from the genetic composition of populations to the viability of particular populations to the structure and species richness of communities to the structure of their habitats and the functioning of ecosystems. It is impossible to derive a simple and practical indicator that would reliably cover all these aspects simultaneously. Any suggested indicator can therefore appear inadequate because it fails to reflect some particular aspect, and this aspect may be particularly important to some particular community, context or conservation concern.

A way forward is to appreciate that the term biodiversity, and hence measures to reflect its status, is rather more equivalent to topics such as 'the economy' or 'climate'. Then it becomes clear that there are multiple potential measures. The best measure depends then on the context, but there are many alternatives from which the measure of choice should be drawn. Biodiversity measures and indicators, therefore, are not simply going to appear out of the extensive data and information that exists. Ideally, they will need to be defined and agreed once the issue they are informing has been specified. In essence the search for general biodiversity indicators is going to be frustrated, just as a single measure of climate (eg average temperature, average rainfall) would never tell the whole story and would go only some way towards meeting needs for understanding change. However, once it is clear what the measure needs to address and to what questions it will provide answers, development of simple indicators becomes feasible.

Second, there may have been insufficient political will to tackle the key issues about conserving biodiversity, because of the common perception that doing so would primarily mean additional costs and with the benefits being less easy to define in monetary terms and to assign to particular interest groups. To many people biodiversity means the number of wild species. Then it seems that it will be assessed and managed independently, and conflict with related issues to do with land use, wildlife management, agriculture, fisheries and forestry. Yet these are not independent. Biodiversity cannot be separated from the natural systems that underpin resources and services to people. A possible way forward is to recognise the biodiversity that communities want and need for different purposes (see section 1.3) and favour the use and development of indicators that reflect these values.

Finally, there are certainly important gaps in data and knowledge that have limited, and will continue to limit, indicator development. Poorly known habitats and ecosystems, and poorly understood dynamics within natural systems, can appear to be obstacles to progress. Lack of expertise on particular groups of organisms and the decline in taxonomic expertise has also limited some initiatives. However, if and when the political will is there to stop the decline in biodiversity, it is definitely possible for ecologists and other scientists to come up with relatively simple measures and indicators of biodiversity that would widely be considered as sensible approximations of the complex set of (ideal) indicators that would accurately reflect all possible aspects of biodiversity.

3 Conclusions and recommended next steps

Drawing on the outline in section 1, and the assessment of available indicators in Annex A, we summarise our conclusions in this section. Given the short time before 2010, some steps will need to be taken very soon if we are to have indicators in place to measure progress against the target. Hence we first make some recommendations for immediate actions. Recognising that these actions, while they are adequate, may prove to be less than ideal over the long term, we then also make some recommendations for actions to be taken now to allow better, more efficient and more relevant indicators to be in place after 2010.

3.1 Immediate and short term – what is needed to have indicators in place to assess progress against the 2010 target

This report is timely, since there is now substantial progress to report resulting from the conclusions of the Malahide meeting (Annex B). The set of indicators reported there, which is assessed in Annex A, was subsequently considered by the European Environment Council in June 2004. The Council welcomed the 'first set of headline biodiversity indicators' as outlined in Annex 1 to the 'Message from Malahide' and urged the Commission 'further to develop, test and finalise this set by 2006, having regard to their evolving nature'.

In 2004, the Implementing European Biodiversity Indicators 2010 Coordinating Group was established to undertake this development and testing. It is led by the EEA, with support from UNEP-WCMC and ECNC, and involves experts from across Europe. This initiative seems very timely and appropriate, and should be welcomed and supported by all. Clearly, given the challenges involved, we believe that mechanisms to support ongoing scientific input from a broad community across Europe are crucial.

Our independent assessment of the available indicators (Annex A) suggests that there is a range of indicators for which the methodology has been established, and for which data exist. Several of these can be implemented immediately. In particular, we note the important biodiversity 'state' indicators under the following broad kinds of measures that are available.

1 *Measures of population trends*. Many population trend data are available, both from the published literature and from existing monitoring programmes. Such data form the basis for the Living Planet Index (LPI). For immediate application, it will be preferable to focus on the indicators that are already established from good data and methods. Foremost among these is the Wild Bird Indicator is derived from annually operated breeding bird surveys spanning different periods from 18 European countries, obtained through the *Pan-European Common Bird Monitoring Scheme*. Experts selected 24 birds characteristic of either woodland or agricultural habitats in Europe. These, and similar data sets, can immediately be used to examine trends and are informative about comparisons between habitats, areas and management practices.

2 *Measures of habitat extent*. The CORINE habitat classification (EEA 2004c) is established and the database from 1990 is already being updated for 2000. This information could form the basis for an ongoing indicator reflecting the area and extent of ecosystem classes, and the way that this is changing over time. Some work will need to be done to turn this into an indicator, partly to complete the reassessment, but also, given that there are 44 classes of ecosystems in the CORINE classification, a new methodology will need to be developed to derive a composite indicator.

3 *Measures of changes in threatened species*. The trend towards extinction is measured by the Red list index, and forms an indicator that is complementary to the population trends index above. Many of the species extinction risk assessments that underpin this indicator exist, and where they do not exist already, there are networks in place to develop them. The methodology is already established (Butchart 2004).

4 *Measures of fishing impacts on marine fishes*. The Marine Trophic Index measures the changing status of fisheries catches and has been shown to be a relevant indicator of fishing pressure. It seems likely that this indicator could be adapted for freshwater exploitative fisheries too, thereby providing a means to balance the terrestrial systems that dominate most of the other indicators.

Additionally, there is one 'response' measure that is available immediately.

5 *Coverage of protected areas*. This information on the extent of protected areas in Europe is already available and highly relevant.

This set of indicators provides information on some key dimensions of biodiversity, and already exists for the EU area, or could be put together from existing initiatives. Importantly, these indicators are all also part of the set chosen by the CBD for their 2010 assessments. Hence we recommend their immediate adoption and implementation.

While we strongly urge that these be further developed and implemented, their limitations need to be recognised and acknowledged. In particular:

- Population trends are largely available for birds, are most reliable for birds in agricultural landscapes, and may or may not represent trends in other terrestrial groups of animals and plants, or in other terrestrial habitats. We have no good datasets from which to derive trends in freshwater and marine habitats. For many groups the bird data may prove to be an effective surrogate, but we know that for certain groups, especially organisms that live at small spatial scales, and those that depend upon very specific habitat types, the indicator ought to supplemented by information from other species. Most important here will be data on invertebrates and plants, and equivalent datasets from freshwater and marine habitats.

- Habitat extent does not measure habitat quality. The indicator could present an over-optimistic assessment of habitat status, or protected area status, if key species are not maintained or if the habitat becomes fragmented or subdivided. A particular concern is that using the CORINE data set to measure trends in habitat extent may prove to be a rather coarse tool, and this may not be enough for a robust trend assessment.

- Species lists and red list assessments are fully developed for mammals, birds, butterflies and amphibians, and in certain member countries (especially NW Europe). Other significant groups (plants, fungi, invertebrates, freshwater species, marine species) are less well to negligibly represented.

A second area for consideration is the attributes of biodiversity that are being reflected in these indicators. The indicators described above have emerged because the data and expert networks already exist, and not because there is a clear set of users for them. As a set they are relevant to certain questions and concerns about the status of biodiversity but it is important to note that they do not address every topic of interest. In particular, some of the key roles in biodiversity discussed in section 2.3 are not addressed by these measures. For example, the provisioning services (such as food and fibre production and genetic resources) are addressed only very indirectly for terrestrial systems. The marine trophic index addresses this area for fisheries but other aquatic provisioning service are missing altogether. Key roles of biodiversity in supporting services such as soil formation and nutrient cycling are also missing from this set, as are the increasingly significant regulating services (eg water regulation, climate regulation). Finally, and in the context of sustainable development, our set has little that addresses biodiversity as a component of sustainable management, especially as it related to agriculture, fisheries and natural resource extraction.

The weaknesses alluded to here are not limited to European indicators. At broader levels, and in the global agenda, the same applies. Hence, we recommend that implementation of existing measures should not be delayed further while additional methods are established. But, at the same time as starting systematically to gather information for the existing indicators, we strongly recommend that new steps are taken to design and establish additional indicators that more fairly represent the range of benefits we receive from biodiversity.

3.2 The longer term – developing indicators for the future

Biodiversity indicators need to be developed within a broader policy environment. Instead of adopting data sets that happen to exist from other initiatives, we recommend a structured approach to indicator development as outlined in the 2003 Royal Society report *Measuring biodiversity for conservation* while feeding into the IEBI2010 work. This specifies three stages:

1 Scoping – what are the aspects of biodiversity that EU members do and should care about? This will require considering the functions delivered by biodiversity (see Part 1), including aesthetic and cultural values as well as intrinsic value. The appropriate measures can be derived from this set of valued attributes of biodiversity. The ideal measure will also depend on the format of a target developed for post 2010, and the process to design these should be run in tandem.

2 Designing indicators – this stage involves choosing measures but also considering how, from what, when and where the data supporting these measures should be gathered. Ideally there would be some pilot projects to test assumptions and statistical properties of the measures before they are fully implemented. This stage is currently being addressed by the IEBI2010 expert groups.

3 Implementation and reporting – once a system is in place, the outputs from the indicators need to be checked to ensure that are still relevant for purpose, and that they are sufficient to meet the needs specified in section 2.3.

This process will require new resources, but the cost of developing good indicators should easily be outweighed by the benefits of good management that they will allow.

Annex A: Assessment of available indicators

Our starting point for this assessment is the selection of a candidate list of indicators. The most comprehensive set of viable indicators is the list that emerged from the Malahide Conference, with the addition of the Living Planet Index and the Natural Capital Index. The following assessment has been made to a standard format and each index has been assessed by at least two members of our project group.

A.1 Trends in extent of selected biomes, ecosystems and habitats

Biomes, ecosystems and habitats are the large-scale components of biodiversity. The CBD plans to use an indicator of the trends in extent of selected biomes, ecosystems and habitats to assess the progress towards the 2010 target (CBD 2004).

(a) *Does it measure things people care about and has it biological relevance?* People care about the extent of natural ecosystems. Recreation activities in natural and semi-natural habitats such as birdwatching are very popular. People also place existence values on wilderness. Finally, the natural capacity of ecosystems to provide services to people depends on the extents of those ecosystems (MA 2003). The extent of ecosystems and biomes is an indirect measure of the condition of finer-scale levels of biodiversity such as populations and species (Sala et al 2005). Land-cover maps can also be used to analyze trends in landscape diversity at a given scale (EEA 2004c), including trends in homogenization of agricultural landscapes.

(b) *What are the drivers that this indicator measures?* Land-use change is the main driver measured by this indicator (Sala et al 2005). To a smaller extent, climate change also affects this indicator (Thomas et al 2004a).

(c) *What data are available?* Data on the extent of ecosystems is available from the CORINE Land Cover (CLC) project, which developed a European map at the resolution of 250x250 m including 44 classes of ecosystems based on the interpretation of satellite images for the year 1990 (although there is debate about the quality of the land cover classes that have been defined). A new CLC map for the year of 2000 was completed in November 2004 (EEA, 2004c), allowing for a detailed examination of recent trends (ETCTE 2004). An alternative set of indicators is the national forest inventories, which often have more detailed information about forest ecosystems than the CLC, and go further back in time. The FAO Global Forest Resources Assessment (2001) compiles information from national inventories and examines trends from 1980 to 2000, with a particular emphasis on 1990-2000. Inventories for other ecosystems are less developed (EEA 2003). For the 14 terrestrial biomes, remote sensing can be combined with biophysical models to estimate how much area has been converted to human-dominated uses (Mace 2005). When this data is combined with historical population patterns and agriculture statistics, maps of biome conversion can be elaborated from 1700 to 2000 (Klein Goldewijk, K., 2001). At the other extreme, integrated data on trends of extent of habitats is more limited. There is an ongoing project to assess current trends of 218 natural and semi-natural habitats based on national expert teams, in response to the Habitats Directive.

(d) *What are the limitations?* This indicator says little about the condition of the remnant habitats and ecosystems. For instance, habitat loss could be halted, but other drivers such as direct exploitation, invasive species and pollution could still push the decline of species and populations. Another limitation is that it is mainly a terrestrial indicator, with no direct analogous for marine systems. For freshwater systems some equivalent indicators could be considered such as the number of free-flowing rivers or the length of free-flowing arms of rivers.

(e) *Can the indicator be aggregated?* This indicator is easily aggregated from smaller to larger spatial scales and is additive. That is, the value at a larger scale can be calculated simply by averaging the values at lower scales. However, the larger the biodiversity component considered, the less relevant the indicator is when aggregated. This happens because a biome can disappear locally with impacts on endemic species and on the ecosystem services provided to local populations, but this local disappearance may go unnoticed when data is aggregated at a large spatial scale.

(f) *Is it complementary to other indicators?* This indicator would become more meaningful if it could be complemented by information on trends of populations of selected species.

(g) *Is it cost-effective?* Satellite data is relatively cheap and easily available. However the classification of the data in ecosystem categories can be time consuming, particularly for detailed habitat types.

(h) *Can it be implemented/used now?* At the ecosystem level this indicator could be implemented immediately for most EU countries based on the CORINE Land Cover project. Indicators at the more detailed habitat level could be implemented in the near future depending on the ongoing national implementations of the Habitats Directive. Indicators at the biome level could be developed in a short amount of time (2-3 years) based on remote sensing data.

A.2 Trends in abundance and distribution of selected species

Populations and species constitute the most essential component of biodiversity. Viable populations indicate the presence of healthy habitats and ecosystems. Therefore, trends in the abundance and distribution of selected species is one of the most direct ways of assessing whether progress towards the 2010 target (CBD 2004) is being made. Recently, the Farmland Bird Index has been adopted for inclusion in the long-list Structural Indicators as a proxy on EU Biodiversity.

(a) *Does it measure things people care about and has it biological relevance?* People care greatly about many species of plants and animals, which have intrinsic value as essential components of the natural environments. Many people enjoy birdwatching and observing mammals, butterflies, and plants and other taxa. Trends in harvested game and fish species are closely followed by people, both professionals and laymen. Recreational fishing and hunting are popular hobbies in many European countries. Trends in abundance and distribution of species have great biological significance, because the occurrence and population size of species is one of the major components of biodiversity.

(b) *What are the drivers that this indicator measures?* The drivers of changes in the abundance and distribution of species are complex, including local, national and global drivers and their interactions. Changes in land use lead to loss and fragmentation of habitats, which is the most significant driver (Hanski 2005); the others include persecution, impact of alien species, and climate change (which is expected to be increasingly important in the future; Thomas et al 2004a).

(c) *What data are available?* Within a few EU countries, high-quality data are available for many species of vertebrates (birds, mammals, amphibians, fishes), some species of invertebrates (especially butterflies), and many groups of plants. For the EU as a whole, data on distribution and abundance of species is available only for birds (Hagemeijer & Blair, 1997; BirdLife International, 2004a, 2004b). For other species groups distribution data are available but fragmented, out of date, with varying quality levels. No abundance nor trend data are available at the European level for these groups. For instance, Thomas et al (2004b) have analysed the declining distributions of birds, vascular plants, and butterflies in Britain over the past 20 years. For some species and countries there are high-resolution atlas data (usually at 10-km resolution) collected at least at two points in time, which allow very detailed assessment of changes in distribution and abundance. Two examples are the butterfly atlas in the UK (Asher et al 2001) and the bird atlas in Finland (Väisänen et al 1998).

(d) *What are the limitations?* When high-quality long-term data on distribution and abundance are already available, the data reflect accurately what is happening to those species for which data have been collected. But as different species will respond in a different manner to particular drivers, it is essential that the indicator species are appropriate for the particular environments. New data take a long time to accumulate, because one needs data for many years before trends in distribution and abundance can be properly assessed.

(e) *Can the indicator be aggregated?* The indicator can be easily aggregated, because large- scale population size and distribution are simply sums of what exist at smaller scales. On the other hand, large-scale trends may hide local deviations from the overall trend.

(f) *Is it complementary to other indicators?* Yes, though to some extent information on species abundance and distribution can be approximated by information on the spatial extent of the habitats of the species. Data on distribution and abundance of species are very complementary in relation to other indicators apart from habitat measures.

(g) *Is it cost-effective?* Much data on species' abundances and distribution are being collected by amateurs and professionals, and it is possible to make these data widely available with little extra cost. On the other hand, initiating programs to collect new data can be expensive. Collecting data for little-studied taxa is expensive because there are often only few experts who can identify samples.

(h) *Can it be implemented/used now?* This indicator has the strongest possibility for including civil science, by using cost-effective on-line collection of observations made by amateurs.

A.3 Change in status of threatened and/or protected species

An indicator of change in status of threatened and/or protected species is being developed by the CBD based on the IUCN-SSC Red List Programme. In Europe, this indicator might usefully be based on information on European Red List species and (other) species mentioned in the annexes of the Birds and Habitats Directives. The European Environment Agency is developing an indicator in this category (BDIV03) combining information on a) the number of threatened taxa occurring at different geographical levels, b) the number of globally threatened taxa endemic to Europe, c) the percentage of globally threatened species per biogeographic region, d) the percentage of European threatened species per biogeographic region and e) threatened forest species. The best current prospect for implementation of this category of indicator is the IUCN-SSC Red List indicator (Butchart et al 2004) and the comments below largely relate to this indicator.

(a) *Does it measure things people care about and has it biological relevance?* This indicator has high public resonance: people probably care more about threatened and protected species than any other aspect of biodiversity, simply because these are the species closest to extinction. However, although in general people care about such species, there are some important differences between species. Because this indicator measures trends in species closest to extinction, it also has high biological relevance: measuring the status of threatened and protected species, albeit often a challenging task, is potentially the best measure of both biodiversity loss and the effectiveness of policies and actions designed to halt the decline of species faced with extinction.

(b) *What are the drivers that this indicator measures?* This indicator relates to multiple drivers – it integrates the impact of all drivers of biodiversity loss. Moreover, it reflects the success or otherwise of conservation policies and practices. Nevertheless, this indicator may be deconstructed to give valuable information on the impact of individual drivers such as excessive hunting or harvesting and of individual policies or conservation measures.

(c) *What data are available?* Data are already available; much of it is coordinated, notably by IUCN, who have developed an indicator that is available for immediate testing. Excellent networks exist for many taxa. Information on many threatened and/or protected species is, however, very poor and patchy – there is a strong bias towards birds, large mammals, higher plants and butterflies. Most invertebrates are poorly covered, as are freshwater species, and the status of marine species is inadequate; even the trends in the status of most harvested fish species are poorly understood.

(d) *What are the limitations?* The status of threatened and/or protected species is always made difficult by the fact that such species are, because they are threatened and/or protected, usually rare and, therefore, their status and trends in abundance are difficult to measure.

(e) *Can the indicator be aggregated?* This indicator can be readily aggregated and disaggregated, providing information by, for example, geographical area or taxonomic group.

(f) *Is it complementary to other indicators?* The data necessary for the assessment of threat status serve many other important uses.

(g) *Is it cost-effective?* This indicator is achieved at high cost and effort but the work of collecting and collating the information underpinning the indicator is well advanced demonstrating commitment to the collection, collation and reporting of the data.

(h) *Can it be implemented/used now?* This type of indicator is already being used in the IUCN-SSC Red List Programme and could readily be expanded to include all species of Community interest i.e. those listed in the annexes to the Birds and Habitats Directives. Its relevance to species that are most threatened by extinction and to species that Community legislation has a particular emphasis on make this a high priority indicator for further implementation.

A.4 Trends on genetic diversity of domesticated animals, cultivated plants and fish species of major socioeconomic importance

Agricultural biodiversity is the diversity of crops, crop varieties and breeds domesticated by humans. The genetic diversity of fish species of major socioeconomic importance is not a component of agricultural biodiversity but is a major component of the biodiversity directly exploited by humans. The CBD plans to develop this indicator further (CBD 2004).

(a) *Does it measure things people care about and has it biological relevance?* The loss of genetic diversity in agriculture and fisheries reduces the genetic material available for use by future generations. Furthermore, widely cultivated varieties are particularly susceptible to pests or environmental hazards. Even when the variety has a resistance gene, a single mutation in the pathogen leaves a population of plant hosts uniformly vulnerable to the pathogen (FAO 1997). Some of the loss of the genetic diversity in agriculture and fisheries is associated with homogenization of agriculture landscapes, which has an impact on non-domesticated biodiversity as well.

(b) *What are the drivers that this indicator measures?* The main drivers associated with the loss of agricultural biodiversity are the intensification of agriculture and the adoption of improved varieties commercialized to farmers (FAO 1997). The main drivers associated with the loss of genetic diversity in exploited species is overfishing and releases from fish farms.

(c) *What data are available?* About 2500 breeds are registered in the FAO breeds database, and trends can be calculated from the 1995 and 1999 updatings of the database (EEA 2003). However, this is a short time span, raising some doubts on the reliability of a trend analysis. Similarly, the FAO has established a database for plant genetic resources which lists about 65 000 varieties from 1249 cultivated crops (FAO 2004). Other databases include the European Central Crop Databases and the SINGER database. Several 'ex situ conservation' programmes were started in the 1970s, by storing seeds from the different varieties in genebanks, under the auspices of the International Plant Genetic Resources Institute (FAO 1997). Less is known about the exact trends in the number of varieties still in use by farmers (OECD 2003), the so-called 'conservation in situ', but the adoption of commercial varieties by farmers has led to a clear decrease in the number of varieties in use. Finally, despite known impacts of fishing and aquaculture on directional selection of life-history parameters, little data is available to quantify trends in genetic diversity of fish species.

(d) *What are the limitations?* This indicator is restricted to a very small subset of biodiversity and does not say much about biodiversity at large. Another limitation is that it is not clear how to assess genetic diversity from the morphological diversity of varieties, but this limitation could be surpassed by performing genetic studies.

(e) *Can the indicator be aggregated?* Data from national or sub-national scale can be aggregated at larger spatial scales, but care should be taken to guarantee that varieties and breeds are named with the same nomenclature across regions.

(f) *Is it complementary to other indicators?* This indicator measures a very small subset of Earth's biodiversity that is not measured by most other indicators and has high relevance for humans.

(g) *Is it cost-effective?* Improving our basic knowledge of in-situ conservation for agricultural crops would not be expensive. This could be done by building on ongoing initiatives such as the agri-environmental measures of the CAP, and the FAO inventories. A more detailed knowledge of genetic diversity will require genetic studies and will be more expensive. For fish resources it would probably be more cost-effective to focus on monitoring genetic diversity of a few selected species through molecular markers and measurements of life-history parameters.

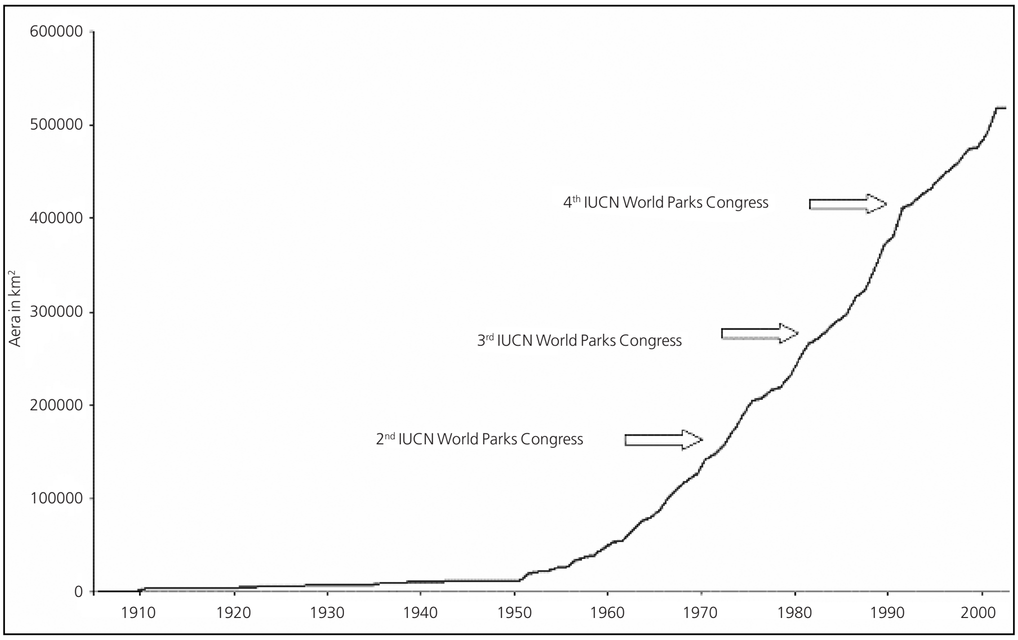
(h) *Can it be implemented/used now?* It will take some time and resources before this indicator can be used for crops, breeds and fish resources.

A.5 Coverage of protected areas

Designation of (semi)natural areas for nature protection purposes has been a key tool in biodiversity conservation for many decades. Reporting of the number and extent of protected areas at various geographical scales is common practice and easily understood. As a consequence, this indicator is the only biodiversity-related indicator broadly adopted within the EU.

(a) *Does it measure things people care about and does it have biological relevance?* The number and extent of protected areas is a relatively straightforward and easy to understand indicator for communication to the wider public and policymakers. People care about this information if it affects their own land (not so much 'how much land is protected?', but 'where is it?') or if it affects their leisure or living activities ('where is the nearest nature reserve and what does it offer me?'). For policymakers the indicator is relevant because it reflects how far they implement biodiversity policies (and almost always it is an indicator which only shows an increasing trend over time). It therefore is by itself purely a response indicator indicating political commitment and level of administration but which, when taken alone, does not reveal much about the quality or value of biodiversity or the effectiveness of policy measures.

Figure 4 Cumulated area of nationally designated areas over time in 30 European countries for the period 1900-2002 (Source: EEA-ETC/NPB, Common Database on Designated Areas, December 2003)



(b) *What are the drivers that this indicator measures?* Key drivers for establishment of protected areas are the sectors that compete for land: agriculture, urbanization and transport infrastructure, and tourism. Drivers that affect the quality of protected areas once they are established are climate change, indirect pressures from agriculture and infrastructure as well as tourism pressures.

(c) *What data are available?* Much data are available at national and international levels, with clearly identified responsibilities for European collection and dissemination to Council of Europe, UNEP-WCMC and ETC/NPB (Common Database on Designated Areas). The level of collection intensity and quality varies by country, which results in differences in completion and accessibility of data. There is a decreasing availability from the local to the EU level due to the various stages of transfer, checking and approval of data.

(d) *What are the limitations?* A key problem is the variation in definitions of protected areas by country (Richard et al 2003) with many overlapping terms. Also, multiple overlapping designations cause errors in the aggregated indicator values, with duplication of values as a result (Delbaere & Beltran, 1999). Interpretation of the indicator requires linking to targets and directions, as well as additional information on management effectiveness. Difficulties also relate to date changes, with areas of protected areas and their national designations and IUCN categories changing over time. Ideally, measures of the quality or effectiveness of the Protected area would be available as well as area, but so far there has been little progress on methods to achieve this.

(e) *Can the indicator be aggregated?* Yes. Although, as with all aggregations of data, information is lost when aggregating, it is perfectly possible to add up number and extent of protected areas at various geographical scales. Aggregation is also possible for selected types of designations (e.g. according to IUCN category).

(f) *Is it complementary to other indicators?* This indicator is not only complementary to other indicators, other indicators are actually required to be able to fully interpret the indicator. It adds value in combination with measurements on extent of habitats, species population size or presence, and management effectiveness. Especially in comparison with similar parameters outside of protected areas it may provide information on effectiveness of protected areas for conservation purposes.

(g) *Is it cost-effective?* The indicator is relatively easy to collect with modest time investment. The information can be (and mostly is) collected by government administrations. Costs do increase with aggregation or transfer to international databases but they are still relatively low compared to other indicators. The information collected is rather accurate and factual.

(h) *Can it be implemented/used now?*
Yes. It is already widely used at various levels.

A.6 Area of forest, agricultural, fishery and aquaculture ecosystems under sustainable management

The area of forest, agricultural, fishery and aquaculture ecosystems under sustainable management is important in itself and as an indicator of biodiversity, given the negative impact on biodiversity of unsustainable management practices. This indicator is being developed by the CBD but excluding fisheries. Proposals for development of this indicator in the EU do include fisheries. Relevant developments in Europe include, in particular, the Pan-European Criteria and Indicators for Sustainable Forest Management, established under the Ministerial Conference on the Protection of Forests in Europe (MCPFE), and indicator reporting on the integration of environmental concerns into agricultural policy (IRENA) by the European Commission. In both cases, the set of indicators includes several of direct or indirect relevance to biodiversity. For example the IRENA set includes area under agri-environment support (IRENA01), area under nature protection (IRENA04), high nature farmland areas (IRENA26), species richness (IRENA28) and impacts of habitats and biodiversity (IRENA33).

(a) *Does it measure things people care about and has it biological relevance?* Public awareness of the term 'sustainable forest management', for example, is low, ranging from about 10-50% according to country (Rametsteiner, 1998). However, the sustainable management of ecosystems is likely to become more important for people as they become increasingly concerned about the sustainability of the ecosystems that supply their food and other natural products. Nevertheless there are potentially serious problems with the degree of acceptance of sustainable management among some stakeholders concerned with the exploitation of these ecosystems. The forest sector appears to be an exception to this, following marked changes in the last 20 years. As mentioned above indicators of sustainability have been developed, notably in forests and agriculture. Some of these indicators have strong biological relevance, others have little relevance to biodiversity.

(b) *What are the drivers that this indicator measures?* This indicator relates mainly to individual drivers such as unsustainable forestry practices. However, it also relates to multiple drivers, some of them complex. For example, economic pressures on traditional farming and husbandry lead to the spread of unsustainable agriculture. This indicator also has the potential to provide information on success or otherwise of conservation policies in all ecosystems, including the marine.

(c) *What data are available?* Data are becoming available for each ecosystem. For forests, the MCPFE Pan-European Criteria and Indicators for Sustainable Forest Management provide a potentially useful starting point. Data are now available for these indicators and for indicators of sustainable agriculture; these could potentially be summarised as a single 'area' indicator (but see below). For fisheries, ICES data provide a credible basis for assessing sustainable management.

(d) *What are the limitations?* Despite the development of indicators of sustainability in forestry and agriculture, only some of these indicators provide information on an area basis. The derivation of a composite indicator or the selection of a single indicator to describe the area of an ecosystem under sustainable management is challenging: information from sustainability indicators that do not provide data on an area basis will be lost. Nevertheless, indicators such as the area of high nature value farmland are potentially valuable single indicators of area under sustainable management (see EEA 2004a). ICES data could be used to establish the area of fisheries under sustainable management, although differences in the assessment of sustainable management of different fish species in the same area is a complicating factor. The prospects for developing this indicator meaningfully for aquaculture is much less good.

(e) *Can the indicator be aggregated?* This type of indicator can be aggregated and dis-aggregated. However, as discussed above, only some of the information available on sustainable management is expressed on an area basis: this information can be readily aggregated.

(f) *Is it complementary to other indicators?* Some of the indicators under development are complementary to other types of indicator (eg area under agri-environment support), but others overlap with other types of indicator discussed in this report (eg area under nature protection, species richness and impacts of habitats and biodiversity). However, the strength of this type of indicator, whether or not the underpinning information is used in other contexts, is that it is ecosystem-specific and therefore provides a useful biodiversity indicator in each of these ecosystems.

(g) *Is it cost-effective?* This type of indicator is not particularly costly or impractical to adopt, as the MCPFE experience has shown.

(h) *Can it be implemented/used now?* This indicator cannot be implemented without further development in each of the ecosystems concerned. The aim of specifying this indicator in terms of area is a good one in that it potentially provides an quantitative measure of sustainable management but this limits the prospects for short-term implementation, despite the work that has already been done on indicators of sustainability in different ecosystems. Some of the indicators of sustainability that are in development or use such as the area of an ecosystem within the NATURA 2000 Network might provide misleading information on the area under sustainable management. Others, such as the area of high nature farmland in Europe, have greater potential as a measure of sustainable management relevant to biodiversity.

A.7 Nitrogen deposition

There is an ample evidence that an increase of nitrogen input to terrestrial and aquatic ecosystems causes a decrease of biodiversity, enhancing the domination of individual species. This concerns vegetation (eg Bobbink et al 1998, Krupa 2003) as well as soil invertebrates and microorganisms . Nitrogen input (in the form of dry and wet deposition) is routinely monitored in all Europe, as a part of standard environmental monitoring (see European Monitoring and Evaluation Programme (EMEP)).

(a) *Does it measure things people care about and has it biological relevance?* Nitrogen deposition is of great interest to the public, as it influences drinking water quality, and eutrophication of water bodies (often used for tourism), which often results in undesirable algal growth. It also has additional resonance because of its relationship with legislation-driven changes in agricultural practice. Moreover, there is growing public awareness that nitrogen deposition influences almost any ecosystem, and that it is responsible for the loss of valuable recreational habitats such as heathlands. Nitrogen deposition is of global importance and a key driver of environmental change in almost any natural, semi-natural or anthropogenic ecosystem, threatening its biodiversity and strongly influencing its ecosystem function. Ammonium and nitrate inputs are predicted for both dry and wet deposition. Ammonium is strongly acidifying and hence most reactive to vascular plant tissue directly. Both enrich the soil with nitrogen, thus influencing ecosystem productivity. This leads to the spread of nitrogen-tolerant species (including alien species from warmer climes that are generally used to greater nitrogen mineralisation rates) at the expense of species typical of nitrogen-poor ecosystems. The latter are, therefore, frequently threatened, some almost with extinction.

(b) *What are the drivers that this indicator measures?* Whereas nitrogen deposition is a widely acknowledged key driver of environmental change, our understanding of the full extent of nitrogen deposition impacts is still in its infancy because of interactions between nitrogen deposition and other environmental drivers such as grazing and climate change. A general pattern is emerging, which suggests that nitrogen deposition has greatest impact on terrestrial systems through amplification of the direct enrichment effects by additional factors such as grazing or disease.

(c) *What data are available?* Good quality data are available in a series of maps from across the EU based on a range of nitrogen deposition measurement networks. Whereas application of the data at the international, national or regional scale is highly appropriate, specific predictions at local scale suffer from under-representation of sampling conditions. This problem manifests itself for high altitude systems in particular and a better coverage of measurements in those extremely nitrogen-sensitive systems is urgently required.

(d) *What are the limitations?* Data quality is high, and well reported on. Most data on nitrogen deposition are available from spatially explicit models. The relationship between nitrogen deposition and impacts on species is established for some habitats. For non-aquatic systems, plants have been the centre of attention, although increasingly impacts on soil invertebrates and birds have also been included. Traditionally, there has been more a species than habitat driven approach. Whereas many questions remain unanswered, the scientific community has made very good progress with its understanding of nitrogen deposition impacts.

(e) *Can the indicator be aggregated?* Disaggregation is possible, although some habitats or species groups are not very well represented in national measurement schemes. Among those are high altitude systems, which are, ironically, at greatest risk due to disproportionately high nitrogen deposition loads and greatest sensitivity associated to their skeletal soils. Aggregation to larger scales is very well handled.

(f) *Is it complementary to other indicators?* Given that nitrogen deposition is such a universal feature of the modern world, it adds considerably to other measures, and allows a far better understanding of biodiversity changes than other individual measures would provide alone.

(g) *Can it be implemented/used now?* This indicator can be implemented immediately because of the information that already exists on nitrogen deposition. However, more effort is needed to relate nitrogen deposition directly to biodiversity impacts. Priority issues have been identified. It now needs the courage of the scientific and funding communities to see through longer-term experiments to unravel the key mechanisms involved in nitrogen deposition effects to allow better predictions for large-scale biodiversity loss from nitrogen enrichment.

A.8 Number and costs of alien species

The introduction of vertebrates is well documented. The incorporation of cultivated plants, trees and some garden plants is also known with some precision. Invertebrates, annuals, small herbs, are largely ignored unless they cause some interference. Pests, plagues and their vectors, have been identified and monitored, but they represent but the 'tip of the iceberg' of a world phenomenon.

The Strategic Targeted Research Project DAISE (Delivering Alien Invasive Species Inventories for Europe) is intended to fill gaps in EU-wide knowledge of species invasion.

The cost is difficult to assess with the exception of plagues where it tends to be high. Costs arise from direct impact on an economic sector (such as pests, pathogens, dangerous organisms), costs of eradication and confinement or trade barriers to products or interference to ecosystem performance in natural cycles, economic services, valued species, communities or ecosystems. Costs, if they have been calculated, refer to a certain organism in an area or the use of some resource.

(a) *Does it measure things people care about and has it biological relevance?* The Issue of biological invasions has a high profile, especially among conservation bodies. The wider public have mixed views. New organisms are often perceived as 'improvements' and people favour the introduction of alien species, races or varieties. It is commonplace in airports to find travellers smuggling live specimens, seeds and the like for their own enjoyment, without commercial implications. In agriculture or husbandry, new species, races, transgenic varieties are the basis for the expansion of the primary sector.

The number of introduced species gives no indication of the extent of ecological disturbance.

(b) *What are the drivers that this indicator measures?* In this case the indicator is a driver.

(c) *What data are available?* Reliable data on vascular plants exist, and maps are available at different scales (Atlas of *Flora Europaea* (although out of date and very incomplete), Vegetation Map of Europe, national Floras). Data on communities or vegetation types are less accurate and more difficult to compare at the EU scale. The categories of native, naturalised or invasive species are not completely consistent among publications. Some species of European origin have been introduced to other European areas as well. Birds and butterflies have accurate records for many areas and long periods. Mammals (other than bats), have good records, and with a lower precision level the same holds true for other vertebrates. Invertebrates, mosses, lichens, fungi or algae, and other groups have a much lower degree of information, and the detection of invasions is more difficult to ascertain.

Continental waters (fish, amphibians), and coastal waters receive a steady flow of alien species escaping from aquaculture and navigation practices but few recording systems exist.

(d) *What are the limitations?* Data on invasive species may encompass information on population size, structure, range and abundance. This is most relevant to conservationists and managers of natural areas. It is important to monitor some especially vulnerable habitats.

(e) *Can the indicator be aggregated?* Data can be aggregated at the scale of a single species, a functional group or a broader taxonomic group, and can be estimated for single habitats up to EU-scale. Disaggregation to finer scales should be undertaken with caution since coarse resolution overestimates the distribution and abundance of invasive species.

(f) *Is it complementary to other drivers?* There will be some overlap of the index with 'Trends in abundance and distribution of selected species' (A.2 above) if natives and non-natives were not separated.

(g) *Is it cost-effective?* Data collection can be costly, but may be collected for other reasons, national strategies on conservation, for example.

(h) *Can it be implemented/used now?* Not really.

A.9 Impact of climate change on biodiversity

Climate change impacts on species can be assessed by tracking over time the distributional ranges of species, the timing of onset of seasonal cycles and population growth rates. Alongside information on local climate these data can provide evidence that climate change is affecting species distributions or viability. In certain cases these studies, which are primarily correlational, may need to be supported by experimental studies.

Establishing indicators for climate change has begun (see eg UK indicators of climate change (Cannell et al, 1999), European level (EEA, 2004b) and global (Green et al, 2001)). In general this will involve selecting some indicators, particularly susceptible species and habitats, and instituting annual recordings of the locations and timing of key events. In much of Europe, amateur and scientific records collected systematically for this and other purposes can easily be adopted into such a scheme to provide a long term data set.

(a) *Does it measure things people care about and has it biological relevance? Climat*e change is now entering public consciousness, and clear evidence for its effects are certainly of interest. However, given that most changes have so far been slight range shifts, or small alterations in the timing of annual cycles, the public perception is not great. Similarly, the biological impacts have so far been small, but over the next 50 to 100 years these small but progressive changes could have a major impact on species and ecosystems.

(b) *What are the drivers that this indicator measures?* Such indicators measure climate change by definition, but there are very important interactions with other drivers, in particular with habitat/landscape change, to the extent that the impact of climate change may be reversed depending on the values of landscape/habitat properties.

(c) *What data are available?* Data quality is very high for some taxa in some regions, especially in northern Europe, but little or no data exist for many other taxa, especially many invertebrates and plants. There are societies and organizations that collect relevant data, and so a European-wide database could be developed without too much difficulty. Data always refer to particular species and often to particular habitats, and it may be difficult to apply results from one situation to another.

(d) *What are its limitations?* Because the changes may be very slight, and are often viewed against a background of high inter-annual variation, trends may be hard to detect over short time periods or slight climate change. Also, some longer-term environmental cycles could be driving the changes observed in some species and habitats, and additional studies may be necessary to eliminate these as the causal factors.

(e) *Can the indicator be aggregated?* The data can probably be aggregated and disaggregated at least to the level of resolution at which they were collected: in the case of distributional changes by summing up results for smaller areas, and in the case of seasonal changes in breeding by averaging over time.

(f) *Is it complementary to other indicators?* These measures are complementary to data on species abundance and distribution, because they allow predictions to be made about the future trends given assumptions about the nature and rate of climate change. In addition, the indicators will relate to the functioning of communities and ecosystems, because climate change may disrupt biological interactions. Seasonality and distributions can be modelled with climatic data, and these models can be used to predict baseline predictions that can be compared with empirical observations. Butterflies and plants provide good examples.

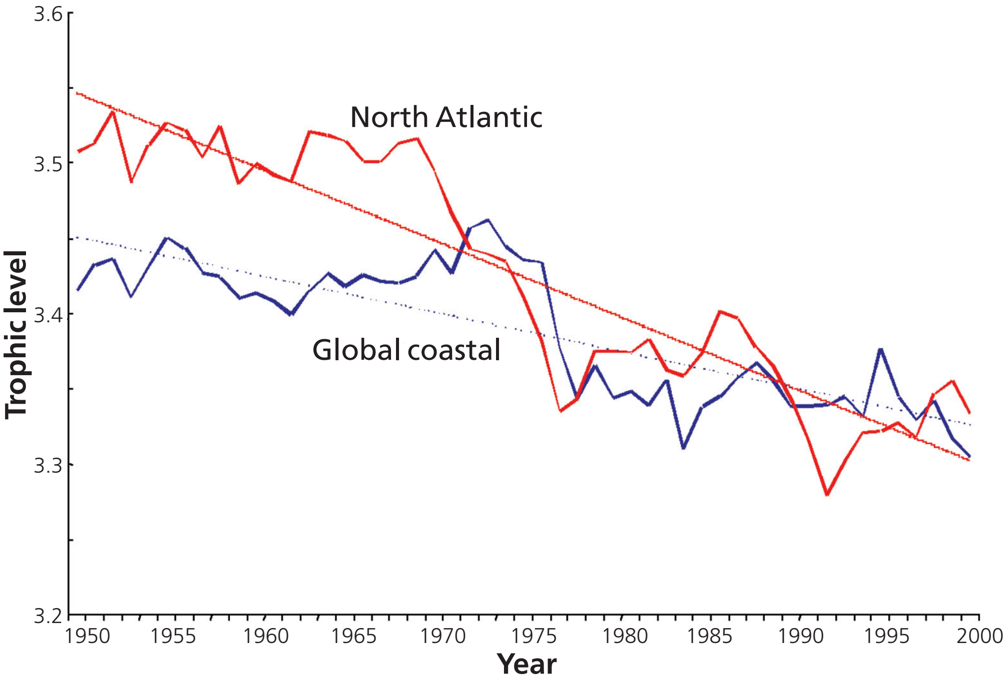
(g) *Is it cost-effective?* Much data on seasonal and distributional data are being collected by amateurs and professionals without any extra cost (eg via national 'nature calendar' web sites), but collecting new empirical data without their help would be expensive. Making comparisons between climate-model predicted patterns and empirically observed patterns is a cost-effective way of getting more information.

(h) *Can it be implemented/used now?* Many data sets are already available and could be assimilated quite quickly – including the historical data. A more systematic sampling programme would require more time and resources but is probably essential to establish soon. Data should be collected within a larger programme that includes climate and species area spatial modelling to extract maximum value from the data.

A.10 Marine trophic index

The term 'Marine trophic index' is the CBD's name for the mean trophic level of fisheries landings. Trophic level measures the position of a species in a food web, starting with 'producers' (eg phytoplankton, plants) at level 0, and moving through primary consumers that eat primary producers (level 1) and secondary consumers that eat primary consumers (level 2), and so on. In marine fishes, the trophic levels vary from two to five (top predators). Pauly et al (1998) demonstrated that fisheries, since 1950, are increasingly relying on the smaller, short-lived fish and on the invertebrates from the lower parts of both marine and freshwater food webs. More work has now been done to establish the widespread nature of trophic level changes in marine fisheries catches, and to demonstrate their usefulness in summarizing fisheries impact on marine ecosystems (see Pauly & Watson, 2005).

Figure 5 Trends in mean trophic levels of fisheries landings, 1950 to 2000



Based on aggregation of data from over 180,000 ½ degree lat./long (based on spatial dissagregation method of Watson et al. (2004). Note strong decline, particularly in the North Atlantic

(a) *Does it measure things people care about and has it biological relevance?* This indicator measures something that people increasing care about: a decline in the abundance and diversity of fish species, specifically the loss of fish species high in the food chain, such as cod. The phenomenon of 'fishing down the food chain' is gradually become appreciated but the public perception is of decline in particular species irrespective of their ecological role. This indicator captures the loss of predatory fish species well but has poor public resonance because of its complexity. In principle it seems very likely that the loss of top predators and the reduction of the trophic structure in the oceans will have some broader consequences for ecosystem stability and function, although this has not as yet been established with certainty.

(b) *What are the drivers that this indicator measures?* Fishing mortality (which is in principle under tight management), is the dominant driver of change in this index. The decline is explained by the intensity of fishing effort on large-bodied, high trophic-level species, and the decline in these over time indicates unsustainable levels of offtake. The continuing decline suggests that as stocks of higher trophic level fishes are depleted, the focus moves to the next level down – thus driving a progressive decline.

(c) *What data are available?* In principle the index can be calculated globally and regionally for any fisheries area for which accurate information on landings can be obtained. Data are therefore already available and can be presented (as an indicator) for separate marine areas (eg Baltic Sea) or presented as composite indicator for all seas relevant to the EU. In addition the trophic level of each harvested species of fish needs to be known – this is available from FISHBASE, and fisheries laboratories such as CEFAS are working independently on how to assess tropic level.

(d) *What are its limitations?* Various alternative explanations for the observed trend have been put forward, especially by the FAO staff (Caddy et al). However, these have now all been further tested and cannot explain the data (Pauly & Watson 2005). It has been suggested that long-term climate change affecting zooplankton to phytoplankton levels can contribute to changes measured in the MTI, but this is unproven as yet.

(e) *Can the indicator be aggregated?* Within the limitations set by how the data are collected, disaggregation should pose no problem. However in practice this may not be so straightforward. For example, if information on fish landings is gathered at national level (where the fish are brought to land) it may not be possible to disaggregate to the population or ocean area from which they were taken.

(f) *Is it complementary to other indicators?* This is really the only measure that reflects change in the marine environment, and is therefore an important one. It is also a measure of the trend in a driver (fishing) rather than simply a measure of the state of marine fish populations. There is an overlap between this indicator and the fishery element of the indicator 'area of forest, agricultural, fishery and aquaculture ecosystems under sustainable management' (A.6 above). However, the fishery element of that indicator is poorly developed, whereas the marine tropic index is well developed and ready for testing and future development.

(g) *Is it cost-effective?* The information on which this indicator is based is already being routinely collected. If issues of data availability and sampling are dealt with this index can be very cost-effective.

(h) *Can it be implemented/used now?* The data are available and the methodology established. This indicator can be implemented immediately.

A.11 Connectivity/fragmentation of ecosystems

Habitat loss is commonly associated with increasing fragmentation of the remaining habitat, hence this indicator is closely linked with trends in the extent of selected biomes, ecosystems and habitats (see A.1 above). Increasing fragmentation leads to reduced connectivity of the populations at the landscape level, which will reduce the viability of metapopulations at large spatial scales.

(a) *Does it measure things people care about and has it biological significance?* People often value landscapes that are not fragmented, though in other cases even highly fragmented landscapes may have recreational value. Because fragmentation greatly influences species diversity at the landscape level this indicator reflects, indirectly, the values that can be attached to species diversity: existence, use, and ecosystem services. In particular, fragmentation may disrupt ecosystem services. This indicator has great biological relevance, because increasing fragmentation decreases the viability at large spatial scales (Hanski 2005). When a species-specific critical threshold value (extinction threshold) in the amount and fragmentation of the remaining habitat has been passed, the species is expected to go extinct (see figure 3).

(b) *What are the drivers that this indicator measures?* The drivers of increasing fragmentation and decreasing connectivity are the same drivers that cause changes in the extent of biomes, ecosystems and habitats. Change in land use is the by far most important driver at present, but in the near future climate change will start to have such important impact on habitats (Thomas et al 2004a) that it will also start influencing fragmentation.

(c) *What data are available?* The data needed to calculate the degree of fragmentation are the same data that are needed to calculate trends in the extent of selected biomes, ecosystems and habitats (see A.1 above). For instance, at the European scale, data produced by the CORINE Land Cover project can be used to calculate measures of fragmentation. At smaller scales, inventories of habitat types based on remote sensing, maps, and ground surveys can be used to calculate the degree of fragmentation. At present, much data are available, but they are patchy, usually having been compiled for particular localities and countries and particular habitats. Different methods have been used to calculate connectivity/fragmentation in different contexts (Turner, 2001), and there is a need to develop more widely used measures.

(d) *What are the limitations?* Data quality is patchy at present, but high-quality data could be collected relatively easily, and there are sophisticated programs to store and manipulate such data (GIS). Data are available at the level of particular habitats. Knowing the habitat selection of species, these data indirectly reflect the abundance and distribution of species (habitat models; Elith and Burgman, 2003), though with the caveat that when the extinction threshold is passed species drop out from a landscape even when there is still some highly fragmented habitat left. A limitation in terms of interpreting impacts of fragmentation is in the species-habitat dependency of the indicator: ie where fragmentation of a certain habitat type is negative for one species, it may be beneficial to another.

(e) *Can the indicator be aggregated?* Yes, though aggregation/disaggregation typically requires a new calculation for the aggregated/disaggregated landscape data. The calculation itself is not time-consuming.

(f) *Is it complementary to other indicators?* Data on connectivity/fragmentation are intimately linked with data on the extent of habitats. The two types of data are usually obtained, stored and analysed simultaneously.

(g) *Is it cost-effective?* Relatively cheap indicator, effort needed to cover large areas not great (remote sensing, existing maps), and not prone to errors (though remote-sensed data have to be properly validated, see A.1 above).

A.12 Water quality in freshwater ecosystems

Water quality is a major influence on the biodiversity of freshwater systems. Apart from species restricted to freshwater, many birds, fishes, amphibians and hundreds of invertebrates are dependent upon freshwater bodies at some point in their reproductive cycle. Hence, freshwater bodies have a disproportionate importance. The widespread use of detergents, antibiotics or hormones pollutes waters. Sewage treatment plants are unable completely to remove them from effluents, so they have increasing effects on wild populations.

(a) *Does it measure things people care about and has it biological relevance?* Drinking water quality is a primary concern for people. This is not solely a health issue: water taste and odour are also relevant even if they were not connected to health. But water quality is not correlated in a linear way to biodiversity. For oligotrophic waters, the addition of nutrients raises productivity and (usually) raises biodiversity, causing the water body to become eutrophic. A high nutrient status or a heavy organic matter load favours some organisms over others, leading to overabundance of some dominant organisms and a drop in diversity. If eutrophication further increases, other consequences such as fermentation of newly synthesized biomass and oxygen depletion may occur, with a marked drop in the biodiversity of organisms. Under heavy pollution, only micro organisms survive.

(b) *What are the drivers that this indicator measures?* There are multiple drivers. Most significant are land use, the addition of fertilizers (especially nitrogen-based fertilizers) in the watershed, water abstraction, irrigation, urban and industrial supply, and treatment of waste water. Soil drainage and water impoundment alter the volume and surface of water bodies and wetlands available for aquatic biodiversity.

Water use and water treatment control quality, affecting its biological diversity. In the Mediterranean region, water abstraction from aquifers may imperil the survival of wetlands.

(c) *What data are available?* Water quality data based on chemical analysis are quite common all over EU. Cross-validation programmes have been running connecting laboratories and water supply companies so that the bulk of available data are reliable. As new legislation has been passed, new indicators have been incorporated into the analysis, including a long list of chemicals, and some aquatic organisms (viruses, bacteria and blue-green algae, dinoflagellate) that may cause diseases. The regular study of planktonic communities in reservoirs and lakes is rather rare. Detailed data series from a number of sites (waterfowl, fish populations, plankton, and benthos) form a network of indicators on diversity at various taxonomic levels and the environmental variables associated with them. Waterfowl data are available over long time periods.

(d) *What are its limitations?* The enormous number of planktonic species (amounting to several hundreds for a single water body) and the scarcity of taxonomists make it difficult to develop an overall assessment of the diversity of all relevant components of the aquatic biota. Unfortunately, the detailed knowledge of diversity trends in a well-studied biological group (such as birds or fishes) cannot be extrapolated to other, less well-known groups.

(e) *Can the indicator be aggregated?* The indicator is suited to the broad EU scale, provided adjustments are made to the different climatic regions.

(f) *Is it complementary to other indicators?* Most other indicators are concentrated in terrestrial biomes. This measure is complementary in that it is directly focused on the aquatic habitats on which many species, not only aquatic species, depend. In addition, water quality is also of interest to human and wildlife health and to aesthetic values.

(g) *Is it cost-effective?* As far as data have been collected and are available the implementation is very cost-effective. Modest additional monitoring programmes could substantially increase the significance of existing data, at rather little cost. Full assessment of freshwater quality would however be very complex and costly. There are also some limitations on what can be achieved because of limitation in taxonomic expertise.

(h) *Can it be implemented/used now?* Yes. A large amount of data on water quality is available, and they are reliable. Biological monitoring is more restricted to some watersheds and water bodies.

A.13 Investment in biodiversity

An array of donors and investors provide money for projects on biodiversity conservation, for administrative support for implementation and development of biodiversity policy, and for organizations that work towards conservation. The amount of money made available by country may give an indication of the commitment of countries for biodiversity conservation. A proper formulation of a definition and further development of the indicator are required before it can be implemented.

(a) *Does it measure things people care about and has biological relevance?* Probably ordinary people do not care about this type of indicator, unless it relates to the benefits associated with funding for biodiversity. Policymakers and investors may care more in relation to analysing the costs and benefits of their funding efforts. The indicator does not say anything about biodiversity value but is a response indicator.

(b) *What are the drivers that this indicator measures?* A key driver for this indicator is the economic situation of a country or other funding body. Additionally public awareness and commitment to biodiversity conservation can be a driver as well.

(c) *What data are available?* At the present, a heterogeneous situation. Examples of monetary measures include: agri-environmental measures, protected area support, preparation of biodiversity action plans, and species protection initiatives. Indirect measures include any natural resource protection measure, as pollution/clean up of air, land and water will always reduce risk to biodiversity. Measures include soil decontamination, nitrogen vulnerable zones, large-scale fresh water filtering, smokestack scrubbers etc. Sources of financing are disparate: international finance institutions (additionality principle), national / local governments, private enterprises / industrial sector agreements. No standardized collection of funding data at present.

(d) *What are the limitations?* Data to underpin this indicator are non-harmonized, fragmented, hardly collected, recorded or reported. It is also difficult to distinguish between species/habitat component. Compatibility of data has to be ensured: eg GEF may fund biodiversity action plans for countries with economies in transition, yet developed countries will do so out of their own budgets. There is also a 'scale' issue: a spent for a BAP in Bulgaria is worth considerably more than a spent in the UK. The main limitation therefore is the lack of a consistent definition of the indicator.

(e) *Can the indicator be aggregated?* If the limitations referred to above can be overcome, then aggregation should be possible by adding up funding from various sources or geographical levels. Most likely funding should be expressed in relative rather than absolute terms.

(f) *Is it complementary to other indicators?* This indicator is not only complementary to other indicators, other indicators are actually required to be able to fully interpret the indicator. It adds value in combination with measurements on state and trends and with effectiveness of the measure being funded.

(g) *Is it cost-effective?* Once defined, the indicator is probably rather easy to collect. This should be in the form of an index. The difficulty in developing indicators on funding biodiversity is implicit in the commentary of the headline indicator 'Funding for Biodiversity' that appears in the 'EU Comments' column of the table on 'EU headline biodiversity indicators based on CBD decision and focal areas' in the Message from Malahide document, which is: Funding biodiversity in economic and development cooperation, research, monitoring, and site management is an issue in EC Biodiversity Strategy. There are NO comments in the three other columns: 'CBD status', 'relevant EEA core set(s)', and 'other relevant developments'.

(h) *Can it be implemented/used now?* No.

A.14 Public awareness and participation

Indicators under the category of public awareness and participation in biodiversity-related activities are being developed in some European countries. This indicator of public opinion is one of the few indicators proposed for implementation in the European Union that had not been identified as a candidate indicator by the CBD.

(a) *Does it measure things people care about and has it biological relevance?* This indicator potentially provides a direct measure of what people care about by measuring their opinions and actions with respect to biodiversity. Indeed, a Eurobarometer survey of attitudes of European citizens towards the environment in 2002 showed that nature protection was second only to pollution in towns and cities as the first environmental issue that people thought of (*The attitudes of Europeans towards the environment* (Eurobarometer 58.0), European Opinion Research Group 2002). This indicator has no direct biological relevance as it does not measure status and trends in biodiversity or the drivers of these trends. Nevertheless, it is a potentially important indicator in the context of biodiversity as it provides a measure of support for action to prevent biodiversity loss.

(b) *What are the drivers that this indicator measures?* This indicator is not directly related to proximate drivers of biodiversity loss but it is a potential indicator of some socio-economic drivers, particularly social drivers such as current and future willingness to exploit natural resources to the detriment of biodiversity and public pressure to support policies and actions to halt biodiversity loss.

(c) *What data are available?* Some data on public awareness and participation are available. In England, for example, the indicator of public attitudes to biodiversity comprises awareness of the word 'biodiversity', expressed concern for loss of wildlife and support for the payment of farmers to protect wildlife. Participation indicators comprise progress with Biodiversity Action Plans (BAPs) in different habitats as well as Local BAPs (LBAPs), public enjoyment of woodland, ease of access to local green space and countryside, proportion of households undertaking wildlife gardening and numbers of visits to nature reserves.

The recent report of the Polish Institute for Sustainable Development (in 2000, involving the research continued since 1992) revealed a decrease of the proportion of pro-ecological attitudes (from about 33% to 22%). A clear division is visible between the economically well situated, high educated and ecologically concerned urban population and the poorer, less educated, rural population, which is ecologically indifferent. For both, however, the major environmental issue is environmental threats to health. These examples and European Eurobarometer survey of attitudes towards the environment demonstrate how readily data for this indicator can be made available.

(d) *What are the limitations?* Data on attitudes suffer from the same problems that all surveys and questionnaires suffer from – are the right questions asked; is the survey representative? Results may be flawed or misinterpreted unless these fundamental questions are addressed. Indeed, a clear understanding of public awareness may only be revealed by means of intensive sociological research, which, eventually, may also result in the development of more robust indicators in this category. Data on public participation may be more reliable but in some countries volunteers' activity is dependent on the leadership of a few individuals. Across Europe, participation in biodiversity-related activities is likely to be related to economic status.

(e) *Can the indicator be aggregated?* This indicator is survey based and therefore easily adapted to any unit of aggregation.

(f) *Is it complementary to other indicators?* This indicator is highly complementary to other indicators.

(g) *Is it cost-effective?* It is very inexpensive.

(h) *Can it be implemented/used now?* This type of indicator is already being used and could readily be implemented across Europe. However, the questions used in public surveys must be carefully constructed and their limitations acknowledged. Furthermore, the influence of a range of factors such as economic status on the participation of the public in biodiversity-related activities must also be acknowledged.

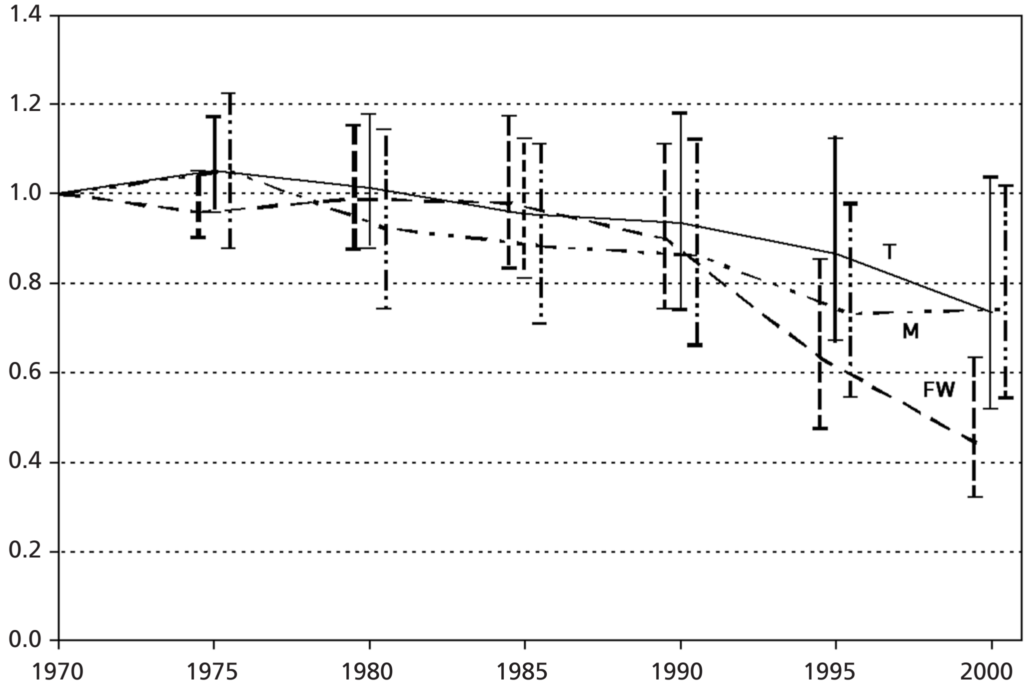
A.15 Patents

We have not assessed this indicator.

A.16 Living planet index

The Living Planet Index (LPI) uses time series data to calculate average rates of change in a large number of populations of terrestrial, freshwater and marine vertebrate species. The dataset contains about 3000 population time series for over 1100 species The first index was published in the WWF Living Planet Report 1998 (Loh and Wackemagel 1998) and has been updated subsequently, most recently in 2004 ((Loh et al 2004). The LPI aims to measure average trends in populations of vertebrate species from around the world since 1970. All species in the index are vertebrates for reasons of data availability: time series data for invertebrate or plant populations exist, but for relatively few, geographically-restricted locations.

Figure 6 The LPI for Terrestrial (T), Freshwater (FW) and Marine (M) species, with 95% confidence intervals



(a) *Does it measure things people care about and has it biological relevance?* People are concerned about declining abundance of birds and fish populations and the LPI, as promoted by WWF, has been a very effective tool for communicating with both the general public and policy-makers. Because it is focused on population trends in vertebrate populations that are relatively sensitive to environmental changes and to vertebrate (fish) populations that are harvested, the index has good biological relevance.

(b) *What are the drivers that this indicator measures?* Any and all drivers contribute to changes in this index. To discriminate among drivers the sampling for the index would need to be carefully organised to compare trends among populations of the same species in areas where drivers of change were known to differ.

(c) *What data are available?* The LPI is based on population trends in selected species, presumably based on data availability. The index as defined is applicable at the global scale, not at smaller scales, though comparable indices could be defined for local, national, and EU scales.

(d) *What are its limitations?* The LPI is a measure of global biodiversity only as far as trends in vertebrate species populations are representative of wider trends in all species, genes and ecosystems. In addition, as currently formulated, LPI values may reflect the distribution of available data as much as the biological status of natural systems. This problem could be avoided given a balanced sampling strategy and adequate data. The index can be made to work well at the global scale (Loh et al 2005), and applications would be possible at smaller scales but would require other sets of species to be selected (often they would be available). One drawback for Europe is that the measures are not necessarily sensitive to changes in forest ecosystems (eg often the species that are monitored or for which data are readily available are habitat generalists, which are not greatly affected by intensive forest management, which may however change the forest ecosystems fundamentally).

(e) *Can the indicator be aggregated?* In principle the LPI can be disaggregated but in practice, as the index is presently defined and used, it cannot because it is meant to be applied at the global scale. In general disaggregation is a very useful feature of measures such as the LPI. However, the component datasets need to be designed to be disaggregatable in a particular way – ie each sub-element should be sampled so that on its own it is giving an unbiased measure, with adequate sample size.

(f) *Is it complementary to other indicators?* To some extent the information on species abundance and distribution can be approximated by information on the spatial extent of the habitats of the focal species. The LPI is very complementary in relation to many other indicators apart from habitat measures.

(g) *Is it cost-effective?* As long as the measure is based on data drawn from the published literature, it can be very cost-effective. Once new data and field work are needed to gather information on the right species and places, it could become very costly.

(h) *Can it be implemented/used now?* The index cannot be implemented immediately as information would need to be sourced and appropriate sampling planned. Retrospective values may be calculated which could be an advantage.

A.17 Natural capital index

The natural capital index is an integrated indicator developed by RIVM to measure the condition of biodiversity. It equals the product of the percentage of the remaining area of natural ecosystems with the quality of the remaining habitat. The quality is measured on the basis of the abundance of a group of selected species relative to a baseline level. This indicator is not a part of the CBD indicators, although it can be composed by combining the extent of ecosystems with species abundance.

(a) *Does it measure things people care about and has it biological relevance?* Because it measures the population and ecosystem components of biodiversity, this indicator is intrinsically related with ecosystem services that depend on species richness. It is also important for existence values of biodiversity. It is an improvement over the simple extent of ecosystems indicator (A.1 above) in that it also measures the impact of drivers directly in species populations. However, this indicator separates the contribution of non-natural ecosystems towards the conservation of biodiversity from that of natural ecosystems, which need to be calculated separately.

(b) *What are the drivers that this indicator measures?* Land-use change is the main driver measured by this indicator, but it also measures the effects of direct exploitation, invasive species, climate change, etc.

(c) *What data are available?* The data needed are a combination of the data on the extent of ecosystems with data on trends of populations of selected species, but with the complication of requiring data on the baseline year. In Europe, we have very few populations for which we have data going back more than a couple of decades (see also indicators A.2 and A.3). Data quality is high for the extent of ecosystems and intermediate for the population abundances.

(d) *What are the limitations?* First there is the problem of how to define the baseline. A more recent baseline provides more data on population abundances but may be erroneous because the populations could have decreased significantly prior to that baseline. Second, the result will depend on the group of populations selected. Third, it may miss species extinctions or quasi-extinctions as long as many of the species in the selected group increase in population levels. Fourth, it assumes that populations are restricted to natural habitats.

(e) *Can the indicator be aggregated?* The indicator perfectly (dis)aggregates values by ecosystem, sector or species group but cannot be implemented in some countries because of data shortage.

(f) *Is it complementary to other measures?* It gives the same information as the combination of the indicators of populations and ecosystems, but in a more condensed and visual way.

(g) *Is it cost-effective?* It will be an expensive indicator to implement across all member states in a comparable way.

(h) *Can it be implemented/used now?* For some countries it can (and is). It will require a considerable amount of time and resources to implement in all member states.

Annex B: Policy context: an overview of biodiversity policies in europe

B.1 The international policy framework

International biodiversity policy in Europe has developed over the last few decades and is being led by a number of key international organizations, such as the European Union, the Council of Europe and the United Nations Environment Programme. Where originally policy instruments for biodiversity conservation were developed in isolation, today there is a strong move towards integration of approaches and creation of synergy between policies at various geographical and sectoral levels. The following paragraphs highlight the most important international policies for Europe, while indicating their interrelations.

At the **global level**, the key policy framework is the United Nations Convention on Biological Diversity, adopted in Rio de Janeiro in 1992 (UNEP, 1992). The objectives of this Convention, abbreviated CBD or Rio Convention, are 'the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources'. The implementation of the CBD is directed by the Conference of the Parties (COP), which agrees decisions on priority activities and topics. An important component of the CBD work is embedded in the 'Strategic Plan for the CBD' (Decision VI/26, CBD 2002). In its Strategic Plan's mission statement Parties commit themselves to a more effective and coherent implementation of the three objectives of the Convention, to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth. This target was subsequently endorsed by the World Summit on Sustainable Development in Johannesburg in 2002.

Other important and complementary policy instruments that focus on biodiversity components at global level include the Ramsar Convention on the conservation of wetlands, the UNESCO World Heritage Convention, the Washington Convention on International Trade in Endangered Species (CITES), and the Bonn Convention on the Conservation of Migratory Species of Wild Animals.

The **pan-European** implementation of the CBD is framed by the Pan-European Biological and Landscape Diversity Strategy (PEBLDS; Council of Europe et al, 1996). Endorsed by the European government leaders at the 'Environment for Europe' conference in Sofia, 1995, this Strategy increasingly forms the translation of the CBD for Europe. At the 5th Ministerial conference 'Environment for Europe' (Kyiv, 2003) the Kyiv Resolution on Biodiversity was adopted, which formulates the pan-European target for 2010 as well as nine more specific targets for action.

Three other policy instruments at pan-European level are of high importance and are closely linked to the PEBLDS process: the Bern Convention on the Conservation of European Wildlife and Natural Habitats, the European Landscape Convention, and the Ministerial Conferences on the Protection of Forests in Europe.

The **European Union** has the most legally binding policy instruments with regards to biodiversity. The two key pieces of legislation are the Birds and Habitats Directives. Together they form a solid basis for the conservation of species and habitats of European Community interest. They also set out to establish a network of protected areas, called Natura 2000.

Also within the EU there is increasing integration of biodiversity policy into other sectoral policies. For example, the implementation of the CBD at EU level is foreseen through the European Community Biodiversity Strategy and its four sectoral Biodiversity Action Plans. Priorities for implementation have been agreed during the Malahide stakeholder conference 'Biodiversity in the EU: Sustaining lives, sustaining livelihoods' in May 2004. In a broader sense environmental and biodiversity concerns are integrated in more general EU policy, such as the Lisbon Strategy.

The Lisbon Strategy is a commitment to bring about economic, social and environmental renewal in the EU. In March 2000, the European Council in Lisbon set out a ten-year strategy to make the EU the world's most dynamic and competitive economy. Under the strategy, a stronger economy should drive job creation alongside social and environmental policies that ensure sustainable development and social inclusion.

The Lisbon Strategy touches on almost all of the EU's economic, social and environmental activities. The European Commission's annual Spring Report examines the Strategy in detail. The Spring Report is the only document on the agenda of the Spring European Council, where EU Heads of State and Government assess the progress of the strategy and decide future priorities in order to realize the Lisbon targets.

Progress in achieving the Lisbon Strategy objectives is reported by way of annual Spring Reports. These reports are based on a set of 'structural indicators'. The Structural Indicators are compiled into a long list and a short list. The latter is based on political priorities of the Lisbon Strategy. To date the short list of 14 indicators includes five three environmental indicators. There is no biodiversity indicator included, although in November

2004 the Farmland Bird Index was adopted as an EU long-list Structural Indicator, in addition to the 'Protected Areas for Biodiversity'.

The Gothenburg Council in 2001 added an environmental component to the Lisbon Strategy, which was largely geared towards economic sustainability. It adopted the EU Strategy for Sustainable Development. The implementation of the Sustainable Development Strategy is evaluated in annual synthesis reports and uses a set of 12 headline indicators for sustainable development.

Other important Directives and EU policies for biodiversity conservation include for example the Water Framework Directive and the reformed Common Agricultural Policy, including the Rural Development Regulation.

The 2010 biodiversity target

2001 European Union: EU Strategy for Sustainable Development adopted by the European Council in Gothenburg. One of the headline objectives as part of the priority for action 'Manage natural resources more responsibly' says: 'Protect and restore habitats and natural systems and halt the loss of biodiversity by 2010.' One of the measures at EU level to reach this objective reads 'The Commission will establish a system of biodiversity indicators by 2003.'

2002 Global level: Strategic Plan for the Convention on Biological Diversity adopted by the 6th Conference of the Parties to the CBD in The Hague. Its mission says: 'Parties commit themselves to a more effective and coherent implementation of the three objectives of the Convention, to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth.' This target is also included in the World Summit on Sustainable Development Plan of Implementation (Johannesburg).

2003 Pan-Europe: The Kyiv Resolution on Biodiversity, as adopted by the UNECE Environment for Europe ministerial conference, holds the following paragraph: 'We, the European Ministers of Environment and Heads of Delegations of the States participating in the process of the Pan-European Biological and Landscape Diversity, reinforce our objective to halt the loss of biological diversity at all levels by the year 2010, and to work towards it through concerted actions and a joint commitment to achieve the following key targets: […] Biodiversity Monitoring and Indicators

2008 By 2008, a coherent European programme on biodiversity monitoring and reporting, facilitated by the European Biodiversity Monitoring and Indicator Framework, will be operational in the pan European region, in support of nature and biodiversity policies, including by 2006 an agreed core set of biodiversity indicators developed with the active participation of the relevant stakeholders.'

B.2 Current biodiversity indicator initiatives

This section gives a brief overview of the international initiatives that have been developed to support and implement the core sets of biodiversity indicators that have been agreed at global, pan-European and EU levels (see B.1 above).

As said, the 7th COP of the CBD provided a major political breakthrough with regards to biodiversity indicators. At this conference in Kuala Lumpur in February 2004, heads of state and government leaders agreed a limited number of trial indicators for assessing progress towards and communicating the 2010 target at the global level. Incorporated in Decision VII/30, a provisional list of indicators in Annex I to the Decision includes eight 'indicators for immediate testing' and 13 'possible indicators for development by SBSTTA or working groups'.

During a meeting on 19-22 October 2004 in Montreal an Ad Hoc Technical Expert Group (AHTEG) reviewed the use of the indicators listed in Decision VII/30 and identified indicators for the sub-targets as formulated to facilitate coherence among the CBD's programmes of work. The review of the indicators was partly done by considering a draft of the Second Global Biodiversity Outlook, which will be the global indicator-based report on the state of biodiversity. The meeting confirmed the listing of the indicators for immediate testing and proposed speeding up the work on five out of the 13 indicators for further development (table 2).

The report of the AHTEG meeting will be submitted to the 11th SBSTTA meeting, to be held in February 2005.

At the pan-European level a core set of biodiversity indicators, based on the CBD list, was discussed during a joint meeting of the European Environmental Information and Observation Network (EIONET), the International Working Group on Biodiversity Monitoring and Indicators (IWG-BioMIN) and the Pan-European Biological and Landscape Diversity Strategy (PEBLDS) in Copenhagen in April 2004. The list includes both the CBD indicators for immediate testing as well as those for further development, but it only focuses on state and trends in biodiversity. Six indicators are included (table 2). The proposed list is submitted to the PEBLDS Council for approval in February 2005.

The European Commission has developed a set of Biodiversity Headline Indicators, which is based on the CBD list of indicators. The EU list was endorsed at the stakeholder conference on biodiversity in Malahide (see above) and subsequently approved by the European Environment Council in June 2004.

Following the Joint meeting of EIONET/IWG-BioMIN and PEBLDS mentioned above, a coordination team of EEA, ECNC and UNEP-WCMC drafted a work plan for the implementation of the European biodiversity indicators (both EU and pan-European sets), which will be carried out by expert groups for the individual indicators. This initiative is called IEBI2010 (Implementing European 2010 Biodiversity Indicators) and will be starting in January 2005. The work by the current EASAC biodiversity indicator project group will feed in to this process.

It is worth noting that a specific interest for annual reporting on the state of Europe's biodiversity has been expressed by the European Parliament in its resolution on biodiversity reporting of 14 March 2002. This interest was repeated by a Parliamentary question on 7 January 2003, which specifically addressed the need for indicators for this purpose, and an answer by European Environment Commissioner Margot Wallström on 11 February 2003 explaining the steps taken to this effect. As a follow-up, the European Environment Agency and the European Centre for Nature Conservation organised a seminar in the European Parliament in March 2004 on the possibilities of joining forces in Europe to achieve an annual biodiversity report (ECNC, 2004).

Table 2 Summary of international biodiversity indicators

CBD	Pan-Europe (state and trend indicators only)	EU biodiversity headline indicators
Trends in extent of selected biomes, ecosystems, and habitats	• State and change (trends) of main habitat types in Europe • State and change (trends) in special habitat types (EU Habitats Directive, Bern Convention) • State and change in surface area of selected ecosystems and habitats	Trends in extent of selected biomes, ecosystems and habitats
Trends in abundance and distribution of selected species	Trends of representative selection of species populations associated with different ecosystems	Trends in abundance and distribution of Trends in abundance and distribution of selected species
Coverage of protected areas	Protected areas as percentage of national territory by type of ecosystems, by category/designation type	Coverage of protected areas
Change in status of threatened species	Change in status of threatened species on EU and pan-European red lists	Change in status of threatened and/or protected species
Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance	• Crops and breed genetic diversity • Total number of crop varieties/livestock breeds for the main crops/livestock categories registered and certified for marketing, incl. native and non-native species and landraces	Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socioeconomic importance
Area of forest, agricultural and aquaculture ecosystems under sustainable management		Area of forest, agricultural, fishery and aquaculture ecosystems under sustainable management
Nitrogen deposition		Nitrogen deposition
Numbers and cost of alien invasions		Numbers and costs of invasive alien species
		Impact of climate change on biodiversity

CBD	Pan-Europe (state and trend indicators only)	EU biodiversity headline indicators
Marine Trophic Index		Marine trophic index
Water quality of freshwater ecosystems		Water quality in aquatic ecosystems
Connectivity/Fragmentation of ecosystems		Connectivity/Fragmentation of ecosystems
Status and trends of linguistic diversity and numbers of speakers of indigenous languages		
Official development assistance provided in support of the Convention		
		Patents (to be developed)
		Funding to biodiversity
		Public awareness and participation

Bold = Indicator considered ready for immediate testing and use
Bold italic = Indicator considered ready for immediate testing and use by the AHTEG and therefore recommended for upgrading

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