Climate Change and Biodiversity in Europe

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Abstract: *Climate change is already affecting European biodiversity, as demonstrated by changes in species' ranges and ecosystem boundaries, shifts in reproductive cycles and growing seasons, and changes to the complex ways in which species interact (predation, pollination, competition and disease). These effects vary between regions and ecosystems. Strategies adopted to mitigate or adapt to climate change also impact biodiversity. And land use changes with subsequent changes to biodiversity can also alter levels of greenhouse gas emissions thus affecting the global climate. This article describes the many linkages between climate and biodiversity. It stresses the need for more integrated policy responses, at international, regional and national levels. Nationally, activities that meet biodiversity and climate change objectives need promoting and mainstreaming into various sectoral areas of policy making. Reducing energy consumption, increasing energy efficiency and promoting renewable energy technologies are priorities. Activities which meet both climate and biodiversity objectives also need exploring. These include adopting new landscape management approaches, and ensuring that carbon sequestration projects and renewable energy projects incorporate biodiversity considerations.*

Keywords: climate change, Europe, species, ecosystems, integrated policy responses

Introduction

THE EARTH'S CLIMATE has gone through many periods of significant warming or cooling throughout its history. The fossil record demonstrates that these changes have had important ecological impacts, and have at times coincided with a number of mass extinctions (IPCC 2001). Current global warming, however, is unusual. It is fuelled mostly by human activities; especially greenhouse gas emissions from burning fossil fuels. Agriculture and land use changes, and other industrial processes that release greenhouse gases also contribute to climate change (IPCC 2001). Carbon dioxide concentrations in the lower atmosphere have increased from pre-industrial concentrations of 280 parts per million to 375 parts per million concentrations in 2003. This is the highest level in the last 50,000 years (IPCC 2001). These changes in carbon dioxide and other greenhouse gas concentrations have led to changes in climate.

The climate is warming in most parts of the world. The global average temperature has increased by about 0.7°C and the European average by about 0.95°C in the last 100 years (EEA 2004). It is estimated that temperature will increase by 1.4–5.8°C globally and 2.0–6.3°C in Europe by 2100 (EEA 2004). Precipitation patterns are more varied. In the last 100 years northern Europe has become 10–40% wetter and southern Europe up to 20% drier. These changes are projected to continue (EEA 2004). The Intergovernmental Panel on Climate Change (IPCC 2001) states that 'the risk of water shortage is projected to increase particularly in southern Europe.... Climate change is likely to widen water resource differences between northern and southern Europe.' Eight out of nine glaciated regions in Europe have shown significant recent retreat. From 1850 to 1980 glaciers in the European Alps lost about one third of their area (EEA 2004). In the past 100 years, European sea levels have risen by 0.1 to 0.2 m (IPCC 2001). Currently the sea level around European coasts is rising at a rate of 0.8 mm/year (in Brest and Newlyn) to 3.0 mm/year (in Narvick) (Liebsch et al. 2002). In addition, extreme weather events such as droughts, heatwaves and floods have increased in Europe, while cold extremes have decreased (Klein Tank 2004).

The extent and rate of current climate change exceeds all natural variation in the last 1000 years and possibly further back in history (Houghton et al. 2001). The speed of change makes it hard for humans, other species and ecosystems to adapt. The modern landscape also provides little flexibility for ecosystems to adjust to rapid environmental change. In contrast with historical migration responses, species today must move through a landscape that is increasingly impassable due to the widespread loss and fragmentation of habitats (Kappelle et al. 1999; Walther et al. 2002). Indeed, the IPCC (2001) states that in Europe, 'adaptation potential for natural systems is generally low' in part because 'Europe is predominantly a region of fragmented natural or semi-natural habitats in a highly urbanised, agricultural landscape.'

The debate about climate change has now reached a stage where most scientists accept that, whatever happens to future greenhouse gas emissions, we are now locked into a future characterised by significant human-induced changes to our climate. There are two types of response to these changes: the first is to try and reduce the extent to which our climate is altered. This is known as climate change mitigation. The second is to learn to live with the inevitable changes. This is known as adaptation to climate change.

Biodiversity is inextricably linked to climate. Changes in climate affect biodiversity and changes to natural ecosystems affect climate. This article considers the linkages between climate change (mitigation and adaptation) and biodiversity. It then discusses the need for integrated policy responses, and ends with some practical ways forward to provide both biodiversity and climate change benefits on the ground.

Direct Impacts of Climate Change on Biodiversity

This section discusses the most important direct impacts that climate change could have on biodiversity.

Species Ranges

Climate change is likely to have a number of impacts on biodiversity—from ecosystem to species level. The most obvious impact is the effect that temperature and precipitation changes have on species' ranges and ecosystem boundaries. Any particular ecosystem consists of an assemblage of species, some of which will be near the edge of their ranges and others of which will not. Those at the edge of their ranges may need to move due to climate change (Leemans and van Vliet 2004). Species that are highly mobile or opportunistic are likely to benefit at the expense of those that are not (Hughes 2000; Secretariat of the CBD 2003). The invasion of alien species may be facilitated in some parts of Europe. Root et al. (2003) found that out of 1700 species reviewed globally, 81% of observed shifts in range were in the direction expected by climate change. In Europe, Bakkenes et al. (2002) predict that under existing climate change forecasts only 32% of plant species existing in an average 'grid cell' in 1990 would still be present in 2050.

In terrestrial Europe, trees and shrubs have replaced many Arctic and tundra communities (Molau and Alatalo 1998). The treeline and the level at which alpine plants are found in Europe is moving towards higher altitudes (Walther et al. 2002). In Sweden, the treeline is predicted to rise by 233 to 677 m depending on the climate scenario and location (Moen et al. 2004). European tree species may be replaced by new species that are better adapted to higher temperatures and drought stress. Plants or trees that need low temperatures in winter to trigger bud bursting in spring may be adversely affected (Chuine and Beaubien 2001). In the Netherlands, thermophilic plant species have become 60% more common compared with 30 years ago, and cold-tolerant species have declined (Tamis et al. 2001).

European insects, mammals and diseases also demonstrate range shifts (Leemans and van Vliet 2004). For example, out of 35 butterfly species in Europe, 63% have shifted their ranges northwards by 35–240 km over the last century, whereas only 3% have shifted south (Parmesan et al. 1999). In Finland, macrolepidopteran species richness is expected to increase as southern species shift their ranges northwards (Virtanen and Neuvonen 1999). Conversely, the distribution of northern species, comprising 11% of Finnish species, may shrink (Virtanen and Neuvonen 1999). Thomas and Lennon (1999) report that the ranges of many British bird species have moved an average of 18.9 km northwards in the last 20 years.

In European seas, temperate species have migrated about 250 km northward per decade (Parmesan and Yohe 2003), whereas sub-Arctic and Arctic species have declined in number (Beaugrand et al. 2002). More temperate species are now found in the North Sea (EEA 2004). European seas have shown surface temperature increases, especially in isolated basins like the Baltic Sea and the North Sea (EEA 2004). This has increased phytoplankton biomass, and moved the ranges of zooplankton species by up to 1000 km in the last few decades (EEA 2004). Clark et al. (2003) predict that the North Sea cod population will increasingly decline due to higher sea temperatures.

Shifts in ecosystem boundaries could mean that protected areas, such as the Swiss National Park, no longer contain the species and habitats they were established to protect. The Pasterze Glacier has also retreated several hundred metres since the 1970s, thus affecting the Hohe Tauern National Park in Austria (Dudley 2003). Under existing static conservation paradigms, little emphasis is placed on changing patterns of biodiversity. And few protected area systems have been formulated with reference to climate change, even in countries where effects will probably be large (Hannah et al. 2002). The World Wide Fund for Nature (WWF) argues that protected areas offer limited defence against problems posed by rapid environ-mental change, and that protected areas themselves will need to adapt to meet the challenges posed by global warming (Dudley 2003).

Flooding and sea level rise will affect species' ranges and ecosystem boundaries as well as threatening wetlands and coastal ecosystems (Dudley 2003). Man-made coastal defences across the UK are eroding faster than ever and destroying important inter-tidal habitats for birds (RSPB 2004a). The IPCC (2001) states that in European 'coastal areas, the risk of flooding, erosion, and wetland loss will increase substantially... Southern Europe appears to be more vulnerable to these changes, although the North Sea coast already has high exposure to flooding.'

Changes in Phenology

Climate change is also causing shifts in the reproductive cycles and growing seasons of certain species. This can alter the frequency of pest and disease outbreaks. Research by Parmesan and Yohe (2003) on the timing of spring events, such as egg laying by birds or flowering by plants, showed that in 61 studies, the timing had shifted earlier by an average of 5.1 days per decade over the last half century. Likewise, Root et al. (2003) found that out of 1700 species reviewed, 87% of observed shifts in phenology were in the direction expected by climate change. In Europe, phenological data shows an increase in the length of the growing season by about 10 days from 1962 to 1995 (Menzel and Fabian 1999). Leemans and van Vliet (2004) note phenological shifts in certain mammal, reptile, fish and bird species. For example, bird life cycle events such as migration and egg laying appear to be occurring earlier (Crick et al. 1997). Increasingly warm winters associated with the North Atlantic Oscillation influence the development and fecundity of red deer (Cervus elaphus) in Norway (Post et al. 1997). And in the UK, amphibians are spawn- ing nine to ten days earlier than they were 17 years ago (Beebee 2002).

Changes in Species Interactions

The impact that climate change will have on many of the more complex interactions (predation, competition, pollination and disease) that constitute functioning ecosystems remains largely unknown (Walther et al. 2002; Leemans and van Vliet 2004). However, some studies provide indications of what might be expected. For example, the indirect effects of climate change can be seen in a food chain in the North Sea where warmer water is driving cold water plankton further north. This reduces the survival of young cod and sandeels. A sandeel shortage may in turn have contributed to the large breeding failure seen in seabirds on the North Sea coast of Britain in 2004 (Lanchbery 2004; RSPB 2004a).

Changes in competitive ability may also emerge. For example, early leafing trees will get a two-week head start on their competitors in terms of growth, and thus occupy an increasing proportion of woodland (Dudley 2001). Numbers of long distance migrating birds in the Lake Constance region (a Ramsar site at the border of Austria, Germany and Switzerland) have declined, probably due to warmer winters increasing the competitive advantage of resident bird species (Lemoine and Böhning-Gaese 2003).

Mismatches in timing between interdependent species may occur, especially when changes in some species are cued by day length, and others by temperature (Hughes 2000). For example, in one wood in Oxfordshire, UK, there is evidence that blue tit hatching no longer coincides with peak caterpillar numbers (Dudley 2001).

Disease and predation may also increase. For example, numbers of native pests such as the green spruce aphid may increase due to milder winters, and non-native pests such as the pinewood nematode, gypsy moth and Asian long-horn beetle are now found in southern British woods (Broadmeadow 2000; Dudley 2001).

Extinction Rates
Climate change may lead to a sharp increase in rates of extinction. Thomas et al. (2004) studied five regions of the world, and predicted that if the present rate of climate change continues, 24% of species in these regions will be on their way to extinction by 2050. This study indicated that for many species, climate change poses a greater threat to their survival than the destruction of their natural habitat. Evidence directly linking climate change and species extinction is difficult to procure, but at least one species: the golden toad of Costa Rica, may have become extinct due to climate change (Pounds et al. 1999).

Effects of Extreme Climate Events
Climate change related extreme events such as disease, drought, fire or an El Niño are likely to increase, and can seriously affect biodiversity (Hannah et al. 2002). These extreme events may affect organisms, populations and ecosystems more than gradual global or regional changes in averages (Leemans and van Vliet 2004; Walther et al. 2002). For example, Spain lost more than 485,622 hectares of forest to wildfires in 1994 and Italy lost 149,734 hectares in 1998 (Pinol et al. 1998). The 1976 drought in the UK severely affected tree health, and vulnerable species like beech took years to recover (Dudley 2001). About 15 million trees were blown down in the UK during the October 1987 storm (IPCC 2001). Broadmeadow (2000) predicts that higher mean wind speed and an increase in the occurrence of storms will make British wood-lands more vulnerable to wind damage.

Variations between Regions, Species and Ecosystems
The impacts of climate change on biodiversity will vary between regions. The most rapid changes in climate are expected in the far north and south of the planet, and in mountainous regions (Pauli et al. 2001). Unfortunately, these regions are also home to many species which have no alternative habitats to which they can migrate in order to survive, and species which cannot easily compete with new immigrating species (Pauli et al. 2001). In Europe, the greatest effects of climate change are projected for Arctic Regions, the moisture-limited ecosystems of eastern Europe, and the Mediterranean region (Bakkenes et al. 2002). The IPCC (2001) states that ‘the Arctic is likely to respond rapidly and more severely than any other area on earth, with consequent effects on sea ice, permafrost, and hydrology’. It adds that ‘polar warming probably should increase biological production, but different species compositions are likely on land and in the sea, with a tendency for poleward shifts in major biomes and associated animals’. Theurillat and Guisan (2001) state that high mountain systems such as the Alps will also be particularly vulnerable.

Some species and ecosystems are also more vulnerable than others, particularly small populations or those restricted to small areas. For example, endangered birds in the UK, especially those living in fragile mountain habitats, such as the dotterel (*Charadrius morinellus*), ptarmigan and snow bunting, may have nowhere to move to and be lost from the UK forever (RSPB 2004a). In mountainous regions of Europe, endemic tree species have been replaced by other species (such as spruce and pine), which have migrated upwards due to a number of factors including climate change (Pauli et al. 2001). The IPCC (2001) states that in Europe, 'Tundra areas have practically no adaptive options available'.

Indirect Impacts of Climate Change on Biodiversity

It is not just climate change itself that can impact biodiversity. In some cases, the strategies that are adopted to mitigate or adapt to climate change can affect biodiversity. This section discusses the most important indirect impacts that climate change could have on biodiversity.

Classic top-down approaches to climate change often equate to large infrastructure construction projects. Projects designed to support adaptation to climate change are often associated with physical protection. For example, large sea walls may be built to protect against storm surges and floods. These are particularly important in Asia, and the Netherlands continues to invest millions in improving its sea defences against sea level rise and storms (Mortished 2005). Such projects often negatively impact biodiversity. Alternative adaptation options, such as strategic placement of artificial wetlands (or protection of existing mangroves or coral reefs outside Europe) can benefit biodiversity (Secretariat of the CBD 2003). Other adaptation projects involve using pesticides and herbicides to control pests and diseases that might increase due to climate change. Use of such chemicals may damage existing plant and animal communities (Secretariat of the CBD 2003).

Projects designed to reduce global greenhouse gas emissions and thus mitigate climate change are often associated with large renewable energy schemes. These often have poor outcomes for biodiversity. For example, large hydropower schemes can cause loss of terrestrial and aquatic biodiversity and inhibit fish migration (Fearnside 2001; Fu et al. 2003). Locating dams near river estuaries is particularly damaging, as it disrupts the whole watershed. Dams can also be net emitters of greenhouse gases if submerged soils and vegetation decay and release carbon dioxide and methane (Secretariat of the CBD 2003; World Commission on Dams 2000). Europe accounts for 70% of the total installed wind energy capacity in the world (Secretariat of the CBD 2003). Wind farms pose three main problems for birds: disturbance, habitat loss/damage, and collision. For example, wind turbines in Tarifa and Navara in Spain have killed many raptors. The design, location and management of wind farms can limit these problems (RSPB 2004b). The effect that offshore wind farms will have on sea mammals, fish and marine aquatic communities is largely unknown (Secretariat of the CBD 2003).

Afforestation and reforestation activities designed to sequester carbon and therefore mitigate climate change can restore watershed functions, establish biological corridors and provide considerable biodiversity benefits if a variety of different aged native tree species are planted. Monocultures, however, not only reduce biodiversity, but also increase the chances of pest attacks, thus challenging the permanence of carbon stocks. The location of afforestation and reforestation projects is also important. Replacing native grasslands, wetlands, shrublands or heathlands may lead to dramatic biodiversity losses, and also lower the relative increase in carbon sequestered compared to implementing such projects on degraded land (IUCN 2004; Reid 2003; Secretariat of the CBD 2003).

How Ecosystems and Biodiversity Affect Climate

Just as climate change affects biodiversity, so changes in biodiversity can affect the global climate. This section documents some of the most important ways in which biodiversity affects the climate.

Land use changes and subsequent changes to biodiversity can both increase and decrease greenhouse gas emissions. Countries like Ireland, the Netherlands and Denmark are significant carbon sources, but countries like Slovenia and Slovakia are significant carbon sinks (Janssens et al. 2003).

Forests are a major carbon store. Carbon dioxide is released whenever there are forest fires, or when forests are cut down. Globally, deforestation, mainly in tropical regions, is thought to be responsible for annual emissions of 1.1 to 1.7 billion tonnes of carbon per year, or approximately one fifth of human carbon dioxide emissions (Brown et al. 1996). European forests were almost completely cleared during the agricultural expansion of the 16th to 18th centuries. This released considerable quantities of carbon from the vegetation and soil. European forests currently store on average 70–160 g of carbon per square metre per year, 70% of which is in trees, and 30% in soils. This makes them an important carbon sink. During the 1990s the European terrestrial biosphere stored 7–12% of the annual anthropogenic carbon dioxide emissions (Janssens et al. 2003). Nabuurs et al. (2002) predict that this is likely to continue, as climate change will increase the quantity of stemwood in European forests with an additional 0.9 m3 per hectare per year in 2030.

Peatlands provide many environmental services, such as improving water quality. Many are important biodiversity reservoirs or stopover points for migratory species. Peatlands also hold roughly one-third of the soil carbon worldwide, and greenhouse gases are released every time they are burned, drained, converted to agriculture or degraded. Peatland forest fires in Indonesia during 1997 released an amount of carbon dioxide equivalent to 40% of the world's average yearly carbon emissions from fossil fuels (Page et al. 2002). In Europe, peat extraction for horticulture, agriculture and energy is reducing stored carbon amounts. In Russia, permafrost peatlands appear to be melting and drying out and fire frequency is increasing (Janssens et al. 2003). Melting permafrost and the consequent release of greenhouse gases from northern wetlands can enhance climate change (Secretariat of the CBD 2003). Overall, European peatlands are a net source of carbon to the atmosphere of 70 Tg of carbon per year, equivalent to about 20% of the carbon sequestered by the European forest sector (Janssens et al. 2003).

Currently, some 60% of anthropogenic global greenhouse gas emissions originate from the generation and use of energy. While the use of renewable energy sources, such as wood, instead of fossil fuels can help mitigate climate change, this can also have negative impacts. For example, using relatively undisturbed natural fuel sources (such as native forests as opposed to plantations) can lead to significant biodiversity losses. Some bio-energy plantations replace sites with high biodiversity, introduce alien species and use damaging agrochemicals (Secretariat of the CBD 2003).

There are also many complex feedback mechanisms at work between biodiversity and climate change. For example, some species of ocean algae release dimethylsulfide into the atmosphere. Rising ocean temperatures due to global warming can lead to algal blooms, and resultant increases in dimethylsulfide release contribute to cloud formation. This in turn may help reduce temperatures, as less heat will be able to reach the Earth's surface (Sciare et al. 2000). Rising temperatures can stimulate the growth of phytoplankton in the sea, which can increase carbon dioxide uptake. Likewise higher atmospheric carbon dioxide concentrations and warmer temperatures can stimulate forest growth and hence carbon dioxide uptake in mid and northern European forests (Broadmeadow 2000; EEA 2004). In high latitudes, the replacement of shrub/tundra vegetation with trees can affect the radiation balance. Unlike snow, trees are more likely to absorb sunlight rather than reflect it. This in turn can enhance climate change (Secretariat of the CBD 2003).

Integrated Policy Responses

The many ways in which climate and biodiversity interact suggest a need for more integrated policy responses. Synergies between the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD) need to be explored. The Ad Hoc Technical Expert Group on Biological Diversity and Climate Change has identified some possible linkages (Secretariat of the CBD 2003), and the convention secretariats have established a joint liaison group to help link initiatives relating to climate change and biodiversity. However, getting those responsible for implementing the two conventions to work together is difficult. The conventions have separate constituencies, administration arrangements, negotiators and guiding scientific bodies. Encouraging countries to set up a single institution to deal with obligations under all international environmental agreements could be one way forward (Reid 2004; Reid et al. 2004b).

The UNFCCC (in Article two) states that the ultimate objective of the convention is to ensure atmospheric greenhouse gas concentrations stabilise 'within a time-frame sufficient to allow ecosystems to adapt naturally to climate change'. Parties to the UNFCCC are guided by the principle that carbon sequestration activities should also contribute to biodiversity conservation and the sustainable use of natural resources. But common guidelines on what this timeframe is or how these principles might be realised have not been agreed. The Kyoto Protocol and Marrakech Accords (under the UNFCCC) do not explicitly exclude practices such as afforestation of native grasslands or wetlands (IUCN 2004). The Clean Development Mechanism (CDM), established under the Kyoto Protocol, helps developed countries to meet emissions reduction targets, by allowing them to take credits from emissions reduction projects in poor nations. Projects are supposed to provide global benefits from carbon sequestration, but also sustainable development benefits. These benefits could actively incorporate biodiversity conservation, soil protection and other environmental concerns (IUCN 2004; Huq and Reid 2005). However, without a minimum set of common international standards, CDM and other climate change mitigation projects could flow to countries with minimal standards, thus adversely affecting biodiversity (Secretariat of the CBD 2003). The UNFCCC also currently classifies harvested forest products as emissions as soon as they leave the forest site. This fails to recognise the value of carbon sequestered in wood products and the biodiversity benefits of a well-managed forest (Reid et al. 2004a).

Biodiversity-related agreements must also incorporate climate objectives. For example, many projects and policies to conserve and sustainably manage ecosystems undertaken by parties to the CBD and other biodiversity-related agreements (such as the Convention on Migratory Species, Convention on Wetlands and World Heritage Convention) could impact climate change mitigation and adaptation objectives (Secretariat of the CBD 2003).

Regional policymaking also needs improved integration of climate change and biodiversity concerns. Europe has various policies on each, and although suggestions have been made on how to integrate these concerns (Usher 2005), policy coherence on these issues remains inadequate. For example, Dudley (2001) states that the Common Agricultural Policy needs reforming to support the protection of natural woodland in the UK in order that it can adapt to climate change. European forest policy has made some efforts at integrating climate and biodiversity concerns. The Pan European Criteria, Indicators and Operational Level Guidelines for Sustainable Forest Management, adopted in 1998, aim to support carbon sequestration in conjunction with biodiversity conservation. For example they promote afforestation and reforestation with native species. The General Guidelines for the Sustainable Management of Forests in Europe under the Ministerial Conference on the Protection of Forests in Europe does likewise (IUCN 2004).

Hannah et al. (2002) point out that species range shifts will not respect political boundaries, so effective conservation management will require new regional collaboration. The Pan European Biological and Landscape Diversity Strategy, endorsed in 1995 by 54 European states, recognises the importance of ecological networks and calls for the development of a Pan European Ecological Network (Nijhoff 2005). The Habitat Directive of the European Union also acknowledges the importance of landscape elements that enhance connectivity, and other global and European policies such as the Bonn and Bern Conventions oblige parties to conserve and manage listed species and habitats (Nijhoff 2005). Whilst not overtly considering climate change issues, such policies help reduce the vulnerability of biodiversity to climate change.

Nationally, policies and activities that benefit biodiversity and climate change adaptation and mitigation need promoting and mainstreaming into various areas of national policy making (IUCN 2004). This will avoid a purely sectoral approach and help enhance coordination between different government agencies (IUCN 2004). But it is not easy as many climate change and biodiversity-related activities are located within the Ministries of Environment, which are traditionally relatively weak when compared to ministries dealing with finance or land use planning (Reid 2004; Reid et al. 2004b). At present, coordination among sectoral agencies to exploit potential synergies is poor (Secretariat of the CBD 2003). National plans to deal with climate-induced disasters could identify vulnerable ecosystems as well as vulnerable human settlements (Reid 2004; Reid et al. 2004b). The development of a workable carbon intensity labelling system, pro-wood building and packaging standards and invigorated recycling programmes would help to maximise the climatic advantages of wood use (Reid et al. 2004a). This in turn could provide biodiversity benefits if wood is sourced from well-managed forests. Afforestation and reforestation guidelines could be incorporated into national forest programmes and National Biodiversity Strategies and Action Plans (IUCN 2004). Protected area policies and other species conservation initiatives also need to become more aware of the effects of climate change and to include this in their prioritisation of hazards and risk management schemes.

Practical ways to Link Climate Change and Biodiversity
The first step to address climate change must involve reducing greenhouse gas emissions. This requires lifestyle changes to reduce per capita energy consumption, and also technological innovations to increase energy efficiency and help the shift to more renewable technologies. The location of renewable energy initiatives, such as dams or wind farms needs careful consideration of biodiversity impacts. For example, the location of offshore wind farms in Germany is considering ecologically sensitive sites as well as wind energy qualification areas (BMU 2002). However, climate change is already happening, and will continue to do so whatever steps we now take (IPCC 2001). We therefore need to look at how we can adapt our countryside to reduce biodiversity losses.

Many conservation practitioners in Europe recommend adopting a landscape approach to reduce the negative impacts of climate change on biodiversity (Hannah et al. 2002). For example, the Woodland Trust in the UK advocates a move from focusing on protecting a few individual sites to a landscape approach. This would involve integrating protection, restoration and extension activities. Wide application of green corridors and buffer areas around particularly important woodland sites is needed (Dudley 2001). Functionally diverse communities may be better able to adapt to climate change than functionally impoverished systems. Conserving genotypes and species along with reducing habitat loss, fragmentation and degradation may therefore promote the long-term persistence of ecosystems (Secretariat of the CBD 2003). In Britain and Ireland, the Modelling Natural Resource Responses to Climate Change (MONARCH) programme of research led by English Nature uses modelling approaches to help nature conservation policy and management practices adapt to climate change. Results suggest the need for a flexible dynamic approach that can adjust to the changing distribution of species and habitat types (Secretariat of the CBD 2003). In Europe, the ACCELERATES (Assessing Climate Change Effects on Land use and Ecosystems: from Regional Analysis to The European Scale) Project funded by the European Commission is also assessing the vulnerability of European agroecosystems to environmental change.

Larger protected areas, which cover a range of elevations, microclimates and ecosystems, will be less vulnerable, as species will be able to migrate to another safe habitat within the protected area if climate change adversely affects their present one. Connections between existing protected areas will be increasingly important, as will buffer zones around protected areas, landscape connectivity and management of areas between core protected areas (Hannah et al. 2002; Dudley 2003; Secretariat of the CBD 2003). This is the thinking behind Natura 2000: a Europe wide network of protected areas (http://www.natura2000benefits.org).

Integrated watershed management can increase water retention and availability in times of drought, decrease the chance of flash floods and maintain vegetation as a carbon sink. It can also conserve watershed biodiversity. Avoiding degradation of peatlands and mires is particularly important for retaining soil carbon stocks and protecting biodiversity (Secretariat of the CBD 2003).

Certain forest management activities can simultaneously provide biodiversity and climate benefits. These include encouraging native species, increasing rotation age, low intensity harvesting, reduced impact logging, leaving woody debris, harvesting which emulates natural disturbance regimes, avoiding fragmentation, provision of buffer zones, corridors and natural fire regimes, and limiting the use of toxic chemicals and fertilisers (Reid 2003; Secretariat of the CBD 2003; IUCN 2004). Biodiversity and climate benefits are also possible from agro-forestry, revegetation, grassland management and agricultural practices. These include conservation tillage, recycling and use of organic materials, maintaining continuous ground cover, intercropping and reduced use of pesticides and herbicides (Secretariat of the CBD 2003; IUCN 2004). Planting hedges reduces soil loss and landscape degradation from erosion (problems exacerbated by climate change-induced droughts, floods and winds) thus increasing soil carbon stocks and agricultural productivity, and benefiting biodiversity (Secretariat of the CBD 2003).

The concept of becoming 'carbon neutral' is gaining popularity with many businesses, which wish to contribute to climate change mitigation activities by offsetting their carbon emissions. Likewise, many nations have committed to reducing their net greenhouse gas emissions under the Kyoto Protocol of the UNFCCC. The CDM provides one mechanism for doing this. Projects designed to sequester carbon, and hence mitigate climate change, present opportunities to incorporate biodiversity considerations. For example, The Netherlands Forest Absorbing Carbon Emissions (FACE) Foundation has invested in forest restoration activities and indigenous tree planting in areas of Mount Elgon National Park, Uganda, that were previously degraded. The Ugandan Wildlife Authority has implemented these activities. The aim is to offset Dutch greenhouse gas emissions from the foundation's clients, which include power generating companies and industrial and business clients in Europe. Certified Emissions Reduction credits would be awarded under the CDM. Tree Farms, a private Norwegian company, has also funded tree planting in the Bukaleba Forest Reserve, Uganda, in anticipation of the CDM becoming operational. Both these projects could have been improved if local community needs had been accounted for (Secretariat of the CBD 2003).

Using more wood products can sequester significant amounts of carbon, particularly if products have a long useful life and are recycled when no longer useful. If wood is sourced from well-managed forests, biodiversity benefits can also accrue. This is particularly true for European countries where over 90% of imports of roundwood and sawn wood are from other European states and most forests are managed sustainably (Reid et al. 2004a). For short life cycle packaging materials, substituting one tonne of virgin card for glass, plastic, steel or aluminium results in average savings of 1.1, 2.8, 2.9 and 4.1 tonnes of carbon dioxide respectively (Ministry for Environment 2001). Despite this, many people think using wood substitutes is better for the environment (Reid et al. 2004a).

Several possible tools for integrating biodiversity and climate change concerns exist. The ecosystem approach could incorporate climate concerns, and Environmental Impact Assessments, and Strategic Environmental Assessments can be adapted to support broad uptake of environmental priorities. For example, Finland is applying a Strategic Environmental Assessment approach in developing its national climate strategy. Using these approaches to assess climate adaptation and mitigation projects, however, might raise assessment and compliance costs and ultimately prevent beneficial projects from occurring (Secretariat of the CBD 2003).

Conclusions

The impacts of climate change on European biodiversity can already be seen in terms of changes in species' ranges and ecosystem boundaries, shifts in reproductive cycles and growing seasons, and changes to the complex ways in which species interact (predation, pollination, competition and disease). The extent of these effects varies between regions, and between species and ecosystems, some of which are more vulnerable than others. Existing protected areas are unlikely to be particularly effective in the face of expected changes, and many species extinctions are likely.

Strategies adopted to mitigate or adapt to climate change, such as construction of sea walls, dams and wind farms, or afforestation and reforestation activities, also impact biodiversity. And land use changes (such as cutting down forests or draining peatlands) and subsequent changes to biodiversity can also alter levels of greenhouse gas emissions thus affecting the global climate.

The many linkages between climate and biodiversity suggest the need for more integrated policy responses, at international, regional and national levels. Nationally, activities that meet biodiversity and climate change objectives need promoting and mainstreaming into various sectoral areas of policy making. Reducing energy consumption, increasing energy efficiency and promoting renewable energy technologies are priorities. But existing trends in temperature changes, precipitation level changes and sea level rise will continue regardless. The unprecedented speed of this change provides much cause for concern. A continuing increase in the frequency of extreme climatic events may also affect biodiversity more than the gradual changes expected. Activities which meet both climate and biodiversity objectives therefore need exploring. These include adopting new landscape management approaches, and ensuring carbon sequestration projects and renewable energy projects incorporate biodiversity considerations.

Such approaches are also relevant to a broader audience than Europe. Indeed, rapidly expanding human populations in countries like India also make conservation strategies that exclude local people from relatively small protected areas both inequitable and inadequate in the context of climate change. Just as extensive landscape management approaches are needed in Europe, broader inclusive conservation strategies involving the wider landscape and seascape are appropriate and necessary in low-income countries to effectively tackle large global issues such as climate change.

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References

Bakkenes, M., J.R.M. Alkemade, F. Ihle, R. Leemans and J.B. Latour. 2002. Assessing effects of forecasted climate change on the diversity and distribution of European higher plants for 2050. *Global Change Biology* 8:390–407.

Beaugrand, G., F. Ibañez, J.A. Lindley and P.C. Reid. 2002. Diversity of calanoid copepods in the North Atlantic and adjacent seas: Species associations and biogeography. *Marine Ecology Progress Series* 232:179–195.

Beebee, T.J.C. 2002. Amphibian phenology and climate change. *Conservation Biology* 16:1454–1455.

BMU. 2002. *Strategy of the German Government on the Use of Off-Shore Wind Energy*. German Government, Berlin, Germany.

Broadmeadow, M. 2000. *Climate Change–Implications for Forestry in Britain*. Forestry Commission, Edinburgh, United Kingdom.

Brown, S., J. Sathaye, M. Cannell and P.E. Kauppi. 1996. Management of Forests for Mitigation of Greenhouse Gas Emissions. In: *Climate Change 1995–Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses* (eds. R.T. Watson, M.C. Zinyowera, R.H. Moss and D.J. Dokken), pp. 773–797. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom.

Chuine, I. and E.G. Beaubien. 2001. Phenology is a major determinant of tree species range. *Ecology Letters* 4:500–510.

Clark, R.A., C.J. Fox, D. Viner and M. Livermore. 2003. North Sea cod and climate change – modelling the effects of temperature on population dynamics. *Global Change Biology* 9:1669-1680.

Crick, H.Q.P., C. Dudley, D.E. Glue and D.L. Thomson. 1997. UK birds are laying eggs earlier. *Nature* 388:526.

Dudley, N. 2001. *A Midsummer Night's Nightmare? The Future of UK Woodland in the Face of Climate Change*. The Woodland Trust, Grantham, United Kingdom.

Dudley, N. 2003. *No Place to Hide: Effects of Climate Change on Protected areas*. WWF Climate Change Programme, Godalming, United Kingdom.

EEA. 2004. *Impacts of Europe's Changing Climate. An Indicator-Based Assessment*. European Environment Agency, Copenhagen, Denmark.

Fearnside, P.M. 2001. Environmental impacts of Brazil's Tucurui Dam: Unlearned lessons for hydroelectric development in Amazonia. *Environmental Management* 27(3):377–396.

Fu, C.Z., J.H. Wu, J.K. Chen, Q.H. Qu and G.C. Lei. 2003. Freshwater fish biodiversity in the Yangtze River basin of China: Patterns, threats and conservation. *Biodiversity and Conservation* 12(8):1649–1685.

Hannah, L., G.F. Midgley, T. Lovejoy, W.J. Bond, M. Bush, J.C. Lovett, D. Scott and F.I. Woodward. 2002. Conservation of biodiversity in a changing climate. *Conservation Biology* 16(1):264–268.

Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell and C.A. Johnson (eds.). 2001. *Climate Change 2001–The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

Hughes, L. 2000. Biological consequences of global warming: Is the signal already apparent? *TREE* 15(2):56–61.

Huq, S. and H. Reid. 2005. Benefit Sharing under the Clean Development Mechanism. In: *Making Kyoto Work: Legal Aspects of Implementing the Kyoto Protocol Mechanism* (eds. D. Freestone and C. Streck), pp. 229–247. Oxford University Press, Oxford, United Kingdom.

IPCC. 2001. Climate Change 2001: *Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change Published for the Intergovernmental Panel on Climate Change by Cambridge University Press, Cambridge, UK. 1005 pages.

IUCN. 2004. *Afforestation and Reforestation for Climate Change Mitigation: Potentials for Pan-European Action*. IUCN – The World Conservation Union – Programme Office for Central Europe, Gland, Switzerland.

Janssens, I.A., A. Freibauer, P. Ciais, P. Smith, G.J. Nabuurs, G. Folberth, B. Schlamadinger, R.W. Hutjes, R. Ceulemans, E.D. Schulze, R. Valentini and A.J. Dolman. 2003. Europe's terrestrial biosphere absorbs 7 to 12% of European anthropogenic CO2 emissions. *Science Express* 300(5623):1538–1542.

Kappelle, M., M.M.I. Van Vuuren and P. Baas. 1999. Effects of climate change on biodiversity: A review and identification of key research issues. *Biodiversity and Conservation* 8:1383– 1397.

Klein Tank, A.M.G. 2004. Changing temperatures and precipitation extremes in Europe's climate of the 20th century. Ph.D. thesis. Utrecht University, Utrecht, The Netherlands. 124 pp.

Lanchbery, J. 2004. *Ecosystem Loss and its Implications for Greenhouse Gas Concentration Stabilisation*. Paper presented at the International Symposium on Stabilisation of Greenhouse Gases, 1–3 February 2005, Met Office, Exeter, United Kingdom.

Leemans, R. and A. van Vliet. 2004. *Extreme Weather: Does Nature Keep Up?* WWF/Wageningen University, The Netherlands.

Lemoine, N. and K. Böhning-Gaese. 2003. Potential impact of global climate change on species richness of long-distance migrants. *Conservation Biology* 17(2):577–586.

Liebsch, G., K. Novotny and R. Dietrich. 2002. *Untersuchung von Pegelreihen zur Bestimmung der Änderung des mittleren Meeresspiegels an den europäischen Küsten*. Technische Universität Dresden (TUD), Germany.

Menzel, A. and P. Fabian. 1999. Growing season extended in Europe. *Nature* 397:659.

Ministry for Environment. 2001. *Environmental Impact of Packaging Materials*. Ministry for Environment, Denmark.

Moen, J., K. Aune, L. Edenius and A. Angerbjörn. 2004. Potential effects of climate change on treeline position in the Swedish mountains. *Ecology and Society* 9(1):16.

Molau, U. and J.M. Alatalo. 1998. Responses of sub-alpine plant communities to simulated environmental change. *Ambio* 27:332–329.

Mortished, C. 2005. Post-Katrina U.S. can learn plenty from the Dutch. Europe infrastructure spending. *Globeandmail.com*, Thursday September 8th 2005, Canada. http: //www.globetechnology.com/servlet/ArticleNews/TPStory/LAC/20050908 IBEUROPE08/TPTechInvestor/

Nabuurs, G-J., A. Pussinen, T. Karjalainen, M. Erhard and K. Kramer. 2002. Stemwood volume increment changes in European forests due to climate change – a simulation study with the EFISCEN model. *Global Change Biology* 8:304–316.

Nijhoff, d.P. 2005. Climate Change and Biodiversity: Challenges for European Policy. http://www.rlg.nl/website/uitgaven/lezingen/lezing_14.html

Page, S.E., F. Siegert, J.O. Rieley, H.D. Boehm, A. Jaya and S. Limin. 2002. The amount of carbon released from peat and forest fires in Indonesia during 1997. *Nature* 420:61–65.

Parmesan, C., N. Ryrholm, C. Steganescu, J.K. Hill, C.D. Thomas, H. Descimon, B. Huntley, L.Kaila, J. Kullberg, T. Tammaru, W.J. Tennent, J.A. Thomas and M. Warren. 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature* 399:579–583.

Parmesan, C. and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421:37–42.

Pauli, H., M. Gottfried and G. Grabherr. 2001. High Summits of the Alps in a Changing Climate.The Oldest Observation Series on High Mountain Plant Diversity in Europe. In: *Fingerprints of Climate Change – Adapted Behaviour and Shifting Species Ranges* (eds. G.R. Walther, C.A. Burga and P.J. Edwards), pp. 139–149. Kluwer Academic Publisher, New York, United States of America.

Pinol, J., J. Terradas and F. Lloret. 1998. Climate warming, wildfire hazard, and wildfire occurrence in coastal eastern Spain. *Climatic Change* 38:345–357.

Post, E., N.C. Stenseth, R. Langvatn and J.M. Fromentin. 1997. Global climate change and phenotypic variation among red deer cohorts. *Proceedings of the Royal Society of London*, *Series B*, 264:1317–1324.

Pounds, J.A., M.P.L. Fogden and J.H. Campbell. 1999. Biological response to climate change on a tropical mountain. *Nature* 398:611–615.

Reid, H. 2003. A framework for biodiversity and climate. *Tiempo* 50:7–10.

Reid, H. 2004. Climate Change – Biodiversity and Livelihood Impacts. In: T*he Millennium Development Goals and Conservation* (ed. D. Roe), pp. 37–54. IIED, London, United Kingdom.

Reid, H., S. Huq, J. MacGregor, D. Macqueen, J. Mayers, L. Murray, R. Tipper and A. Inkinen. 2004a. *Using Wood Products to Mitigate Climate Change: A Review of Evidence and Key Issues for Sustainable Development*. IIED, London, United Kingdom.

Reid, H., B. Pisupati and H. Baulch. 2004b. How Biodiversity and Climate Change Interact. *SciDev.Net* Biodiversity Dossier Policy Brief. http://www.scidev.net/dossiers/index.cfm?fuseaction=policybriefs&dossier=11

Root, T.L., J.T. Price, K.R. Hall, S.H. Schneider, C. Rosenzweig and J.A. Pounds. 2003. Finger-prints of global warming on wild animals and plants. *Nature* 421:57–60.
RSPB. 2004a. *Climate Change and Birds*. RSPB information leaflet, Sandy Bedfordshire, United Kingdom.
RSPB. 2004b. *Wind Farms and Birds*. RSPB information leaflet, Sandy Bedfordshire, United Kingdom.
Sciare, J., N. Mihalopoulos and F.J. Dentener. 2000. Inter-annual variability of atmospheric di-methylsulfide in the southern Indian Ocean. *Journal of Geophysical Research* 105:26,369–26,377.
Secretariat of the CBD. 2003. *Interlinkages Between Biological Diversity and Climate Change: Advice on the Integration of Biodiversity Considerations into the Implementation of the United Nations Framework Convention on Climate Change and Its Kyoto Protocol*. CBD Technical Series No. 10. Secretariat of the CBD, Montreal, Canada.
Tamis, W.L.M., M. Van't Zelfde and R. Van der Meijden. 2001. Changes in Vascular Plant Biodiversity in the Netherlands in the 20th Century Explained by Climatic and other Environmental Characteristics. In: *Long-term Effects of Climate Change on Biodiversity and Ecosystem Processes* (eds. H. Van Oene, W.N. Ellis, M.M.P.D. Heijmans, D. Mauquoy, W.L.M. Tamis, F. Berendse, B. Van Geel, R. Van der Meijden and S.A. Ulenberg), pp. 23–51. NOP, Bilthoven, The Netherlands.
Theurillat, J-P. and A. Guisan. 2001. Potential impact of climate change on vegetation in the European Alps: A review. *Climatic Change* 50:77–109.
Thomas, C.D., A. Cameron, R.E. Green, M. Bakkenes, L.J. Beaumont, Y.C. Collingham, B.F. Erasmus, M.F. De Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A.S. Van Jaarsveld, G.F. Midgley, L. Miles, M.A. Ortega-Huerta, A.T. Peterson, O.L. Phillips and S.E. Williams. 2004. Extinction risk from climate change. *Nature* 427:145–148.
Thomas, C.D. and J.J. Lennon. 1999. Birds extend their ranges northwards. *Nature* 399:213.
Usher, M.B. 2005. *Conserving European Biodiversity in the Context of Climate Change*. Committee for the activities of the Council of Europe in the field of biological and landscape diversity. Council of Europe, Strasbourg. Virtanen, T. and S. Neuvonen. 1999. Climate change and macrolepidopteran biodiversity in Finland. Chemosphere: Global Change Science 1:439–448.
Walther, G-R., E. Post, P. Convey, A. Menzel, C. Parmesan, T. Beebee, J-M. Fromentin, O. Hoegh-Guldberg and F. Bairlain. 2002. Ecological responses to recent climate change. *Nature* 416:389–395.
World Commission on Dams. 2000. *Dams and Development: A New Framework for Decision Making*. Earthscan, London, United Kingdom.

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