Trends in Biodiversity in Europe and the Impact of Land-use Change

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1 Introduction

The loss of biodiversity in Europe and elsewhere has been highlighted for several decades.[1–5] The scale and potential consequences of this loss has led to action to combat it, notably the Convention on Biological Diversity (CBD). Realising that current policies and action taken to conserve biodiversity were inadequate, the European Union at its 2001 summit meeting in Göteborg, Sweden, set the ambitious target to "protect and restore habitats and natural systems and halt the loss of biodiversity by 2010". A similar target was set by the CBD in 2002 "to achieve by 2010 a significant reduction of the current rate of biodiversity loss" and endorsed by the World Summit on Sustainable Development (WSSD) in 2002.

In this chapter, we discuss the available data on the loss of biodiversity in Europe, the probable causes of this loss, future threats to biodiversity, the policy response to these threats and recent research on measuring trends in biodiversity, with particular emphasis on detecting the impact of one major threat to biodiversity, change in land use. Nigel Boatman *et al*. present additional related and complementary material in Chapter 1 of this volume, with particular emphasis on farmland in the UK.

2 Biodiversity in Europe: Current Status

There are an estimated approximately 250 mammal, 500 bird, 70 amphibian, 200 reptile, 220 freshwater fish, 200 000 invertebrate and 12 500 plant species in

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Europe.[6] The numbers of species of some groups, like plants, birds and butterflies, are well known[7] but the biodiversity of other groups, such as many invertebrate taxa, is poorly understood. Likewise, although the distribution of some groups is well documented, particularly at the national scale,[8] there are no readily available sources of information on other taxa. For some groups of organisms, there are good data on their diversity and distribution but they have not been coordinated. Recent European initiatives to coordinate data on biodiversity include the Species2000[9] and Fauna Europea[10] projects. Globally, the Global Biodiversity Information Facility (GBIF)[11] coordinates biodiversity information, working in collaboration with existing programmes and with natural history museums and other organisations. The European Network for Biodiversity Information (ENBI)[12] and the European Invertebrate Survey[13] are among several major initiatives to coordinate information on Europe's biodiversity. Notable national initiatives, in some cases covering several taxa, include the Swedish Species Information Centre,[14] the Luomus project[15] in Finland, the Swiss Biodiversity Forum[16] and the biodiversity monitoring network in Hungary.[17] In the UK, biodiversity data are coordinated by the Biological Records Centre (BRC).[18] The BRC was established in 1964 as the national centre for the recording of freshwater and terrestrial biota, except birds for which the British Trust for Ornithology has major data holdings. The function of the BRC is to capture, manage, interpret and disseminate data on the past and present distributions of species at the geographical scale in the UK. The BRC archives currently contain >14 million records of >12 000 UK species of plant, mammal, reptile, amphibian, fish, and 39 invertebrate groups ranging from spiders, beetles and butterflies to water-fleas, molluscs and annelids. These data have been used to map species' UK distributions at the 10 km^2 scale.[19,20] In 2004, the National Biodiversity Network (NBN) Gateway[21] became fully operational. Founded by a consortium including the BRC, the NBN is the UK node of GBIF and brings together information on biodiversity from statutory agencies, national societies, local records centres and non-departmental government bodies. Over 20 million species records are currently accessible through the NBN from over 130 different datasets.

Although our knowledge of Europe's biodiversity is steadily increasing, it suffers from several problems in addition to the lack of coordination. One of the main problems is the patchy nature of the available data, not only because data from some countries or regions are scarce but also because of actual or potential recording biases within countries, a problem common throughout the world.[22] Data on biodiversity are frequently collected in areas where biodiversity is already known or thought to be high, leaving the biodiversity of some areas, particularly remote areas, poorly documented. Managed landscapes, particularly agricultural areas and managed forests, and urban areas are also relatively neglected. This problem results from the fact that the collection of data on biodiversity has rarely been planned so as to provide adequate biogeographical coverage. Much of the data have been collected by amateurs who are often not funded to collect data rigorously, although a high standard of systematic monitoring and survey of birds is now being achieved through volunteers in several countries. An even more serious problem is that few datasets provide useful information on temporal trends in biodiversity. There are notable exceptions, some of which are discussed below, but the lack of spatially and temporally comprehensive data on biodiversity is a serious impediment to quantifying biodiversity loss, understanding its causes and adequately responding to it.

3 Biodiversity in Europe: Information on Current Trends

There are many reports of biodiversity loss in Europe, most of which relate to the declining abundance of species or reduction in their distribution.[5,23,24] Since 1600, 16 species have been recorded as extinct in Europe, compared with 784 globally[25] (Table 1). However, IUCN list 142 as critically endangered, 143 as endangered, 425 as vulnerable, 27 as conservation-dependent and 223 as near-threatened.[25] National extinctions are well documented in Europe but several have led to successful reintroduction programmes.[26] Local loss of biodiversity has often been recorded too[27–30] but, considering the number of species and habitats in Europe, information on trends in biodiversity is extremely poor. Nevertheless, useful data on trends in biodiversity come from several sources.

3.1 Habitat Extent and Quality

Europe is extremely rich in habitats.[31] The CORINE classification of habitats for the EU Habitats Directive lists 58 different forest habitats alone.[32] Larsson *et al.*[32] present maps of 25 different forest types, many of which, including mixed oak forest and laurel forest, now cover a very small proportion of their potential extent. Data on the total area of forest in Europe show an expansion in forest cover in the last 30 years.[33] However, these statistics can mask decreases in areas of natural forest and increases in plantations of non-native species such as eucalyptus in Portugal.[34] Information on current trends in the extent of forest in Europe is provided by forest inventories and remote sensing.[35,36] Recent changes in the extent of many other habitats are also being recorded. The amount of semi-natural grassland in Europe has declined sharply in recent years;[6] between 1990 and 1998 it declined by 13% in the UK.[37] There has been a decrease in low-intensity farming systems, or "high nature value farmland", across Europe.[38,39] The loss of wetlands in Europe has been particularly dramatic, ranging from 60% in Denmark to 90% in Bulgaria since around the start of the twentieth century.[40]

Information on habitat quality is currently being assessed through various initiatives, such as the monitoring of habitats covered by Biodiversity Action Plans (BAPs) in the UK, with reporting every three years. However, more comprehensive monitoring of habitat quality will form part of the assessment of "favourable conservation status" of habitats in sites designated by the EU Birds and Habitats Directives. The favourable conservation status of a habitat

Table 1 Recent known extinctions of European species.[25]

Species	*Order and family*	*Country and date of extinction*
Astragalus nitidiflorus	Fabales Leguminosae	Spain
Belgrandiella intermedia	Mesogastropoda Hydrobiidae	Austria
Bythinella intermedia	Mesogastropoda Hydrobiidae	Austria
Chondrostoma scodrense	Cypriniformes Cyprinidae	Albania, Serbia and Montenegro
Telestes ukliva	Cypriniformes Cyprinidae	Croatia
Gallotia auaritae	Squamata Lacertidae	Spain
Graecoanatolica macedonica	Mesogastropoda Hydrobiidae	Greece *etc.* (1988–1992)
Haematopus meadewaldoi (Canary Islands Oystercatcher)	Charadriiformes Haematopodidae	Canary Is *etc.* (1980s)
Hydropsyche tobiasi (Tobias' Caddisfly)	Trichoptera Hydropsychidae	Germany
Leiostyla lamellosa (Madeiran Land Snail)	Stylommatophora Pupillidae	Madeira
Ohridohauffenia drimica	Mesogastropoda Hydrobiidae	Serbia and Montenegro
Pinguinus impennis (Great Auk)	Charadriiformes Alcidae	Iceland *etc.* (1850s)
Prolagus sardus (Sardinian Pika)	Lagomorpha Ochotonidae	France and Italy
Pseudocampylaea loweii	Stylommatophora Helicidae	Madeira
Radula visiniaca	Jungermanniales Radulaceae	Italy (1930s)
Siettitia balsetensis (Perrin's Cave Beetle)	Coleoptera Dytiscidae	France

is defined within the Habitats Directive as: "Its natural range and areas it covers within that range are stable or increasing, and the species structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and the conservation status of its typical species is favourable as defined [by when] population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and there is, and will probably continue to be, a sufficiently large habitat to maintain its population on a long-term basis". Unsurprisingly, the implementation of favourable conservation status monitoring is seen as a major challenge.[41]

3.2 Species Diversity

Long-term data on species diversity at specific locations or habitats are generally lacking but, for example, Welch and Scott[42] report 20-year trends in the plant species richness and composition of 15 moorland sites in Scotland. Such time series can be used to detect fluctuations in species diversity but comparisons between two periods can also reveal long-term trends; Linusson *et al.*,[43] for example, used two datasets, one from the 1960s and one from 1990, to show changes in the species composition of semi-natural grasslands in Småland, southern Sweden. More widespread trends are being quantified through initiatives such as the UK's Environmental Change Network[44] and Countryside Surveys.[45]

3.3 Species Abundance and Biomass

For plants, monitoring usually includes assessments of cover and/or biomass.[42,46] The periodic assessments of the UK Countryside Surveys have revealed different trends in plant diversity in different habitats: although plant diversity between 1990 and 1998 increased in arable field boundaries, it decreased in agriculturally improved grasslands, road verges and streamside vegetation.[37] Using archive biological information, McCollin, Moore and Sparks[47] demonstrated changes in the commonness of plant species between the 1930s and 1990s in different habitats in Northamptonshire in England.

For mobile species such as insects and birds, data on trends in abundance are frequently available. Good data now exist on long-term trends in the abundance and diversity of butterflies, moths and some other insects. Trends in the abundance of mirids and other Heteroptera, for example, have been obtained from a single light trap for over 67 years.[48] Light traps have also been used to quantify long-term trends in single species of moths[49] and to analyse general trends in macrolepidoptera.[50] Data on British macrolepidoptera have been collected by the Rothamsted Insect Survey since 1968. In analysing the data collected over 35 years, 54% of the 338 species investigated had undergone a significant decline in abundance and 22% had shown a significant increase.[51] Long-term data on the abundance of British butterflies have been provided by the Butterfly Monitoring Scheme.[52]

Although there is some information on trends in insect species across Europe, notably on butterflies,[53] the geographical extent of the monitoring networks for insects is not as good as that for birds. Information on the abundance of birds has been collected from many years[7,54] and reported first in the UK as a headline indicator of biodiversity[55] and now across Europe in the Wild Bird Indicator derived from annual breeding bird surveys in 18 European countries, obtained through the Pan-European Common Bird Monitoring Scheme.[56]

Information on the abundance, biomass, average size and/or trophic structure is available for many harvested species. The most notable example of this is fish.[57] Amongst terrestrial species, data exist for some game species.[58] Data on wetland birds, many of which are hunted, are extensively collected.[59]

3.4 Distribution of Species

Information on the distribution of individual species is available for many groups of organisms. In the UK, the BRC has produced atlases for butterflies, plants, fish and other taxa.[8,19,20] Information on changes in distribution is less available but Thomas *et al.*[5] analysed data on changes in the distribution of plants, birds and butterflies in Britain over the last 20 to 40 years and demonstrated declining distributions for all three taxa, particularly the butterflies, which disappeared on average from 13% of the 10 km squares between the 1970s and the 1990s.

3.5 Threatened Status of Species

Data on threatened species, principally the data collated by the IUCN, provide another source of information on biodiversity (see above). In Europe, for example, 12% of the 576 butterfly species known to occur are regarded as threatened.[60] Recently a measure of trends in threatened species has been developed by the IUCN-SSC Red List Programme. In Europe, this Red List Index is based on information on European Red List species and (other) species listed in the annexes of the Birds and Habitats Directives.[61]

Taken together, these sources of information on biodiversity will provide an improving assessment of trends in biodiversity in Europe. As discussed in the previous section, there are many gaps in our knowledge of biodiversity across Europe: these gaps are particularly serious in relation to quantifying trends in most components of biodiversity and even in better-known components such as birds. This problem is made worse by the fact that Europe's biodiversity has changed so much in the past and is likely to face continued pressure. These aspects are considered in the following sections.

4 Biodiversity in Europe: an Historical Perspective

A historical review of European biodiversity places the present situation in a temporal perspective and emphasises the balance between cultural and natural processes in the generation and maintenance of characteristic European biodiversity. Two important conclusions can be drawn from a historical survey: (1) natural changes to European biodiversity occur on a continual basis in response to climate change, so the concepts of equilibrium and long-term stability are not useful in this context; (2) natural and anthropogenic drivers and pressures have developed simultaneously in shaping European biodiversity. The anthropogenic drivers are generally more pervasive, rapid and extreme, but these two sets of drivers are so closely linked that the concept of a natural baseline is of only theoretical interest.

Europe's recent geological past (last 2 million years) was characterised by extreme and rapid climate change. These climate changes forced the species to move, a process that was influenced by physical geography and the location of mountain chains and seas. One major consequence has been that loss of diversity has exceeded creation of diversity by evolutionary processes and Europe is relatively species poor compared with comparable regions in Asia and America[62] (Figure 1).

There is a great contrast between the distribution of biomes during the last glacial maximum (*c.* 22 000–14 000 years ago) and the present day. Forest species in particular had very restricted distributions for long periods of time that inevitably led to loss of species and genetic diversity. As forest area increased in response to altering climate, species characteristic of open habitats experienced habitat fragmentation and loss. These long-term, natural dynamics of habitats comprise an important background to understanding present-day biodiversity status and trends. A significant consequence of repeated glaciations is the concentration of genetic diversity in glacial refuge areas on the margins of Europe. Refugia are usually in the mountains with large topographic variation, offering a variety of contrasting habitats within a small area. Recent genetic analyses have confirmed the importance of refugial regions as current centres of long-term diversity, making such regions of particular importance for biodiversity protection.[63] European biodiversity development during the last 10 000 years has been driven by a combination of natural, climate-driven spreading of species from glacial refugia interacting with increasing anthropogenic influence. A general correspondence between European and North American tree spreading since the last ice age has been used to

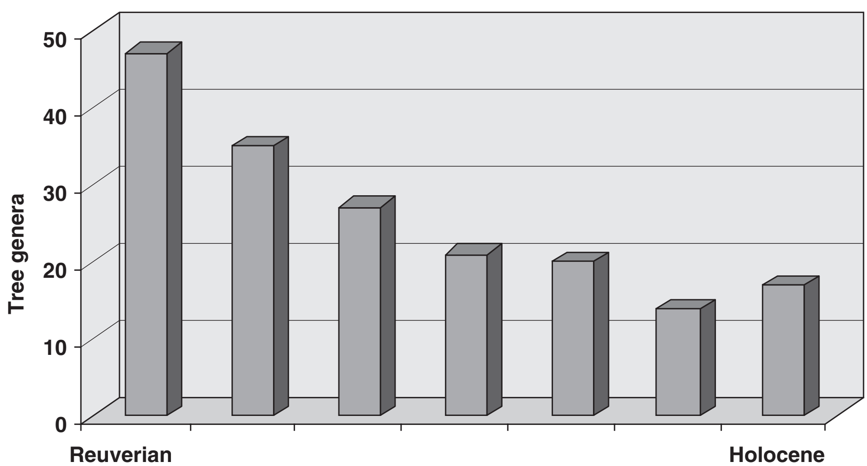

Figure 1 The number of woody genera recorded as fossils from selected inter-glacials during the last two million years in NW Europe.

suggest that climatic change and spreading dynamics from glacial refugia were the major determinants of post-glacial range changes in forest trees.[64] A close correspondence between present-day observed and modelled tree species distributions in Europe, where climatic variables interacted with physiological constraints to generate the modelled species range limits also indicates the importance of climate in determining species ranges[65,66] (Figure 2).

The spread of settled agriculture in Europe is a further key influence on European biodiversity. Neolithic agricultural methods spread from south-east to north-west Europe between 9000 and 5000 years ago.[67] Its major consequences were alteration of the balance between forest and open habitats, massive population increases in species directly (crops, domestic animals) and indirectly (weeds, pests) associated with agriculture. Its impact is recorded in pollen diagrams throughout Europe, typically as increases in the number of common species present on the landscape.

Archaeology and palaeoecology have documented the long history of agricultural development within Europe. It is this history that was the foundation for the biodiversity that has been impacted by industrialisation and intensification of land use that forms the background to the current biodiversity crisis. Studies of the past record an evolution of tools and techniques used to alter land surfaces that have impacted biodiversity. A study from southern Sweden documented systems of shifting cultivation (3000 BC–1000 BC) that utilised stone, bone, then wooden tools, fire, domesticated plants and animals. These systems developed into settled agricultural systems (1000 BC–0) that were based upon use of metal tools, hay meadows and manuring.[68] The palaeoecological record indicates that these earlier systems of agriculture led to increased local diversity of higher plants, but decreased diversity associated with forest systems. Doubtless some forest-dependent insects or decomposers were lost or had their populations seriously reduced, but the widespread opening up of forest structure and the increased proportion of open land benefited a very large group of light-demanding species of plants and animals that were more widespread during glacial periods and during the dry, warmer conditions prevalent during the Tertiary. There is a lively ongoing debate about the "natural" structure of north-west European temperate forest that stresses the biodiversity values of grazed forests with extensive but light anthropogenic impact.[69]

Traditional systems of agriculture varied in intensity in space and time, which was favourable for ruderal species that require occasional disturbance. Palaeoecological records document periods of increased landscape exploitation; for example, widespread pressure at the opening of the Bronze Age in north-west Europe, but also periods of landscape abandonment and forest re-growth, such as during the plague years of the 1300s. Patterns of species dynamics and local diversity changed significantly with the onset of industrialisation beginning during the 1800s, producing a significant increase in rate of change of vegetation associated with intensification of landscape management.

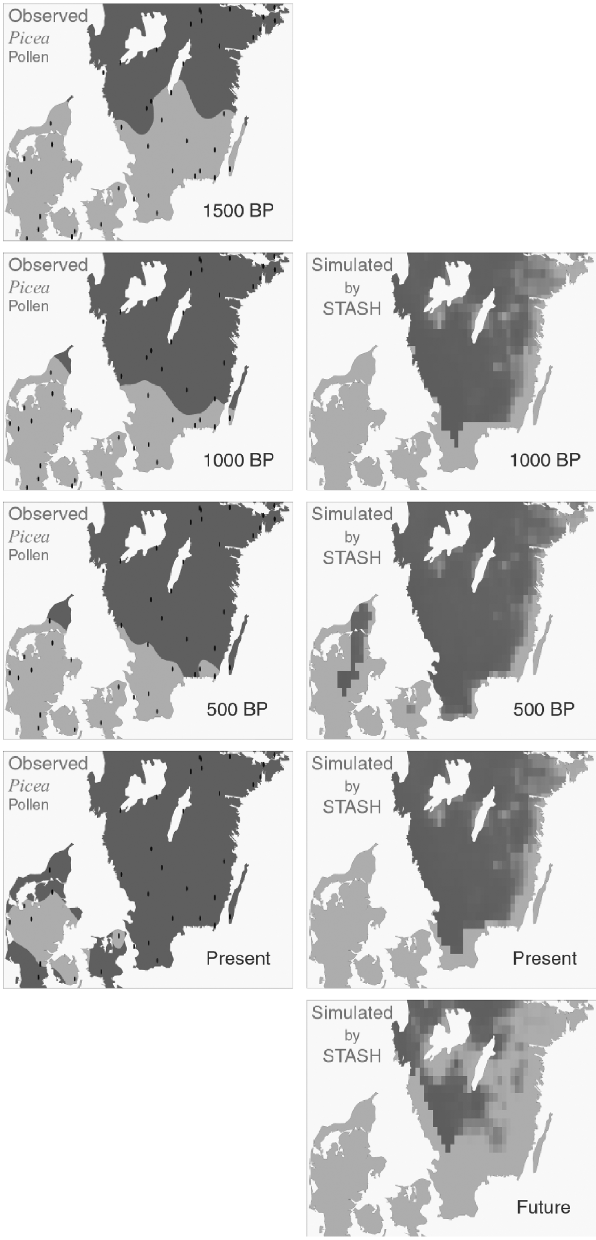

Figure 2 Observed and simulated *Picea* distributions during the last 1500 years. The observed distributions are reconstructed from fossil pollen data. The simulated distributions are generated by the bioclimatic model STASH. The predicted future distribution assumes an atmospheric CO_2 concentration twice that of present.

5 Biodiversity in Europe: Current and Future Threats

The biodiversity that we now have in Europe is threatened by many pressures, particularly habitat degradation, fragmentation and loss. These pressures, often considered together as land-use change, are discussed below. Other pressures include pollution, particularly eutrophication and nitrogen deposition, climate change, invasive organisms, and hunting and fishing pressure.[6,70,71] Some of the pressures on biodiversity are generic but many are specific to the main landscape types occurring in Europe: agriculture, grasslands, forests, wetlands and aquatic habitats, and uplands.[72,73]

Agricultural landscapes, including arable land, permanent grassland and permanent culture, cover about 43% of the European Union. Modern European agriculture is characterised by low labour input, large fields, a loss of genetic diversity both for crops and animal production, high yielding varieties, heavy applications of fertilisers and biocides and removal of landscape features such as woodlands and hedges. Many endangered and threatened species in Europe are now those that depend on the gradually diminishing areas where traditional forms of agriculture still exist.[74,75] Three main categories of pressure threaten biodiversity in agricultural areas, namely intensification, abandonment and scale of operation:[76,77]

1. Intensification of agriculture, particularly:
    - fertiliser application leading to eutrophication,
    - application of biocides, antibiotics and endocrine substances,
    - release of genetically modified organisms (GMOs),
    - conversion of extensive land use into high-intensity production areas,
    - improved field drainage.
2. Abandonment of agriculture, leading to:
    - afforestation though planting,
    - expansion of scrub and woodland through natural regeneration,
    - conversion into urban areas,
    - loss of old varieties of cultivated species,
    - loss of the cultural heritage associated with ancient agricultural landscapes and types of production systems.
3. Change in scale and organisation of agriculture, particularly:
    - monoculture, often a consequence of simplified crop rotations,
    - loss of small-scale heterogeneity in landscape features,
    - loss or disruption of dispersal routes for plants and animals.

The relative importance of these three categories differs among the biogeographical regions of Europe. In Eastern Europe, for example, abandonment of traditional forms of agriculture is a major current pressure on biodiversity.

Pressures on biodiversity are continually changing. Genetically modified organisms are often considered to be a major threat to biodiversity but there is little evidence of a direct impact.[78,79] The main threat of GMOs is that they support further intensification of agriculture, particularly the use of herbicides.[80] This may have consequences for biodiversity similar in extent to the wide-reaching consequences that followed previous changes in agricultural practices such as the development of agro-chemicals.[81,82]

Although technological development is a major driver of the pressures which directly threaten biodiversity, there are others, notably the Common Agricultural Policy (CAP), the establishment of the Trans-European traffic networks (TENs), large-scale demographic and socio-economic changes, and landscape-related policy and planning mechanisms at the national level.[76]

Loss of forest habitats has occurred in Europe for centuries. Europe (including the Russian Federation) covers 2260 million ha, of which 1007 million ha are natural forest and 32 million ha are plantations.[83] Although deforestation is a global problem, particularly in the tropics, the major pressures on forest biodiversity in Europe relate to changing demands on its forests.[84,85] In the eighteenth century, the demands placed on forests in Europe escalated due to population growth. Concerns about wood shortage triggered systematic forest management in Europe to increase productivity, control the rate and type of exploitation and conserve the area of forest.[86] This approach was adopted across large parts of Europe, particularly in landlocked countries that did not have access to the sea and hence could not readily import wood from other parts of the world. This advent of silviculture and the intensification of management gave rise to a range of pressures on biodiversity,[84,85] comprising:

1. Overall changes in forest management:

   - changes in ownership structure, *e.g.* concentration of ownership, commercialisation of state forests,
   - changes in systems for transportation of wood to industry, *e.g.* to road transport,
   - changing of planning strategy, *e.g.* regional focusing of timber harvesting,
   - suppression of natural forest fires in naturally fire-prone forest types.

2. Changes in silvicultural systems:

   - changes in harvesting, *e.g.* introducing clear cutting, and/or increase in size of areas cut,
   - shortening of crop rotation length,
   - introduction of exotic species and plantation forestry,
   - installation and/or alteration of drainage systems,
   - use of fertilisers, pesticides and herbicides,
   - removal of dead wood and diseased trees.

3. New technologies:

   - new machinery for timber harvesting and, for example, treatment of regeneration areas (*e.g.* soil scarification),
   - new types of forest roads.

Globally, the biodiversity of freshwater systems is rapidly deteriorating as a result of human activities.[87] Across Europe, a number of pressures act singly or in combination in deleteriously affecting the biodiversity of freshwater ecosystems. The type and severity of pressures affecting freshwater ecosystems differ across Europe. For example, although there is no shortage of water for Europe as a whole, regional imbalances can occur between supply and demand. In southern Europe, water availability is often considered as a severe problem and the combined effect of overexploitation and drought have markedly affected regional and local biodiversity.

The eutrophication of freshwater ecosystems occurs in all parts of Europe where intensive agriculture is prevalent and is a major pan-European problem.[6,88] The effects of nutrient enrichment by phosphorus and nitrogen are well documented, with excessive growths of algae resulting in increased turbidity, shifts in community composition and subsequent oxygen deficiency in bottom waters[87] (Table 2). In some instances population growths of toxin-producing species may also result, strongly affecting the usability of the water body. Phosphorus inputs are predominantly from point sources (domestic and industrial), but with the implementation of water treatment facilities and improved chemicals (*e.g.* low phosphorus detergents), eutrophication is expected to decrease. However, significant effects are evident from non-point sources, particularly as surface runoff from agriculture but also from forestry. Both activities may result in nutrient enrichment of receiving waters and loss of biodiversity. In addition, inputs of inorganic matter (*i.e.* sediment) from both agriculture and forestry activity may result in loss or degradation of habitat due to siltation.

The effects of organic pollution on the biodiversity of freshwater systems is another area of concern, particularly in densely populated areas with no or insufficient treatment of sewage effluents.[87] For example, the effects are most prevalent in many Eastern and Southern European countries where advanced sewage treatment is lacking or rare. The effects of organic pollution on aquatic life are similar to those outlined above for eutrophication – high levels of organic input result in major shifts in community composition, ultimately resulting in communities predominantly consisting of only a few tolerant species. However, in contrast to the input of inorganic nutrients and subsequent changes in trophic structure, sewage inputs often are also laden with a wide variety of other pollutants (such as pathogens and heavy metals) that may affect aquatic life.

A third major pressure affecting aquatic ecosystems in large areas of Europe is the acidifying effect of sulfur and nitrogen.[87] Acidification has had profound effects on the biodiversity of lakes and streams, in particular systems situated in

Table 2 Examples of common pressures and related impacts that may lead to the loss of biodiversity in freshwater ecosystems in Europe.

Activity and/or pressure	*Impacts*
Agriculture and Forestry	
Fertiliser use and ploughing	Erosion, increased nutrient load leading to eutrophication
Application of agrochemicals and antibiotics	Contamination with toxic or ecotoxic compounds leading to alteration of population dynamics and community structures
	Scarification
Forestry and afforestation	Enhanced water runoff, with consequences for erosion, eutrophication and local acidification
Alterations of natural hydrology	
Irrigation, drainage Water abstraction Flood prevention (damming) Channelisation	Change of natural hydrology leading to habitat alteration and destruction (such as loss of wetlands) migration barriers
Acidification	
Acidifying effects of runoff Metal (Al) toxicity	Alteration of community composition
Waste disposal (organic pollution)	
Sewage, treated wastewater Slurry Direct disposal of waste	Contamination with nutrients, organic compounds, toxic or ecotoxic compounds leading to eutrophication, alteration of population dynamics and community composition
Fishing, fishery and pisciculture	
Fish farming: use of antibiotics, direct feeding or fertilisation	Same impacts as waste disposal Alteration of community composition
Fish stocking and harvest of stocked fish	Dilution of native genetic stocks
Harvest of natural stocks	
Introduction of new species	
Exotic fish Other species	Alteration of the community composition, leading to displacement of indigenous species

the southern parts of Norway, Sweden and Finland. To mitigate the deleterious effects of acidic deposition, liming activities are widespread (particularly in Sweden). In the last decade S and N emissions have decreased markedly and recent studies have shown "chemical" recovery of some ecosystems.[89] However, in many areas and ecosystems, biological recovery will greatly lag behind that of chemical recovery due to the slow processes of recolonisation by many aquatic organism groups (*e.g.* fish and invertebrate groups that lack aerial dispersal mechanisms).

Although threats to biodiversity can be considered ecosystem-by-ecosystem, policies and actions in one ecosystem can influence other ecosystems. For example, policies pursued at local, regional or national scales may favour economic development and urbanisation, agriculture or grazing, all of which may have an impact on, for example, forest biodiversity.[84] In addition, changing land ownership patterns and economy, such as those taking place in the eastern parts of Europe, may lead to conflicts with biodiversity conservation. A range of policies may also indirectly result in land-use changes. For instance, depopulation of rural areas leads to abandonment of land, including forested land. This may lead to both positive and negative outcomes for biodiversity. One negative outcome is an increased risk of forest fires. In southern Europe (Spain, France, Greece, Italy, Portugal), the area burnt increased exponentially between 1970 and 2000,[90] with an average of almost 480 000 hectares annually destroyed by fire.

A further important consideration is that human-generated pressures can cover large spatial scales, affecting regions often far away from the area of origin. For example, the biodiversity of lakes and streams in the Nordic countries, particularly the southernmost regions of Norway, Sweden and Finland, has been altered by the deposition of sulfur and nitrogen (SO_4 and NO_x) compounds emanating from elsewhere.[87]

6 The Policy Response to Biodiversity Loss

Action to prevent biodiversity loss began long before the CBD was born in 1992. The French Nature Conservation Act, for example, was established in 1976, the UK Access to the Countryside and National Parks Act in 1949 and the establishment of protected areas started in the nineteenth century.[2] In Europe, the first Environmental Action Programme was launched in 1973, the Birds Directive in 1979 and the Habitats Directive in 1992. However, the CBD led to a rapid increase in the development of policy on biodiversity in Europe and elsewhere. At the national scale, biodiversity strategies have been published in Austria (1998), Denmark (1995), Finland (1997), Ireland (2002), The Netherlands (1995, revised 2002), Portugal (2001), Spain (1998), Sweden (1994), UK (1994), Estonia (1999), Latvia (2000), Lithuania (1996), Poland (1997), Slovenia (2001) and Slovakia (1997) and are in preparation in other countries. The European Community published a biodiversity strategy in 1998, based on a policy of incorporating biodiversity concerns in sectoral policies[91] and adopted four Biodiversity Action Plans in 2001 – on the Conservation of Natural Resources, Agriculture and Fisheries and on Economic and Development Co-operation. In 2006, the European Commission published a policy communication on biodiversity.[92] At the pan-European level, the Pan-European Biological and Landscape Diversity Strategy (PEBLDS) was established to stop and reverse the loss of biological and landscape diversity in Europe.

In Europe the flagship initiative on biodiversity is Natura 2000, a network of protected sites containing natural habitats of the highest value and species that are rare, endangered or vulnerable in the European Community. The Natura 2000 network includes Special Areas of Conservation (SACs) designated under the Habitats Directive, which support natural habitats and species of plants or animals other than birds, and Special Protection Areas (SPAs) classified under the Birds Directive, which support wild birds and their habitats. The Natura 2000 network has met with mixed success. The UK has had a long history of implementing legislation for nature conservation, including recent amendments to the 1981 Wildlife and Countryside Act. The main focus of this legislation has been the notification, protection and management of a national series of Sites of Special Scientific Interest. The many landowners involved (approximately 25 000) have long been used to the issue of statutory designations and so the relatively recent proposals for Natura 2000 comes on top of an already well-established system of both regulation and financial incentives. In other parts of Europe, however, there has been strong local opposition to designation of Natura 2000 sites.[93,94]

Despite the progress being made in combating biodiversity loss in many species and habitats following the implementation of the CBD across Europe, there are few signs that the rate of loss is declining. Indeed, a recent report concluded that "The living world is disappearing before our eyes".[95] However, as argued above, the available information on trends in biodiversity covers only a small fraction of Europe's habitats and species and is an inadequate basis for policy makers seeking to halt biodiversity loss.[96]

7 Quantifying Biodiversity Loss

The fundamental problem with quantifying biodiversity loss is the enormous variety of habitats and species: there will always be insufficient resources to monitor every European habitat and species. Even the monitoring of Natura 2000 sites represents an enormous challenge: as of March 2005 there were 19 516 candidate SACs and 4169 SPAs.

In response to this problem, biodiversity indicators have been proposed as means of providing rapid measures of biodiversity by both researchers[32,97] and policy makers.[96] From the policy perspective, the CBD has led the recent development of biodiversity indicators: eight biodiversity "focal" indicators were considered ready for immediate testing while another 13 were recommended for further development (Decision VII/30 (CBD COP7); see Table 3). This Decision notes the need for a framework to:

- facilitate the assessment of progress towards the (CBD) target to significantly reduce the rate of loss of biodiversity by 2010 and the communication of this assessment;
- promote coherence among the programmes of work of the CBD;
- provide a flexible framework within which national and regional targets may be set, and indicators identified.

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. These indicators were subsequently taken up in the Council Conclusions (Environment, June 2004). This list shows close

Table 3 Summary of CBD focal and EU biodiversity headline indicators.

EU biodiversity headline indicators [with variation from CBD focal indicator noted where appropriate][a]
Trends in extent of selected biomes, ecosystems and habitats
Trends in abundance and distribution of selected species
Coverage of protected areas
Change in status of threatened and/or protected species [CBD focal indicator does not include protected species]
Trends in genetic diversity of domesticated animals, cultivated plants and fish species of major socioeconomic importance
Area of forest, agricultural, fishery and aquaculture ecosystems under sustainable management [CBD focal indicator does not include fisheries]
Nitrogen deposition
Numbers and cost of alien invasions
Impact of climate change on biodiversity [Not included in CBD list]
Marine trophic index
Water quality in aquatic ecosystems [CBD focal indicator refers only to freshwater ecosystems]
Connectivity/fragmentation of ecosystems
Funding to biodiversity [Not included in CBD list]
Public awareness and participation [Not included in CBD list]
Ecological footprint and related concepts[b]

[a]CBD list also includes: status and trends of linguistic diversity and numbers of speakers of indigenous languages; official development assistance provided in support of the Convention.
[b] Additional indicator added in 2006.

overlap with the CBD list (Table 3). An overlapping set of pan-European biodiversity indicators has also been developed through PEBLDS. The Streamlining European 2010 Biodiversity Indicators initiative (SEBI2010) has been established by the European Environment Agency (EEA) to coordinate the implementation of these indicators.

These indicators vary markedly in the degree to which they are ready for use.[96] For example, a strong candidate for the implementation of the focal indicator "Trends in abundance and distribution of selected species" is the European Wild Bird Index, based on the UK Wild Bird Index[98] applied across Europe,[56,99] and the Red List Index[61] provides a measure of "Change in status of threatened and/or protected species". These indicators could probably be rapidly implemented.[96] Three other indicators are close to implementation: the marine trophic index,[57,100] coverage of protected areas and trends in habitat extent.[96]

Although the European Wild Bird Index and the Red List Index already have the potential to provide valuable information on trends in many European species, the degree to which these and other indicators provide adequate information on general trends in biodiversity remains unclear. The main concern is that trends in one group of species do not reflect trends in other groups. A number of studies have critically evaluated this concern and these have usually shown that spatial and temporal trends in the diversity of one taxon provide poor predictions of the diversity of other taxa.[101–109] For example, the species richness of birds and seven invertebrate taxa were found not to correlate with each other along a gradient of forest disturbance in Cameroon.[103]

These studies usually considered the congruence of different taxa in either different habitats in relatively small areas[103] or in the same habitat types in different parts of the same country.[109] The purpose of the BioAssess project, involving partners from ten European countries and conducted between 2000 and 2004, therefore, was to assess the potential of a range of taxa as indicators of biodiversity in managed terrestrial habitats in Europe. Using standardised protocols, the diversity of different taxa was sampled in 64 sites across Europe (see below). The following taxa were chosen both as representing major components of biodiversity and as potential indicators of biodiversity; birds, butterflies, lichens, plants, ground beetles (Carabidae), soil macrofauna (invertebrates greater than 1 cm in length) and soil Collembola.

No single taxon was found to be an adequate indicator of the diversity, as measured by species richness, of all other taxa. There were, however, significant relationships between the species richness of several taxa, notably between plants, lichens, butterflies and birds. In contrast, no significant relationships were found between the species richness of the three other taxa studied, two soil-dwelling taxa, soil macrofauna and soil Collembola, and epigeal (ground-surface dwelling) ground beetles. Furthermore, the species richness of above-ground taxa generally failed to correlate with below-ground biodiversity. This study suggested that some species-based indicators, such as birds, might succeed in predicting the status and trends in some other major components of biodiversity. International initiatives to monitor trends in the abundance and diversity of birds and associated indicators such as the European Wild Bird Index[56] may therefore be important in indicating trends in some other components of biodiversity. However, this study also showed that this index would fail to predict trends in the diversity of many taxonomic groups, particularly soil-dwelling and epigeal invertebrates.

8 Biodiversity and Land-use Change

Although monitoring trends in biodiversity is a major challenge, information on trends alone, without an assessment of what is causing these trends, provides an inadequate basis for taking action against biodiversity loss. We know, as discussed above, that there are many anthropogenic drivers of biodiversity loss. However, we have very little quantitative information on the contribution of each of these drivers. There are some notable exceptions. Our understanding of the impacts on biodiversity of aquatic pollutants[87] and agricultural practice[81] is relatively good. This understanding has led to specific measures to alleviate these impacts, although some of these have not been as effective as intended.[110]

Although studies on particular species and habitats are increasing our understanding of the impact of many of the pressures affecting biodiversity, there have been few assessments of the impact of major drivers across Europe. The MIRABEL framework, however, was developed to assess the impact of land abandonment, eutrophication, afforestation and other pressures on biodiversity in 13 European ecological regions, and showed that agricultural intensification is one of the main threats to European biodiversity.[70]

General assessments of the impact of different drivers on biodiversity are made difficult by possible differences in the impact of these drivers on different species and habitats. Research in forest ecosystems, for example, demonstrates that different invertebrate taxa respond in different ways to forest management.[111,112]

In an attempt to provide an assessment of the impact of major land-use changes across Europe, the BioAssess project (see above) measured the diversity of several taxa along gradients of land-use intensity in eight countries (Portugal, Spain, France, Switzerland, Hungary, Ireland, Finland and the UK), thereby encompassing six major biogeographical zones (Boreal, Atlantic, Continental, Alpine, Mediterranean and Pannonian). A total of more than 3450 species were recorded from six 1 km^2 sites in each of eight countries, ranging from 1442 plant to 111 bird species. Mean species richness across the land-use gradient ranged from 321 plant to 34 butterfly species. In terms of species richness, different taxa varied in their sensitivity to land use: the impact of land use ranged from a mean difference of 40% (27 species) between the species richness of carabids recorded in the most and least species-rich sites to a mean difference of 25% (17 species) between the species richness of soil Collembola. The most speciose taxa, plants and lichens, showed a 31% (98 species) and 35% (61 species) difference, respectively. Several taxa responded similarly to land use: plants, birds, butterflies and lichens showed similar trends in species richness across the land use gradient (Figure 3). The diversity of each of these taxa was greatest in sites with a mixture of land uses and tended to be lowest in managed forests and sites dominated by arable fields. The soil-dwelling and epigeal invertebrates, however, responded differently. Carabids, for example, showed an increase in diversity across the gradient from forest to agricultural sites.

The BioAssess project confirms that biodiversity is unlikely to show a simple, unified response to major anthropogenic drivers such land-use change: these drivers may have different impacts on different groups of plants and animals. Indeed, individual species within each taxa are also likely to respond differently, as analyses of the BioAssess data are beginning to demonstrate.[113–115]

9 Discussion

Despite our gaps in knowledge and the lack of data, the evidence of biodiversity loss in Europe is convincing.[5,116,117] Further pressure on land use is likely to have a continued impact on biodiversity, as is climate change[118] and the interaction between climate change and land-use change.[24,119]

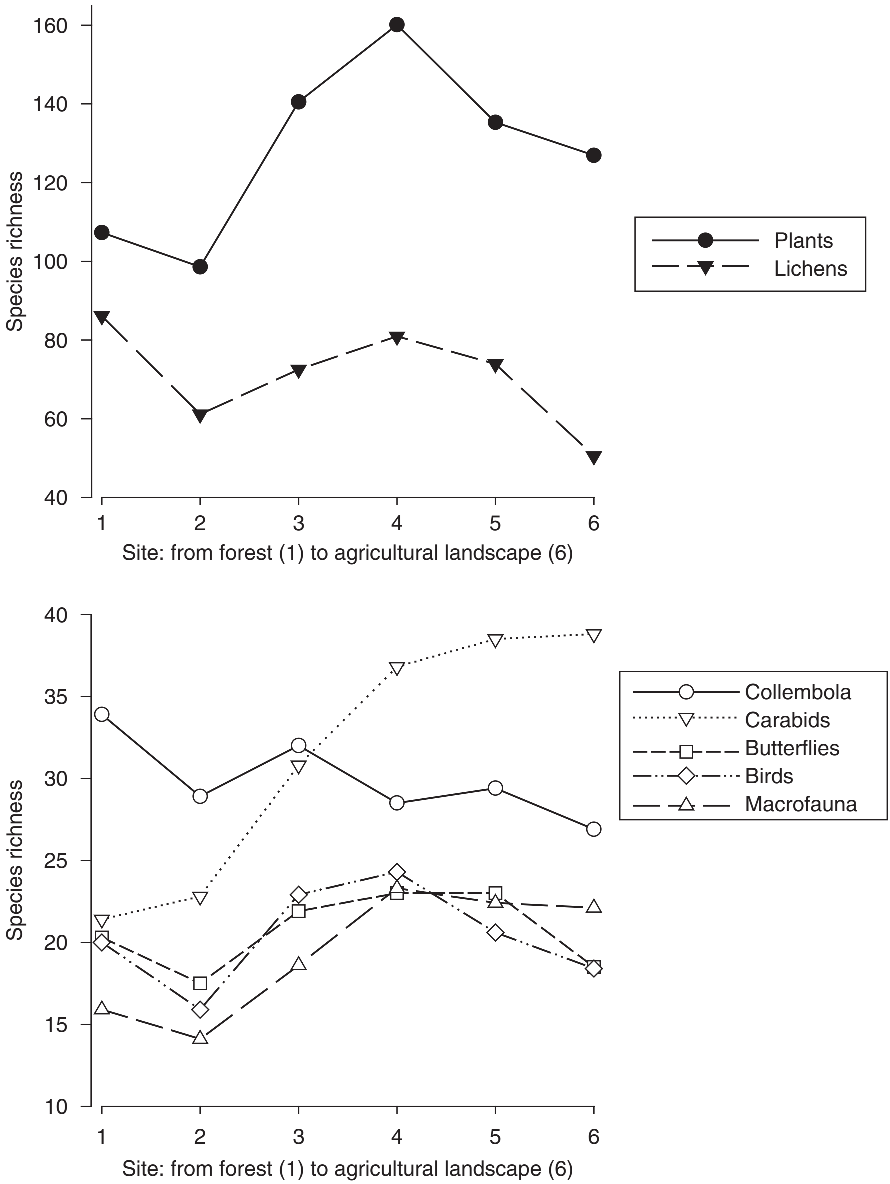

Figure 3 Average species richness of seven different taxa across a land-use gradient of sites from unmanaged forest to intensive arable in eight different countries in Europe.

The policy responses to biodiversity loss in the last twenty years have demonstrated a commitment to conserve biodiversity but despite major initiatives, notably NATURA 2000 and the growing list of Biodiversity Action Plans, there are worrying signs that action to conserve biodiversity is not always effective.[110,120] And despite the increasing amount of available information on biodiversity, most of which is provided by the action of NGOs, there are inadequate data available for many taxa.

The implementation of headline biodiversity indicators in Europe is to be welcomed but it is unlikely that their implementation will provide direct information on many taxa other than birds. The Red List Index[61] will provide an assessment of a range of taxa but it is biased towards species groups that are well known. As discussed above, indicators derived from information on a restricted range of species do not provide reliable information on trends in all taxa.

We clearly need better information on trends in biodiversity, particularly for taxa that have been relatively neglected. We also need information that allows us to quantify the impact of major drivers of biodiversity and to evaluate the policies and measures put in place to conserve biodiversity loss. But it is unrealistic to expect that monitoring programmes to assess trends in more than a very few taxa will be established across Europe, at least at the scale that bird monitoring is being conducted. We therefore argue for a two-level approach to monitoring biodiversity in Europe and elsewhere, the first comprising extensive monitoring of a limited number of taxa, such as birds, which are both intrinsically important and are also potential indicators of other components of biodiversity. In addition to the monitoring initiatives on birds referred to above, there are other extensive monitoring programmes in various stages of development.[121] Most of these programmes have a limited geographical coverage but methods do exist to aggregate data from a variety of sources to provide comparable indicators of biodiversity.[122]

Given the limited value of one or few taxa as indicators of all other components of biodiversity, however, a network of a limited but carefully selected number of sites is needed for the intensive observation of a wider range of taxa. Such a network should provide information on those components of biodiversity that extensive monitoring programmes do not address. It should also serve as a focus for research, evaluating indicators of biodiversity used in extensive programmes and developing new indicators, including indicators based on earth observation. In addition, this network of intensively monitored sites would provide a basis for an improved understanding – through observation, experimentation and modelling – of the impact of anthropogenic drivers and pressures on biodiversity in the context of natural temporal and biogeographical influences on biodiversity.

To address effectively the 2010 targets to reduce or halt the loss of biodiversity we need information on trends on biodiversity delivered to those that need it to take the required action in the timescale needed to do so.[123] Effective action does, however, require that we have a much better understanding of the impacts of various anthropogenic drivers and pressures on biodiversity. A network of intensively monitored observation and research sites, linked to the extensive monitoring networks of a limited number of taxa such as birds, would therefore serve to provide both an improved understanding of trends in biodiversity and also a better understanding of their causes. It would also serve to bring scientists, policy makers and other stakeholders closer together and, therefore, improve the likelihood of effective action to conserve biodiversity.

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