Parliamentary Office of Science and Technology

postnote

October 2009 Number 341

BIODIVERSITY AND CLIMATE CHANGE

The effects of climate change on biodiversity are already evident in the UK, and with continued climate change, are expected to increase. This POSTnote explores the observed and future impacts of climate change on biodiversity. It also examines the relationship between biodiversity and adaptation to a changing climate.

Background

Biodiversity is the variability among living organisms and their habitats, including the diversity within species, between species and within ecosystems. Biodiversity is essential for human well-being because it provides services, such as food, medicines, clean water and soil stabilisation (POSTnote 281). This biodiversity is already under threat from the loss and fragmentation of habitat, pollution and invasive non-native species. Climate change poses a new challenge as it often exacerbates the impacts of other pressures. Commissioned by the G8, a recent report on The Economics of Ecosystems and Biodiversity estimates the loss of biodiversity worldwide could be worth 7% of world GDP in 2050.[1]

The Need for Adaptation

Efforts to reduce greenhouse gas emissions (mitigation), aim to minimise the rise in average global temperatures to 2°C. However, due to inertia in the climate system (the slow response to a change in emissions), impacts on biodiversity are inevitable. Along with the urgency of mitigation, adaptation measures are essential to deal with the consequences of climate change. Adaptation and biodiversity are interlinked in two ways:

- **adaptation for biodiversity –** Adaptation measures are needed to protect biodiversity, to enable the widest range of biodiversity to survive and adapt, and to meet legal duties for biodiversity protection.
- **biodiversity for adaptation –** Biodiversity can also play an integral part in adaptation measures for other sectors, such as coastal protection by saltmarshes.

Policy Context

The UK is committed to protecting biodiversity from adverse climate change impacts, and several policy agreements give scope to address this threat. EU member states have agreed to "halt the loss of biodiversity by 2010" and post-2010 targets are currently being discussed. The EU White Paper (2009) Adapting to Climate Change highlights the relationship between biodiversity and climate change and identifies the need for integrated policy development. In the UK, the Climate Change Act (2008) recognises the need for adaptation measures, which are being examined by the cross-government programme Adapting to Climate Change.

UK Climate Projections

In June 2009, the government-funded UK Climate Impacts Programme published observed and projected climate change trends for the UK (Box 1).

Box 1. Changes in the UK Climate[2]

Observed Changes

- The annual mean Central England temperature has risen by about 1ºC since the 1970s.
- Over the past 45 years, the UK had an increase in winter rainfall from heavy precipitation events; in summer many regions showed decreases.
- Sea level around the UK rose by about 1mm/yr in the 20th century, with higher rates in the last two decades.
- The sea surface temperature around the UK coast rose by 0.7°C in the last 30 years.

Projected Changes

- The UK will get warmer, especially in the summer.
- Overall annual precipitation will remain the same, but more of it will fall in the winter, with drier summers for much of the UK.
- Rates of sea level rise will increase in all future scenarios (POSTnotes 315 and 342).
- The sea surface temperature around the UK will be warmer by the end of the 21st century, by up to 4°C.

UK Overseas Territories (UKOTs)

The UK government also has a duty to help protect the biodiversity in the UKOTs.[3] The biodiversity of the UKOTs is of global importance, due to their unique species and variation in ecosystems from tropical to Antarctic. The impact of climate change is likely to be extensive in the 14 UKOTs, as many are small islands, which are vulnerable to rising sea levels, warmer temperatures and increased erratic weather events.

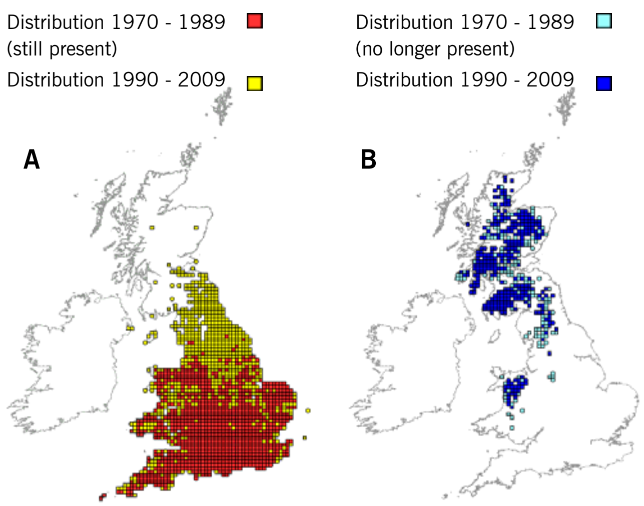
Climate Change Impacts on Biodiversity

Observed Impacts

Changes to Geographic Distribution

Some birds, insects, mammals and plants are already showing changes in their geographic distribution and have moved northwards or to higher altitudes in response to the observed changes in the UK climate. There is increasing evidence that many species with the northern limit of their range in the UK are expanding further north and onto higher ground (275 of 329 animal species analysed moved north by 31-60km in the last 25 years)[4] (Figure 1A). In contrast, some cold-adapted species with their southern limit in the UK are retreating northwards and are being lost from now climatically unsuitable southern sites and lower ground (Figure 1B).

Figure 1. Comma butterfly with an expanding northern limit (A), and black grouse with a retreating southern limit (B) (Data from the National Biodiversity Network).



Species respond independently to climate change, but typically, widespread species with general habitat requirements and good dispersal ability are expanding into new areas; whereas species with small geographical distribution, poor ability to disperse and specific habitat requirements are less able to move, as they are limited by non-climatic factors, such as habitat loss and fragmentation. These shifts in geographical distribution also include the spread of non-native species (Box 2).

Changes to Timing of Seasonal Events

Phenology is the study of changes in the timing of seasonal events. As temperatures have increased, spring and summer events are taking place earlier in the year. Evidence includes leafing, fungal fruiting, bird egg laying, spawning of amphibians, arrival of migrants and insect emergence (Box 3). Autumn events are occurring both earlier and later in the year, and the trends are less clear.

Box 2. Climate Change and Non-native Species

- Climate change may allow non-native species previously unable to survive in the UK climate to become established.
- Climate change increases the chance that some non-native species, already established in the UK, will increase in abundance or spread geographically, and some of these species may become invasive (POSTnote 303).
- Climate change can interact with other disturbances and native species may be out-competed by invasive non-native species. Certain disturbances, such as floods, may also accelerate the spread of invasive non-natives by affecting existing species negatively.

Many non-native species that establish themselves in the UK are not invasive or detrimental to wider biodiversity. Some species arriving through natural range expansions may in fact be seen to enhance biodiversity, for example, a non-native bumble bee *(Bombus hypnorum)* and the little egret *(Egretta garzetta)*. In that context, prevention measures and eradication attempts are not desirable. However, it is advised that non-native species displaying invasive characteristics driven by climate change should be monitored and contingency plans put in place.[5] Also invasive non-native species are the second greatest threat to biodiversity in the UKOTs after climate change.

In Britain, the first flowering date for 385 plant species has advanced by 4.5 days during the past decade in comparison with the previous four decades.[6] A recent study of 726 UK plants and animals (SPACE) found an average advance of spring and summer events of 3.9 days per decade between 1976 and 2005, with faster shifts at the bottom of food chains. In a European study of 542 species, 78% of records showed advancing trends of, on average, 2.5 days per decade.[1]

Changes to Abundance and Habitat Preference

Two recent studies of birds (including 42 rare birds in the UK and 122 common breeding birds in Europe) showed that species are both increasing and decreasing in abundance in correlation with climate change.[7] Climate change can also cause a change in habitat preference. For example, the silver-spotted skipper butterfly is now seen breeding in cooler north-facing grasslands.[8]

Box 3. Mismatch in Species Interaction[9]

As species respond independently to climate change they are becoming mismatched with other species that depend on them. One such example is the wading bird the golden plover (*Pluvialis apricaria*) and its food source the cranefly.

Warmer spring temperatures influence the timing of both golden plover nesting and cranefly emergence. However, it is increasing late summer temperatures, over the last 35 years, that is the most important climatic factor affecting the golden plover populations. The growth and survival of golden plover chicks depends on abundance of cranefly prey. Increasing summer temperatures and lower rainfall kill cranefly larvae in peatland soils as the surface dries out, this means a reduction in adult craneflies emerging the following spring, resulting in low golden plover chick survival.

However, with active restoration of the peatland habitat by raising water levels, there is increased resilience of cranefly populations to future warming - one solution to help both species adapt to the impact of climate change.

Changes to Species Interactions

Species do not respond simultaneously to climate change, which in turn leads to changes in the species composition found in a particular habitat and in the interaction between these species. The conservation implications of interacting species becoming mismatched in space (geographical shifts) or in time (phenology shifts) are only just emerging (Box 3) and are likely to need increased attention as climate change progresses.

Changes to Ecosystems

Changes in species composition and in species interaction eventually lead to ecosystem-level changes. Changes to ecosystems can affect their ability to provide essential services, such as carbon sequestration and food provision. The marine ecosystem is one of the most vulnerable and climate change has already had an impact on seabirds and North Sea cod (Box 4).

Box 4. Climate Change and the Marine Ecosystem

The UK Marine Climate Change Impacts Partnership (MCCIP) reports on the climate change impacts on the marine environment.[10] Its latest report highlights the potential impacts of climate change and linkages between coastal economies (POSTnote 342), ocean acidification (POSTnote 343), non-native species and seabirds.

Climate change has already caused changes in plankton, fish distribution and species composition in the seas around the UK. Recent warmer conditions and associated shifts in plankton composition, abundance and geographical distribution have led to reduced availability of prey fish for some seabirds, which has been strongly linked to recent poor breeding success, reduced survival rates and thus population declines. The decline and shift of prey plankton has also exacerbated the decline in North Sea cod stock.[10]

Forecasted Impacts

The projected future changes to temperature and rainfall (Box 1) will have further impact on biodiversity. For long-lived species with slow dispersal ability, there may also be a time lag in the response to already observed climate change. Projections of future impacts to biodiversity come from field experiments and modelling.

Field Experiments

Field experiments manipulate variables such as CO_2 concentrations, temperature and precipitation in the field to mimic future climate scenarios. Impacts are assessed on different levels, including changes to biodiversity and ecosystem processes such as water processing, nutrient cycling and carbon storage. Due to natural variability, experimental studies often need to be long-term to detect significant changes.[11] It is also difficult to separate the impacts of climate change from other threats, and to control the non-manipulated surrounding environment.

Modelling Studies

Modelling studies use future climate scenarios to project changes to the potential distribution of a species. Modelling of UK and European biodiversity has been carried out for a range of species (Table 1). Most studies forecast a mixed response with some species expanding in potential range and others contracting. In agreement with the observed impacts, often cold-adapted species with a northern distribution in the UK are projected to decline, while species with predominantly southern distribution are forecast to increase. Climatic suitability, however, only measures the **potential** distribution of a species; to determine the **actual** distribution other factors need consideration including:

- dispersal capacity;
- presence of suitable habitat;
- interaction with other species;
- the modelling programme and climate scenario used.

Table 1. Modelling Future Impacts on Biodiversity
(red = declining species and blue = expanding species)

Project	Forecasted Impacts
The Climatic Atlas of European Breeding Birds (2008)	• Modelled 431 European breeding birds in 2100. • Three quarters of birds decline in range; with average range reducing by a fifth. • Average range shifts 550km to the north-east. • Average range overlaps with current range by 40%. • Climate in southern Britain allows colonisation by some species from southern Europe.
Climatic Risk Atlas of European Butterflies (2008)	• Modelled 293 European butterflies in 2080. • In the best case scenario, half of the present land occupied by 156 butterfly species is unsuitable for survival. • In the worst case scenario, over 95% of the present land occupied by 70 butterfly species is unsuitable for survival. • 18-30% of species show increases in their potential distribution.
Modelling Natural Resource Responses to Climate Change (MONARCH 3) (2007)	• Modelled 32 UK species (plants, birds, insects and mammals) in 2080. • Eight species (mainly of northern distribution) show significant loss of suitable potential habitat; five of these species risk losing their entire potential habitat in the UK. • 15 southerly distributed species are projected to expand.
British Lichens (2007)	• Modelled 26 British lichen species in 2050. • Ten species of northern forests and mountains show loss in suitable potential habitat. • Eight widespread, southern species show northern expansion of potential habitat.

Adaptation to Climate Change

Adaptation for Biodiversity

Adaptation measures are needed to conserve biodiversity and its associated services in a changing climate. In 2008, the Department for Environment, Food and Rural Affairs, in collaboration with government agencies and NGOs, published five "adaptation principles" aimed at people planning and delivering actions across sectors:[12]

- take practical action now;
- maintain and increase ecological resilience;
- accommodate change;
- develop knowledge and plan strategically;
- integrate action across partners and sectors.

Many elements of these principles are not specific to climate change adaptation, but underpin existing policy and practice in biodiversity conservation. They are built on a guidance document produced by the UK Biodiversity Partnership aimed at conservation practitioners.[13] Many commentators agree that important practical actions to conserve biodiversity in a changing climate include:

- **conserving existing biodiversity** – Future biodiversity will adapt and evolve from that of today.
- **eliminating pressures not linked to climate change** – Biodiversity will adapt more successfully to climate change if other impacts are reduced, as climate change is likely to exacerbate them.

- **maintaining large populations in diverse habitats –** Large population sizes in diverse habitats allow species to maintain maximum genetic diversity, which is critical to adapt and evolve to climate change.
- **promoting dispersal –** For a species to respond and move to suitable climate, it needs increased habitat availability and connectivity (POSTnote 300). However, a species that is unable to disperse naturally with the rate of climate change may need assisted relocation (Box 5), although the technical feasibility, cost and ecological risk must be considered.[14] For some species conservation of genetic material in seed and DNA banks are back-up options to be considered.
- **addressing uncertainty –** Planning action needs to accept uncertainty and to address the full range of variation in projected changes and their impacts. In addition, long-term studies and monitoring of species and habitats are essential to improve knowledge of the impact of climate change, the more complex responses to adaptation measures and to inform decisions of policy makers and managers. Despite some monitoring already in place, the expansion of the Environmental Change Biodiversity Network will significantly improve the UK's monitoring effort in relation to biodiversity and drivers of change. The recent BICCO-Net project also aims to collate and report on biodiversity impacts of climate change in the UK.[15]

Box 5. Relocation, Relocation[16]

The national bird of Bermuda, the Bermuda petrel (*Pterodroma cahow*), is under threat due to the erosion and inundation of its low-lying nesting islands during hurricanes. The increased frequency and intensity of hurricanes and the threat of anticipated sea-level rise due to climate change, has led to a programme to establish a new nesting colony on the Nonsuch Island Nature Reserve that is larger in area and higher in elevation.

This involves physically moving petrel chicks before fledging to the new colony site. Over 100 chicks were moved between 2004 and 2008. In early 2008, the first moved petrels returned to Nonsuch Island. Prospects at the new colony site look promising and developments are closely monitored to ensure the survival of the species.

Biodiversity for Adaptation

In addition to adaptation for biodiversity in its own right, biodiversity also plays a role in adaptation action in other sectors, such as flood management and coastal protection. It is important to seek adaptation measures that address biodiversity loss and climate change in an integrated manner to benefit both society and the environment. The ideal goal is to identify solutions where there are benefits for adaptation, mitigation, as well as for biodiversity and associated ecosystem services – an example of such a solution is the conservation of peatlands (Box 6).

The consequences of losing biodiversity on the provision of a wide range of services mean that adaptation policies need to involve all relevant sectors. Biodiversity loss cannot be halted without addressing climate change, but it is equally unfeasible to adapt to climate change without addressing biodiversity loss.[17]

Box 6. Biodiversity Adaptation in Peatlands

Peatlands are one of the most important carbon stores in the UK. Healthy peatland habitats absorb and store carbon from the atmosphere; however, when degraded this carbon is released. In the UK, the biggest threats to peatlands are drainage, burning, overgrazing, pollution and extraction; climate change now adds to these pressures. If the increased temperatures and altered precipitation expected from climate change are allowed to dry or erode peat soils, significant amounts of carbon will be released.

In addition to the role as a carbon sink, peatlands are hosts to a unique set of species, adapted to this specialised environment. In a study by Natural England,[18] of the impacts of climate change on the Cumbria High Fells, cold-adapted species, such as arctic and alpine vegetation and certain upland butterflies are thought to be at risk as they face increasing competition from lowland species. However, dragonflies which need hot weather to emerge from nymph to adult are likely to do well and expand their range.

Enhanced protection and restoration of the UK's peatlands is thus needed, not only to conserve their unique species and habitats, but also to maintain the UK's largest carbon store. In addition, peatland conservation benefits services such as water quality, flood control, recreation and tourism.

Overview

- Biodiversity is essential for services upon which human well-being depends.
- Impacts of climate change are already evident on UK biodiversity and are likely to continue in the future.
- Adaptation measures are needed to protect UK biodiversity from adverse effects of climate change.
- Biodiversity plays a role in adaptation in other sectors, such as flood management.
- Adaptation policy should, where possible, incorporate biodiversity, mitigation and adaptation measures.

Endnotes

1 Braat & ten Brink 2008, *The cost of policy inaction*, EU study
2 http://ukclimateprojections.defra.gov.uk
3 JNCC, *HMG Strategy for Biodiversity in the Overseas Territories*, 8th July 2009
4 Hickling *et al*. 2006, *Global Change Biology*, 12
5 *The invasive non-native species framework strategy for Great Britain*, 2008
6 Fitter & Fitter 2002, *Science,* 296
7 Green *et al*. 2008, *Biol. Lett.*, 4; Gregory *et al*. 2009, *PLoS ONE*, 4
8 Davies *et al*. 2006, *Journal of Animal Ecology*, 75
9 Pearce-Higgins *et al*. 2009, *Global Change Biology*,
10 http://www.mccip.org.uk
11 Prof. J.P. Grime, University of Sheffield
12 Smithers *et al.* 2008, *Climate change adaptation principles*, Defra
13 Hopkins et al. 2007
14 Hoegh-Guldberg *et al*. 2008, *Science*, 321; Richardson *et al*. 2009, *PNAS*, 106
15 http://www.bicco-net.org
16 Walling 2008, *Climate Change in the UKOTs*, JNCC
17 Conference in Athens, 2009, *Biodiversity Protection - beyond 2010*
18 Natural England 2008, *The natural environment: adapting to climate change*

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of public policy issues that have a basis in science and technology. POST is grateful to Malin Rivers for researching this briefing, to the Natural Environment Research Council for funding her parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Jonathan Wentworth, at POST.

The Parliamentary Office of Science and Technology, 7 Millbank, London, SW1P 3JA; Tel: 020 7219 2840; email: post@parliament.uk

www.parliament.uk/parliamentary_offices/post/pubs2009.cfm