Conserving biodiversity in a changing climate: guidance on building capacity to adapt

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About this guidance

This guidance is aimed at those who plan and deliver conservation of terrestrial biodiversity.[1] The six guiding principles described in this document summarise current thinking on how to reduce the impacts of climate change on biodiversity and how to adapt existing plans and projects in the light of climate change. Although this guidance is intended to inform implementation of the UK Biodiversity Action Plan, taking account of climate change is also relevant to the fulfilment of many international agreements and obligations affecting the UK, including the EU target to halt biodiversity loss by 2010.[2] Proposals for policy change are beyond the scope of this document but because actions are ultimately linked to policy frameworks, there is also much to be done to review and strengthen policy at a country, UK and international level.

Two types of action need to be taken to address the challenge of climate change and biodiversity conservation. The first is *adaptation*, which means increasing the ability of natural systems to absorb and respond to change, given that the world is irrevocably committed to some degree of climate change. This guidance suggests what conservationists can do to contribute to this aim through the conservation plans and activities within their control.

The second type of action is *mitigation*, that is controlling and reducing emissions of greenhouse gases, the root cause of climate change. Although this is not the subject of this guide, it is recognised that hugely important decisions made about land management may exacerbate or reduce greenhouse gas emissions and some actions suggested here may contribute to mitigation.

Our ability to predict the way in which biodiversity will be influenced by climate change is limited. The obvious question is, if we cannot predict the future with certainty, how can we plan wildlife adaptation? In essence, we must learn to manage by taking account of uncertainty. We should choose actions that, on the basis of the best available evidence, are most likely to benefit biodiversity as well as other ecosystem services, such as soil conservation, air and water quality, flood alleviation, high-quality food, health, employment and recreation.[3] Many adaptation actions proposed here will be beneficial whatever the extent, rate or direction of climate change.

Of course, measures or plans should be reviewed frequently and systematically to take account of current research on the impacts of climate change on biodiversity. In the next few years we may know more about the ecological processes involved, and we will need to assess the effectiveness of these guidelines and propose new adaptation techniques based upon research, practical experience and monitoring.

It is imperative to take action as soon as possible. Conservationists across government and the voluntary sector are now considering how to design not only networks of Protected Areas but also broader measures to conserve the ecosystems and biodiversity of the future rather than just trying to maintain what exists now. There will be some tough choices to make about allocations of resources to conserve individual species and habitats in the light of inevitable change, but there are also some real opportunities to integrate action for biodiversity with other sectors like agriculture, forestry, water management and land-use planning so accessing additional resources to secure a countryside rich in wildlife.

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1 Marine biodiversity requires separate guidance to take account of the different pressures upon marine life and the different strategies needed in these more ecologically open and less manageable ecosystems.

2 European Commission (2006) Halting the loss of biodiversity by 2010 – and beyond: sustaining ecosystems services for human well-being. http://ec.europa.eu/environment/nature/biodiversity/current_biodiversity_policy/biodiversity_com_2006/index_en.htm

3 This guidance is seen as a contribution toward the adoption of the 'ecosystem approach' defined by the Convention on Biological Diversity as 'a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way'. See: Convention on Biological Diversity (Undated) Ecosystem Approach Principles. http://www.biodiv.org/programmes/cross-cutting/ecosystem/principles.asp. For a fuller explanation of ecosystem services see: Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.137pp.

Introduction

Changes in the climate of the UK and the rest of the world accelerated in the 20th century, as increasing amounts of greenhouse gas, particularly carbon dioxide, were released into the atmosphere by humankind (Box 1). Virtually all scientists and decision makers now accept that climate change is accelerating due to human activity at a rate far in excess of natural processes.[4]

Drax coal-fired power station
Credit: Natural England, Photographer: Paul Glendell

Climate is one of the most important factors that influences the behaviour, abundance and distribution of species, as well as having a strong influence on the ecology of habitats and ecosystems. Changes in the behaviour, abundance and distribution of species are already being observed and linked to climate. Over time these and other changes are likely to become increasingly profound.

4 Houghton J. (2004) Global Warming the Complete Briefing (Third Edition). Cambridge University Press, Cambridge. 351pp; Hulme M. et al. (2002) Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific report. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia Norwich 120pp; IPCC (2001) Climate change 2001: The scientific basis. A Report of Working Group 1 of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Box 1 – Past and future climate change worldwide and in the UK

How has the climate changed?

The mean surface temperature of the Earth has increased by approximately 0.6°C ± 0.2°C in the 20th century, with a large part of this increase since 1970.[5] In the UK, warming has been higher than the world average. The 1990s was the warmest decade on record and other records have been broken since the year 2000. The number of frost free days and hot summer days has increased and the growing season has become longer.

There has been no detectable overall change in the annual amount of precipitation in the UK, but winters have been getting wetter, with more rain falling as heavy downpours; summers were slightly drier during the 20th century. Although global rise in mean sea level is about 1.8 mm per year, the situation is complicated in the UK as land is sinking in south-east England and rising in parts of Scotland. Sea-level rise has therefore been lower than the global average in parts of Scotland but greater in the south-east of England.

Significantly the global economic costs of all weather-related damage increased dramatically between 1951 and 1999, reflecting the greater frequency of extreme weather events, including floods, droughts and storms.[6]

How will the UK climate change?

Projections of future climate contain two inherent sources of uncertainty. Social and economic uncertainties about the amount of greenhouse gases that will be released into the atmosphere by humankind, particularly later in this century, are compounded by scientific uncertainties about the climate system itself, the frequency of extreme events and our ability to model the future. Climate is determined by the complex interaction between the atmosphere, ocean and land, including soil and vegetation. Climatic projections vary between models; while there is now more consensus across models on the level of future warming, projected changes in precipitation and extreme rainfall events are less certain.

The United Kingdom Climate Impacts Programme (UKCIP)[7] has developed a set of climate-change scenarios which project a rise in UK temperature of between 2°C and 3.5°C by the 2080s, with greater warming in the south-east than in the north-west of the UK. There may be more warming in summer and autumn than in spring and winter; in the south-east summer may become 5°C warmer by the 2080s under the High scenario. By the 2050s current typical spring temperatures may occur between one and three weeks earlier and onset of winter could be delayed by a similar period. Annual average precipitation may decrease slightly but winters may become wetter and summers are likely to become drier, particularly in the south-east where summer precipitation may decrease by 50 per cent by the 2080s under the High scenario. Periods of heavy winter rainfall may become more frequent and account for a higher proportion of winter rain. By the 2080s sea levels in Scotland may be between 2cm below and 58cm above current sea level, with a possible rise of between 26cm and 86cm in south-east England, where the land is sinking.[8]

5 Ibid. IPCC (2001); Houghton (2004).
6 Ibid. Houghton (2004).
7 www.ukcip.org.uk
8 Ibid. Hulme et al. (2002).

The response of biodiversity to climate change

A number of direct key impacts of climate change upon biodiversity have been identified from observational data and models of future trends. They include:

- changes in the timings of seasonal events, leading to loss of synchrony between species and the availability of food, and other resources upon which they depend
- shifts in suitable climate conditions for individual species leading to change in abundance and range
- changes in the habitats which species occupy
- changes to the composition of plant and animal communities
- changes to habitats and ecosystems, such as altered water regimes, increased rates of decomposition in bogs and higher growth rates in forests.

In the view of some scientists, the greater frequency of extreme weather events is likely to have as much impact upon biodiversity as overall trends in temperature and precipitation.

Indirect impacts may become just as significant as a result of climate-induced changes in land use having knock-on effects on biodiversity. For example, growing new crops, increases in summer watering and geographical shifts in arable and livestock production could well occur, but how these indirect changes may affect biodiversity remains less certain.

Observed changes

Both for the UK and the rest of the world, there is a large and increasing body of information about the ecological impacts of climate change.[9] Five types of information illustrate the impacts of climate change on wildlife:

i *Phenology.*
This is the study of the change in timing of seasonal events, such as flowering and migration. There has been a general trend towards spring and summer events taking place earlier in the year. These include earlier first leafing dates of trees (e.g. oak leafing has advanced three weeks in the last 50 years), flight times of moths and butterflies, egg-laying dates in birds, first spawning of amphibians and first appearance of hoverflies and earlier fruiting of species such as blackberry. Autumn events are more complex, with delayed leaf fall and bird migration reported for some species.[10] The conservation implications of such changes are starting to emerge. Of greatest importance may be that interdependent species no longer have life cycles that are synchronised. There is, for example, good evidence that some populations of the pied flycatcher (*Ficedula hypoleuca*) are declining because birds are now breeding after the time of peak caterpillar abundance, which has become earlier.[11]

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9 Parmesan C. & Yohe G. (2003) A globally coherent fingerprint of climate change impacts across natural systems. Nature, 421, 37-42; Root T.L., Price J.T., Hall K.R., Rosenzweig C. & Pounds J.A. (2003) Fingerprints of global warming on wild animals and plants. Nature, 421, 57-60.

10 Beebe T.J.C. (1995) Amphibian breeding and climate. Nature, 374, 219-220; Burton J.F. & Sparks T.H. (2002) Flying earlier in the year: The phenological responses of butterflies and moths to climate change. British Wildlife 13, 305-311; Crick H.Q.P., Dudley C., Glue D.E. & Thomson D.L. (1997) UK birds are laying eggs earlier. Nature, 388, 526; Crick H.Q.P. & Sparks T.H. (1999) Climate change related to egg laying trends. Nature, 399, 423-424; A.G. Fitter & R.S.R. Fitter (2002) Rapid Changes in Flowering Time in British Plants Science, 296, 1689-1691; Morris R.K.A. (2000) Shifts in the phenology of hoverflies in Surrey: do these reflect the effects of global warming? Dipterists Digest, 7, 103-108; Roy D.B. & Sparks T.H. (2000) Phenology of British butterflies and climate change. Global Change Biology, 6, 407-416; Sparks T.H. (1999) Phenology and the changing pattern of bird migration in Britain. International Journal of Biometeorology, 42, 134-138; Sparks T.H., Carey P.D. & Combes J. (1997) First leafing dates of trees in Surrey between 1947 and 1996. The London Naturalist, 76, 15-20; Sparks T.H. & Yates T.J. (1997) The effect of spring temperature on the appearance dates of British butterflies 1883-1993. Ecography, 20, 368-374; Woiwod I.P. (1997) Detecting the effects of climate change on Lepidoptera. Journal of Insect Conservation, 1, 149-158.

11 Both C., Bouwhuis S., Lessells C.M. & Visser M.E. (2006) Climate change and migratory population declines in a long-distance migratory bird. Nature, 441, 81-83.

ii *Species abundance.*
Species are increasing and decreasing their abundance at sites in ways correlated with climate change. This has been shown by long-term monitoring of butterflies and moths, and plants in woodlands and grasslands, changing the composition of plant and animal communities.[12]

iii *Range changes.*
Many species are showing evidence of changes in their range. Those which undergo annual migration are responding particularly rapidly, such as wading birds which migrate to spend winter on the UK coast. Reduced numbers of waders have been found in the south and west of the UK, because warmer winters mean they are able to feed further north and east in the UK, nearer to their overseas breeding sites.[13] There is also increasing evidence of non-migratory species which reach the northern limit of their distribution in the UK expanding their range northwards and onto higher ground, including birds, butterflies, dragonflies and damselflies, aquatic bugs, soldier beetles, longhorn beetles, millipedes, harvestmen, ground beetles, woodlice, mammals, spiders, lacewings, grasshoppers and crickets. In contrast some species which reach their southern limit in the UK are retreating northwards and are being lost from lower ground. Strikingly some continental species, such as the bumble bee (*Bombus hypnorum*) and small red-eyed damselfly (*Erythromma viridulum*), have recently established in the UK as breeding species.[14]

iv *Habitat preference.*
Recent studies of the silver spotted skipper butterfly (*Hesperia comma*) have revealed a change of habitat, so that it now breeds in cooler, taller grasslands. There is contrasting evidence that other butterfly species which over-winter as eggs and larvae are being excluded from grasslands, due to rapid plant growth early in the year which, paradoxically, creates a cooler spring microclimate in the sward.[15]

Silver-spotted skipper butterfly
Credit: Natural England, Photographer: Michael Hammett

12 Conrad, K. F. et al. (2004). Long-term population trends in widespread British moths. Journal of Insect Conservation, 8, 119-136. Dunnet N.P., Willis A.J., Hunt R. & Grime J.P. (1998) A 38 year study of relations between weather and vegetation dynamics in road verges near Bibury, Gloucestershire. Journal of Ecology, 86, 610-623; Kirby K.J., Smart S.M Black H.I. J., Bunce R.G.H., Corney P.M. & Smithers R.J. (2005) Long term ecological change in British woodland (1971-2001). English Nature Research Report No. 653. English Nature, Peterborough; Roy D. B., Rothery P., Moss D., Pollard E. & Thomas J.A. (2001) Butterfly numbers and weather: projecting historical trends in abundance and their future effects of climatic change. Journal of Animal Ecology, 70, 201-217.

13 Austin G.E. & Rehfish, M.M. (2005) Shifting distributions of migratory fauna in relation to climatic change. Global Change Biology, 11, 31-38.

14 Hickling, R., Roy, D.B., Hill, J.K. & Thomas C.D. (2005) A northwards shift of range margins in British Odonata. Global Change Biology, 11, 520-526; Hickling R., Roy D.B., Hill J.K., Fox R. & Thomas C.D. (2006). The distributions of a wide range of taxonomic groups are expanding northwards. Global Change Biology, 12, 450-455; Thomas, C.D & Lennon, J.J (1999) Birds extend their ranges northwards. Nature, 399, 213; Warren M.S. et al. (2001) Rapid response of British butterflies to opposing forces of climate and habitat change. Nature, 414, 65-68.

15 Davies Z.G., Wilson R.J., Coles S. & Thomas C.D. (2006) Changing habitat associations of a thermally constrained species, the silver spotted skipper butterfly, in response to climate warming. Journal of Animal Ecology, 75, 247-256; Wallisdevries M.F. & Van Swaay C.A.M. (2006) Global warming and excess nitrogen may induce butterfly decline by microclimatic cooling. Global Change Biology, 12, 1620–1626.

v *Ecosystem function.*
Although ecosystem changes linked to climate are much less studied than species changes, a few have been reported. European forests have increased their above-ground biomass; and this is thought to be due to a combination of factors including climate change, increased carbon dioxide in the atmosphere and greater nitrogen deposition. Below-ground increased rates of decomposition in bogs, and associated increases in dissolved organic material in streams and rivers, also appear to be linked to climate change as one of several causes of this change.[16]

The patterns of species change described illustrate common responses but the response of each species is individualistic. A significant proportion of species show no change, and a small number show the opposite pattern of change such as delayed spring flowering or southern retraction of range. This complexity is one of the reasons why the guidance developed here makes no detailed assumptions about the patterns of species change that will be observed.

Future changes

Modelling of climate space[17] or potential distribution has been carried out through the Modelling Natural Resource Responses to Climate Change (MONARCH) project,[18] initially for 50 species associated with 12 habitats. The results indicate that there will be both winners and losers; there is a predicted trend for some northern species such as those of montane heath to lose suitable climate space and some species might completely disappear in the UK. Many southern species are likely to gain space with suitable climate. Further modelling of future climate space for a range of UK Biodiversity Action Plan (BAP) species shows similar trends, with the large number of southerly distributed BAP species likely to no longer be confined to their existing range by climate.[19] It seems likely that species will respond to climate change differently so that species abundances will change over time within habitats and sites, while species gains and losses may create new combinations of species or communities. For example, wood crane's-bill (*Geranium sylvaticum*) may be lost from upland hay meadows while the abundance of other species may change such that this habitat would become more akin to lowland meadows today.

However, there is a high degree of uncertainty about the actual future responses of individual species and habitats to a changing climate. This is due to a combination of issues, including inadequate data, problems of carrying out local analyses using global or national data, difficulty in factoring in extreme climatic events, uncertainties over future land use change and habitat availability, the unknown capacity of species to disperse in response to climate change and our limited understanding of other factors controlling distribution such as competition or predation.[20]

Most important in terms of occupying new climatically suitable space may be the impact of habitat fragmentation on the ability of species to disperse.[21] Many species of conservation concern are often separated by large distances that exceed their normal dispersal capabilities from other patches of

16 Bardgett R. (2005) The Biology of Soil – a community and ecosystem approach. Oxford University Press Oxford. 242pp; Cannell M. (2002) Impacts of climate change on forest growth. In: Broadmeadow M.S.J. (ed) Climate Change: Impacts on UK Forests. Forestry Commission Bulletin 125. Forestry Commission, Edinburgh. pp141-150.

17 Climate space is the geographic area that is projected to have climatic conditions similar to the climate of those areas currently occupied by the species and likely to be climatically suitable for their survival.

18 Berry P.M., Harrison P.A, Dawson T.P. & Walmsley C.A. (eds.) (2005) Monarch 2: modelling natural resource responses to climate change. UKCIP Technical Report, Oxford; Harrison P.A., Berry P.M. & Dawson T.P. (eds) (2001) Modelling Natural Resource Responses to Climate Change (MONARCH). UKCIP Technical Report, Oxford.

19 Walmsley C.A. et al. (2007). MONARCH: Modelling Natural Resource Responses to Climate Change – a synthesis for biodiversity conservation. UKCIP Technical Report, Oxford.

20 Ibid. Walmsley C.A. et al. (2007)

21 Malcolm J.R.& Markham A. (2000) Global Warming and Terrestrial Biodiversity Decline. World Wide Fund for Nature. Gland, Switzerland; Travis J.M.J. (2003) Climate change and habitat destruction: a deadly anthropogenic cocktail. Proceedings of the Royal Society of London: Series B., 270, 467-473.

suitable habitat. For example, some butterfly species are increasing in local abundance but not increasing their range, and rare amphibian and reptile species are not showing a northward movement of their range as might be expected of southern species at the northern edge of their range in the UK.[22] In these cases and doubtless others, lack of habitat and habitat fragmentation would appear to be a key factor preventing range expansion as the climate changes, and may threaten some species with extinction on the habitat islands where they are trapped.

Open water and wetland habitats may show particularly complex seasonal patterns of change. There is likely to be greater winter rainfall that could result in increased extents of habitats such as wet heath and coastal dune slack. But in some parts of the UK, increased summer drought may have an adverse impact upon these habitats. For many habitats and species, changes in water availability may be as, or more, important than temperature rises and yet there is far more uncertainty about projected rainfall changes, with different climate models suggesting different seasonal patterns.

Some of the most dramatic changes may occur on the coast as a result of sea-level rise exacerbated by extreme weather events, which may lead to alterations in the balance between accretion and erosion on saltmarshes, sand dunes and shingle beaches on low-lying coasts. There may also be change to the erosion of cliffs and complex changes in the water regimes and landforms of estuaries and tidal rivers.

Coastal Erosion, Montrose
Credit: Scottish Natural Heritage, Photographer: Lorne Gill

22 Ibid. Hickling R. et al. (2006); Warren M. et al. (2001).

Guiding principles and actions

In order to help biodiversity plans and projects take account more explicitly of the impacts of climate change, six guiding principles with actions that flow from them are outlined here. These cover a great deal of sound conservation practice which will ensure the best possible outcome for wildlife conservation in the face of limited knowledge and imponderable future effects of climate change. Crucially, the guidance comes as a package in that it needs to be implemented as a whole to face the challenges ahead.

Box 2 – Summary of the Guiding Principles

1 Conserve existing biodiversity

The richness of future biodiversity, in a changing world, will depend upon the diversity we conserve today.

- **1a Conserve Protected Areas and other high quality habitats**

  These areas will remain important because they have characteristics which will continue to favour high biodiversity: e.g., low-nutrient soils.

- **1b Conserve range and ecological variability of habitats and species**

  It is impossible to predict which localities will continue to have climatic conditions suitable for a given species or habitat; by conserving the current range and variability we will reduce the probability of all localities being lost, although some losses will be inevitable.

2 Reduce sources of harm not linked to climate

Climate change is one of many threats to biodiversity and by reducing other sources of harm we will help natural systems maintain their biodiversity in the face of climate change.

3 Develop ecologically resilient and varied landscapes

By ensuring landscapes remain varied, and allowing space for physical processes to take place, we will increase their ability to retain biodiversity.

- **3a Conserve and enhance local variation within sites and habitats**

  Maintaining diversity in the landscape in terms of features such as vegetation structure, slope, aspect and water regime will increase the chances that species whose current habitat becomes inhospitable will be able to spread locally into newly favourable habitat.

- **3b Make space for the natural development of rivers and coasts**

  Changing rainfall patterns and rising sea levels will affect our rivers and coasts. By allowing natural processes of erosion and deposition to take place we will increase the potential for wildlife to naturally adapt to these changes.

4 Establish ecological networks through habitat protection, restoration and creation

Some species will need to move some distance from their current locality if they are to survive climate change; creating new habitat, restoring degraded habitat, or reducing the intensity of management of some areas between existing habitat, will encourage this.

Box 2 – Summary of the Guiding Principles (continued)

5 Make sound decisions based on analysis

Adopt an evidence-based approach which recognises that biodiversity is constantly changing.

- **5a Thoroughly analyse causes of change**

  Not all change will be due to climate change and by thoroughly analysing the causes of change we will identify those situations where climate-change adaptation is needed.

- **5b Respond to changing conservation priorities**

  Regularly review conservation targets to ensure resources are directed towards genuine conservation priorities as some species increase, others decline and habitats change in character.

6 Integrate adaptation and mitigation measures into conservation management, planning and practice

When reviewing conservation management plans consider the impacts of climate change – for example more frequent summer fires and floods – and make changes as appropriate. Where they can be identified, reduce release of greenhouse gases to the atmosphere.

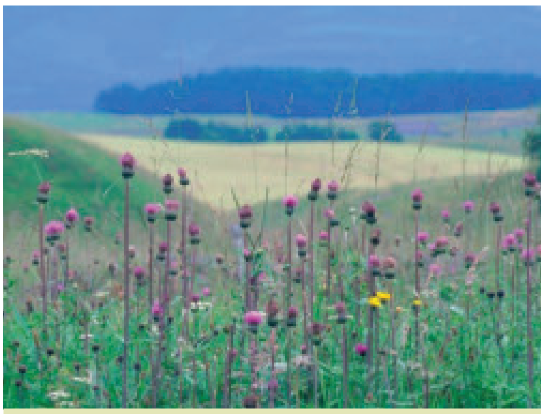
1 Conserve existing biodiversity

The importance of protecting existing biodiversity cannot be overemphasised. Future biodiversity will adapt and evolve from the richness of the biodiversity conserved in the 20th century and from the extent of semi-natural habitats that will be protected, restored and created in the 21st century.

But this is not to suggest biodiversity should be preserved in aspic. Climate change means that at sites currently considered to be of wildlife importance, some of the wildlife features, both species and habitats, may disappear, other species may arrive and habitats may change in their composition and structure.

1a Conserve Protected Areas and other high-quality wildlife habitats

In the 20th century an important focus for UK biodiversity and geological conservation has been the establishment of a series of Protected Areas to conserve protected wildlife habitats and associated species. Sites of Special Scientific Interest (SSSIs) and, in Northern Ireland, Areas of Special Scientific Interest (ASSIs), are the most extensive type of Protected Area for wildlife in the UK and cover about 10 per cent of the land surface. A greater degree of control over conservation objectives is possible for these sites than for most others. The reasons for a site's designation generally include specified habitats and species. Consideration will need to be given to how designations can be applied more flexibly in future to protect changing and dynamic communities.



Glen Fender Meadow SSSI, Perthshire
Credit: Scottish Natural Heritage, Photographer: Lorne Gill

High-quality wildlife habitats[23] may occur outside of Protected Areas within areas managed primarily for purposes other than wildlife conservation, such as agriculture, forestry, water supply and recreation. In some lowland landscapes the extent of high-quality wildlife habitats outside Protected Areas is very limited: e.g. lowland heath. However, a large resource of high-quality wildlife habitats, notably ancient woodlands, moorlands and linear habitats such as hedgerows, streamsides and river banks, lies outside Protected Areas. Collectively these additional areas will play a critical role in the conservation of biodiversity as climate changes.

Two important functions of Protected Areas and other high-quality wildlife habitats will be as core areas for biodiversity and as connecting habitats within ecological networks (see Guideline 4). The early success of an ecological network will depend upon the persistence of large populations of as many species as possible in the core areas, capable of producing a supply of offspring to colonise new areas.

Suggested actions

Vigorous action should be taken to safeguard Protected Areas and other high-quality wildlife sites from destruction and damage such as built development, using the existing planning policy framework and wildlife legislation to full advantage to achieve this.

Opportunities should be actively sought to create buffers of semi-natural habitat around Protected Areas and other high-quality wildlife sites to protect them from external influences such as pesticide and herbicide drift, and to make sites more welcoming for species following chance and long-distance dispersal. This could be achieved through targeted site acquisition, management agreements and encouraging take up of agri-environment scheme options by other land managers.

A more strategic approach to site protection should be developed through Local Biodiversity Action Plans and partnership arrangements with other conservation land managers, including development of local conservation forums, outreach programmes and countryside management schemes.

1b Conserve range and ecological variability of habitats and species

Species and habitats are not likely to be at risk in all the places where they occur unless the risk is widespread. The risk of a species becoming extinct or a habitat being lost will be reduced if a varied set of locations are conserved which should encompass not only the full geographical range of each species and habitat but also the full range of ecological situations in which they occur.[24]

For rare species and habitats it will often be appropriate to include all localities within conservation frameworks, such as action plans. For other species, bearing in mind that even some very common species may become vulnerable over time, sites with currently large populations are most important. Practically speaking, not all populations and habitat patches may be sustainable in the future and for those at the southern edge of their range, their maintenance should not be automatically set as long-term conservation targets requiring great effort but as a strategy for reducing the risk of extinction (see Guideline 5).

Species and habitats across the range of ecological situations in which they occur should be included, even where there are larger populations, or greater areas of habitat, in more typical conditions nearby. In the long term, these ecologically unusual populations and habitats may prove to be the places where the species or habitats persist.

23 In this document the term high quality wildlife habitat is used to describe any semi-natural habitat of high biodiversity value due to its species richness, scarcity as a habitat and / or presence of rare and local species.

24 Saxon E.C. (2003) Adapting Ecoregional Plans to Anticipate the Impact of Climate Change. In Groves C.R (ed) Drafting a Conservation Blueprint: A Practitioner's Guide to Planning for Biodiversity. Island Press Washington DC. pp.319-344.

Suggested actions

Acquisition and site-selection strategies, as well as partnership strategies developed by NGOs and conservation agencies, should seek to protect as great a range of each type of habitat or species locality as possible. They should seek to be representative but also inclusive of atypical examples rather than being just the best or most typical sites in each area. Replication of conservation action for any species or habitat will help increase the probability of a significant proportion of surviving over many decades.

When preparing Protected Area management plans, Local Biodiversity Action Plans (LBAPs), and similar local and regional conservation frameworks, it is important to encompass the range of ecological situations in which habitats and species occur locally, particularly any unusual ecological occurrences.

2 Reduce sources of harm not linked to climate

Climate change is only one of many sources of stress to biodiversity in the UK.[25] Like climate change, many of these stress factors have gradual but persistent impacts upon wildlife. Unless these threats are reduced or removed, action to combat the impacts of climate change is likely to be less successful. In addition, wildlife will be able to resist or adapt more successfully to climate change if these other stress factors are absent. While most are outside the immediate control of practitioners, it is crucial to be aware of their impact and take action where possible. Some examples of the more widespread threats are:

- *Abandonment of traditional management*, particularly in the lowlands;
- *Over grazing*, particularly in the uplands;
- *Nutrient enrichment* through use of artificial fertilisers, discharges of waste water, erosion and run-off of soil into freshwater and other sources;
- *Introductions and spread of non-native species*, some of which may change habitat structure, predate native species, are wildlife diseases, carry wildlife diseases or interbreed with native species;
- *Intensification of farming practices*, such as the creation of large fields that leave little space for wildlife, conversion of meadows to silage fields and increased herbicide and insecticide use;
- *Over abstraction of water*, resulting in low river or stream flows and alteration of water regimes in wetlands;
- *Aerial pollutants*, such as ozone, causing toxic effects and stress to vegetation especially in the uplands;

Overgrazing on PSSSI near Middleton, County Durham
Credit: Natural England, Photographer: Peter Wakely

25 Haines Young R. H. et al. (2000) Accounting for Nature: Assessing Habitats in the UK Countryside. Department of the Environment, Transport and the Regions, London; Hopkins J.J. (2003) How is the countryside changing? British Wildlife, 14, 305-310; Kirby et al. 2005 ibid.; Smart S.M. Bunce R.G. H., Marrs R.M., LeDuc M., Firbank L.G., Maskell L.C., Scott W.A., Thompson K. & Walker K.J. (2005) Large scale changes in the abundance of common higher plant species across Britain between 1978, 1990 and 1998 as a consequence of human activity: Tests of hypothesised changes in trait representation. Biological Conservation, 124, 355-371.

- *Historical legacy of habitat loss and fragmentation*, meaning that many species populations are now too small and isolated to be viable in the long term.

Suggested actions

Review Habitat Action Plans, Species Action Plans, LBAPs and other conservation management plans and projects to ensure that a) all non-climate causes of adverse change have been identified, b) future changes in these pressures are assessed and c) that these are being explicitly addressed wherever possible.

Establish surveillance for the arrival of non-native species that may threaten to become invasive. Ensure early response to tackle threats of invasion while control is possible.

Negotiate with neighbouring landowners and land managers to reduce causes of harm to sites from surrounding land use.

3 Develop ecologically resilient and varied landscapes

Landscapes comprise a variety of habitats and an associated range of land uses. It is likely that landscapes will change in complex ways in response to both the direct impacts of climate change upon habitats and indirectly due to the way in which land use patterns alter or farming, forestry and water management practices adapt and change: for example, through increased irrigation or altered cropping patterns in agriculture. Within the landscape this may well result in some habitats increasing, decreasing or changing in structure, and others appearing for the first time or disappearing.

Maintaining a diversity of semi-natural habitats, increasing the area of semi-natural habitats through habitat creation and restoration, addressing the adverse impacts of unsympathetic land uses, and allowing natural processes to shape the ecology and structure of whole landscapes, will create the best possible chance for conserving the greatest amount of biodiversity. Reducing the intensity of land use in intervening parts of the landscape can greatly increase the chance for species to disperse between existing, restored and newly created high-quality wildlife habitats.

Box 3 – Resilient landscapes through habitat connectivity

Resilience is the ability of a landscape to maintain its functions and characteristics after being disturbed or damaged.[26] The maintenance of species diversity within the landscape is essential for it to be considered resilient and as a consequence it is vital that species are able to disperse to more suitable locations should their existing localities become unsuitable under a changing climate. Habitat connectivity and landscape permeability have been recognised as key to helping species dispersal and enhancing resilience. Habitat connectivity describes the spatial links between core areas of suitable habitat. Landscape permeability is the capacity for dispersal of biodiversity across the wider landscape. Improving the capacity for species to disperse across unsuitable habitats enhances landscape permeability. It has been shown experimentally that physically connecting fragmented habitats or making the intervening habitat less hostile improves dispersal for some species.[27]

26 CBD (2006) Guidance for promoting synergy among activities addressing biological diversity, desertification, land degradation and climate change. Technical Series No. 25. Secretariat of the Convention on Biological Diversity, Montreal.

27 Castellon T.D. & Sieving K.E. (2006) An Experimental Test of Matrix Permeability and Corridor Use by an Endemic Understorey Bird. Biological Conservation, 20, 135-145.

3a Conserve and enhance local variation within sites and habitats

To wildlife the environment is a mosaic of potential habitat patches. Suitable patches are surrounded by varying amounts of habitat offering dispersal but not long-term survival possibilities, while other areas may be hostile. Each species requires a specific range of habitat-patch characteristics, including suitable climatic conditions, which allow it to establish, survive and reproduce. The size of habitat patch required to support a population of a given species varies enormously from a single leaf to many square kilometres. Climate can vary over very short distances – even two sides of a boulder can have very different conditions – and many species are highly sensitive to these very small differences, which are not readily perceived by humans.

Where there is a wide diversity of habitat patches species are more likely to be able to respond to climate change by relocating within the landscape they already occupy. In these cases only short-distance dispersal may be necessary, so giving a higher probability that a population will be maintained than if long-distance dispersal is required to reach a suitable location.

Box 4 – Species Disperal

Virtually all species have a need to disperse, if only because offspring cannot use the same space as their parents. Most species do not rely upon the presence of a continuous habitat in order to disperse, but are able to 'jump' between habitat patches. The great majority of offspring only travel a short distance,[28] so this kind of dispersal can be most expected when habitat patches are close together. Landscapes in which habitat patches are concentrated together are likely to provide the most favourable conditions for species to spread in response to climate change.

From fossil and pollen evidence we know that in the past most species have responded to climate change by dispersing out of areas with an unfavourable climate into areas with a favourable climate, often at surprising rates.[29] At the end of the last glaciation, trees migrated north at an average of 200m per year.[30] These rates of spread might suggest that UK biodiversity has evolved so that it is able to cope with current climate change.

But this may not be the case because:

a The rate of climate change is more rapid than occurred in the past, so that species have to move more quickly to keep pace with a suitable habitat.

b In many parts of the UK large areas of habitat have been destroyed, leaving small, isolated fragments surrounded by unfavourable land use, so that species have to travel over longer distances through hostile areas to colonise new habitat.[31]

c Artificial barriers such as roads, towns, intensively farmed land and waterways compound the problems of dispersal.

It is likely that different species will spread at different rates, and rare long-distance dispersal events may be important in the rate of spread of some species.

28 Howe H.F. & Westley L.C. (1986) Ecology of pollination and seed dispersal. In: Crawley M.J. (ed.) Plant Ecology. Blackwell, Oxford. pp185-216.
29 Coope G.R. (1995) Insect faunas in ice-age environments, why so little extinction? In: Lawton J.H. & May R.M. (eds) Extinction Rates. Oxford University Press, Oxford. pp55-74; Davis M.B. & Shaw R.G. (2001) Range Shifts and Adaptive Responses to Quaternary Climate Change. Science, 292, 673-679; Huntley B. & Birks H.J.B. (1983) An Atlas of Past and Present Pollen Maps for Europe 0-13,000 Years Ago. Cambridge University Press, Cambridge.
30 Williamson M. (1996) Biological Invasions. Chapman and Hall, London.
31 Adams J.M. & Woodward F.I. (1992) The past is a key to the future; the use of palaeo-environmental understanding to predict the effects of man on the biosphere. In: Woodward F.I. (ed) Global Climate Change: The Ecological Consequences. Academic Press, London. pp 257-314; Ibid. Malcolm J.R. & Markham A. (2000).

Those landscapes which are richest in terms of their current biodiversity are also more likely to be most varied in terms of their habitat mosaic and thereby most likely to allow some species to adapt to a changing climate by dispersing to nearby habitat patches in the future. The following characteristics are worth maintaining and enhancing:

a *Diverse and structurally varied vegetation*. Different types of vegetation have different microclimates and some species may be able to adjust to climate change by expanding the range of vegetation types they occupy, or by moving from one type of vegetation to another.

b *Semi-natural habitat on a range of slope and aspect*. Microclimate varies considerably with slope and aspect. At sites with varied topography species adversely affected by higher temperature and summer drought on south-facing slopes may be able to move to cooler, more humid north-facing slopes. Quite small differences in topography, for example on different sides of a hillock, may provide the topographical variation required if the magnitude of change is not too great.

c *Uninterrupted semi-natural vegetation over a range of altitude*. For some species the response to climate change will be to move to higher areas, where climate is generally cooler and wetter. Hence, uninterrupted habitat within mountains and hills will allow the dispersal of species but montane species on the highest peaks are likely to be left with nowhere to go. This and the following point demonstrate the principle of connectivity.

d *Uninterrupted semi-natural habitat across coastal zones*. Coastal areas have complex microclimates compared to inland areas and there is large climate variation over distances of less than one kilometre at the coast meaning species may find suitable nearby habitat patches as climate changes.

e *Diverse water regimes*. Climate change is likely to have a complex effect upon water regimes. Summers are expected to become drier while winters are likely to become wetter and rainfall may become less evenly distributed, with more heavy rainfall events and flooding. The most complex range of habitats, and therefore the most aquatic and wetland species, are likely to survive in landscapes where there is variation from open water to dry land. A diversity of wetland conditions is most likely to persist where the open waters and wetlands are fed by a combination of surface drainage, ground water and aquifers.

Suggested actions

Enhancing local variation within sites and habitats can be achieved in the following ways:

- Remove or fragment commercial forestry in the uplands and restore semi-natural habitats, to allow vulnerable species to disperse to higher ground.
- Manage vegetation to give more varied structure (for example, a range of grassland heights, or varied age structure of the heather canopy on heaths is a way of increasing variability). This must be done with care and with the scale of patch size in mind, to ensure that disturbance created by management for varied structure does not inadvertently increase fragmentation of habitat.
- Design and manage civil engineering structures, such as cuttings and embankments, or restore quarries, to provide added landforms with a range of slope and aspect that will give increased microclimatic variability.

Suggested actions (continued)

- Ensure that a diversity of water regimes are maintained, despite dry summers, by carefully regulating extractions and water flows where possible and increasing water storage within and between sites.
- Seek out opportunities in conjunction with other land managers to modify drainage regimes to increase the range of wet and dry conditions.
- Exploit opportunities for restoring semi-natural habitat and improved conditions for biodiversity on agricultural or other land in coastal areas, thereby increasing variation in the landscape.
- Restore or create transitional habitats, such as scrub between grassland and woodland, to increase variability of habitats and microclimates.

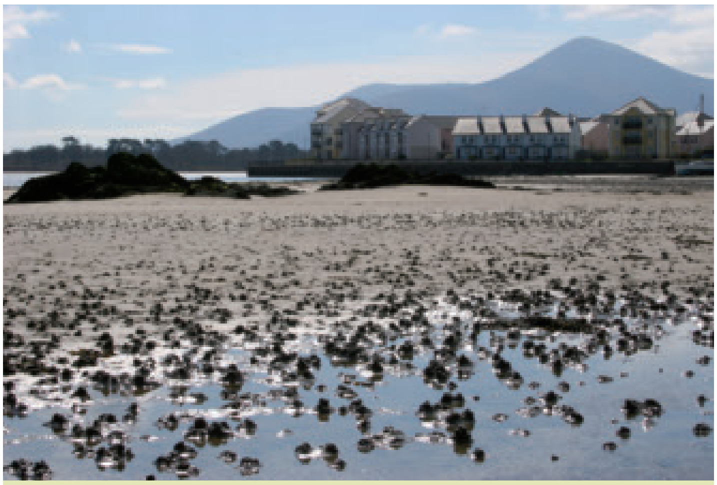
3b Make space for the natural development of rivers and coasts

The rivers and seas of the UK have an important influence upon biodiversity through the physical processes of erosion and deposition, which shape the landforms, and in turn the habitats, of the countryside and coast. In attempting to halt erosion and deposition and stabilise rivers and coasts by building sea walls, canalising rivers or otherwise artificially straightening and banking river courses, the already reduced biodiversity of coast and rivers has become more vulnerable to the impacts of sea-level rise and flooding.

On the coast, as sea level inevitably rises over most of the UK, formerly tidal areas will become permanently flooded. Where sea walls and other 'hard' features prevent the zone of tidal flooding from moving inland, the extent of intertidal habitat will decline and the associated wildlife will be lost unless suitable habitat is created or allowed to develop naturally through allowing tidal flooding further inland.

In the case of rivers an increased incidence of flooding is anticipated.[32] Increased flooding has historically been managed by expensive dredging, straightening and embanking of rivers, a process which is highly damaging to biodiversity.

Making space for natural processes to take their course on rivers and coasts will be difficult to achieve in the short term as this will impact upon other land uses in the area, including built development in some cases. This approach may also mean that coastal freshwater habitats will be affected by saline incursions caused as rising sea levels cause change to their biodiversity. However, the alternative of attempting to delay the impacts of sea-level rise and increased flooding through engineering solutions is likely to become unreasonably expensive in many situations and technically impossible in others.



Coastal development at Dundrum, Co Down
Credit: Northern Ireland Biodiversity Group,
Photographer: Bob Brown

32 Rivers may experience very complex future change to their water regime, including not just flooding, but increased frequency of low flows.

Suggested actions

Implement measures that allow the natural development of coasts and rivers by including them within River Basin Management Plans, LBAPs, Protected Areas management plans, shoreline management plans, Integrated Coastal Zone Management, and other local management frameworks.

Retain or restore natural river profiles and floodplains, including associated semi-natural habitats, which allow erosion and deposition and natural flooding where possible, thereby increasing the potential for maintaining biodiversity while alleviating the risk of flooding downstream.

Implement realignment of coastal defences to restore inter-tidal coastal habitats and natural transition zones between coastal and terrestrial habitats. Such measures are beneficial for biodiversity and can reduce the long-term costs of maintaining coastal defences.

Ensure built development on floodplains receives strict planning scrutiny to ensure it does not compromise options for more natural management of the river system, including floodwater storage on the floodplain.

4 Establish ecological networks through habitat protection, restoration and creation

Creating ecological networks that improve connectivity between habitat patches and allow species to disperse over larger areas (see Box 4) will enhance the resilience of the landscape and further increase the probability of species surviving.

In some landscapes a significant proportion of semi-natural habitats survive, most notably in the uplands and on the least modified coasts. Such relatively *intact landscapes* should continue to be an important focus for conservation activity because it is here that circumstances are most favourable for survival of biodiversity by dispersal.

The challenge lies in *fragmented landscapes*. Historic habitat loss means that in many parts of the UK, particularly in the lowlands, semi-natural habitats often survive as small, isolated patches. If species are to be able to move in response to climate change there is a need to assist dispersal through the wider countryside and colonisation of new sites. It is in these fragmented areas that *ecological networks* should be established and strengthened by programmes of habitat restoration and creation to improve opportunities for dispersal across landscapes and between regions in response to climate change.

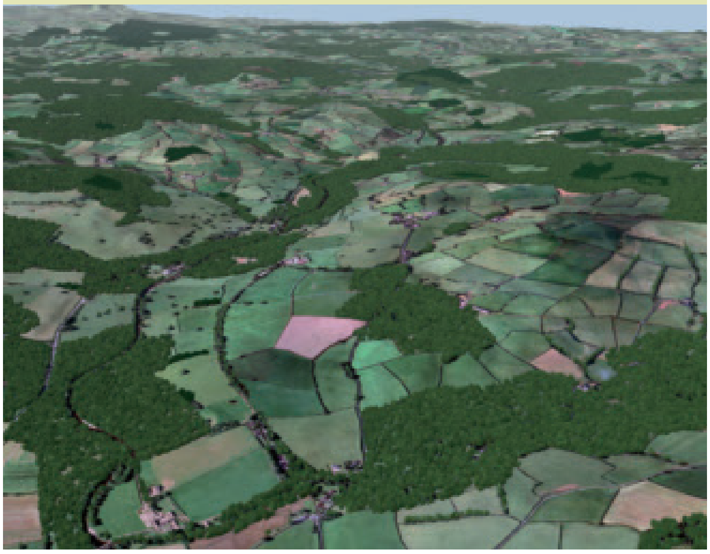
Habitat Creation at Wallasea, Essex
Credit: Defra

Critical to the development of ecological networks is the conservation of Protected Areas and existing areas of high-quality wildlife habitat (see Guideline 1). These will form the *core areas*, rich in biodiversity, which will populate the rest of the network once connections are improved.

Further complementary types of activity are required, firstly to restore habitat that has become degraded due to inappropriate management or abandonment on which there is a large body of practical advice available[33] and secondly to create new habitat, targeting it where there are greatest concentrations of existing semi-natural habitats.

Both restoration and creation are more resource intensive than conservation of existing high-quality wildlife habitat. Furthermore, in most landscapes relatively small areas contain the combinations of land use, land ownership and environmental characteristics that will permit habitat restoration and creation. But the benefits of this approach are now being recognised and this is an area where conservation practice is rapidly developing (e.g. the Wales Woodland Habitat Network Strategy and the Dutch Ecological Network).[34] It is important to recognise that ecological networks can only enhance dispersal of some species and their development will reduce but not prevent biodiversity loss due to climate change.

A visualisation of the Usk valley, near Brecon, at present (above) and with a modelled functional woodland network (below). Credit: Countryside Council for Wales, Photographer: Jonathan Rothwell



Habitat Creation at Wallasea, Essex
Credit: Defra

33 Backshall J., Manley J., & Rebane M. (eds) (2001) The Upland Management Handbook. English Nature, Peterborough; Benstead, P.J., José P.V., Joyce C.B. & Wade P.M. (1999) European wet grassland: guidelines for management and restoration. RSPB, Sandy; Crofts A. & Jefferson R.G. (eds) The Lowland Grassland Management Handbook (2nd Edition). RSNC / English Nature, Peterborough; Day J., Symes N. & Robertson P. (2003) The Scrub Management Handbook. Forum for Application of Conservation Techniques / English Nature, Peterborough; Moss B., Madgwick J. & Phillips G. (1996) A guide to the restoration of enriched shallow lakes. Broads Authority, Norwich; Symes N. & Day J. (2003) A practical guide to the restoration and management of lowland heathland. The RSPB, Sandy; RRC (1999) Manual of River Restoration Techniques. River Restoration Centre, Silsoe; RSPB/NRA/RSNC (1994) The New Rivers and Wildlife Handbook. RSPB, Sandy; Woodland Trust (2005) The conservation and restoration of plantations on ancient woodland sites – a guide for woodland owners and managers. Woodland Trust, Grantham.

34 Ministry of Agriculture, Nature and Food Quality (2005) Ecological Networks: Experiences in the Netherlands 12pp. http://www.minlnv.nl/portal/page?_pageid=116,1640321&_dad=portal&_schema=PORTAL&p_file_id=14783; Watts K., Griffiths M., Quine C., Ray D. & Humphrey J.W. (2005). Towards a Woodland Habitat Network for Wales. Contract Science Report, 686. Countryside Council for Wales, Bangor.

Suggested actions

LBAP officers and LBAP partnerships should encourage the development of ecological networks through spatially targeted action, especially where several LBAPs in close geographical proximity work together.

Use Strategic Environmental Assessments (SEAs) and regional spatial plan reviews to provide an assessment of climate-change impacts within an area and make the case for development of an ecological network.

Substantial emphasis should be placed on co-operative working between land managers and others to encourage the planning and establishment of ecological networks through the following steps:

a *Secure Protected Area by putting in place necessary conservation management actions and seek recognition and management for other high-quality priority habitat areas in the landscape. These areas will form the core of an ecological network, from which wildlife can spread.*

b *Identify areas that are most favourable for habitat creation or restoration through analysis of land ownership, land use, soils, hydrology and other physical features in the landscape taking account of all ecological, social and economic factors. This would be most effectively done at the regional scale to provide the right strategic overview and economies of scale rather than as a separate exercise for each LBAP.*

c *Establish a multi-disciplinary team of ecologists, GIS specialists and land managers to collaborate in the development of ecological networks. Equally important is the involvement of stakeholders, such as local planning authorities, landowners and local-community representatives.*

d *Prioritise as far as practicable the expansion of existing habitats by their restoration and creation to buffer core areas against adverse surrounding land use or environmental conditions and facilitate the establishment of arriving species.*

e *Where possible, reduce the intensity of land use and establish landscape features such as headlands and hedgerows to enhance the potential for dispersal. The ability of many species to spread between habitat patches is reduced due to the presence of intervening highly intensive land uses like extensive conifer plantation, intensive arable or built development. By reducing the overall intensity of land use in suitable areas through targeted implementation of agri-environment schemes or widespread use of sustainable forestry guidelines, dispersal of a higher proportion of species will be far more likely to occur. Within urban areas green space, including parks and gardens, can play a valuable role in enhancing dispersal.*

5 Make sound decisions based on analysis

Although our information is not perfect, we are fortunate in the UK to have a significant body of ecological research about our biodiversity, and long-term monitoring initiatives such as the Countryside Survey, New Plant Atlas and Butterfly Atlas[35] which provide us with a more complete understanding of biodiversity change than occurs anywhere else in the world. It is important that these and other monitoring programmes continue and their results are available to those who plan or manage biodiversity conservation.

35 Asher J. et al. (2001) The Millennium Atlas of Butterflies in Britain and Ireland. Oxford University Press, Oxford; Ibid. Haines-Young et al. (2000); Preston C.D., Pearman D.A. & Dines T.J. (2002) New Atlas of the British and Irish Flora. Oxford University Press, Oxford.

5a Thoroughly analyse causes of change

One of the greatest challenges for nature conservation will be both identifying and responding to declines of species caused by climate change. It is important that all biodiversity change is not seen as an inevitable and unavoidable consequence of climate change. In many cases cessation of management, nutrient enrichment and other factors, often working in combination, will be the most important causes of habitat degradation and species decline. For some species, climate change may be only a small component of the problem but for others it may be the main cause.

Detailed criteria for identifying and responding to declines and extinctions induced by climate change do not currently exist but below we suggest actions which will focus conservation appropriately.

Suggested actions

Ensure that all other factors which might explain the decline in a species have been thoroughly considered and action taken (see Guideline 2). Sources of information include UK BAP reports,[36] the UK Air Pollution Information System (APIS)[37] for information on the effects of pollution on habitats and species, and national and local surveys.

Accept local decreases if there is clear evidence that the species is increasing elsewhere within its range, as this forms part of an inevitable change in distribution related to climate. Sources of data include the Biological Records Centre,[38] local Biological Records Centres and the National Biodiversity Network[39] data, and published reports of national surveys.

Identify any long-term monitoring schemes already under way for relevant habitats or species and assess their implications. It will be important to maintain and continue existing monitoring and initiate additional schemes or research where the cause of declines are possibly the result of a changing climate.

Undertake interventions to address decline where this is strategically the right thing to do. For example, breeding populations in captivity and releasing them into the wild is only appropriate where changes to habitat management to allow long-term survival have been achieved. Translocation is an option for species unable to disperse quickly enough to keep pace with climate change, though it will be limited on the grounds of cost, technical difficulty and risk of unintended ecological damage by translocated species. Successful translocation projects in the UK include the reintroduction of white tailed eagle,[40] red kite and large blue butterfly. Any translocation exercise should follow procedures and guidance laid out by the UK Joint Nature Conservation Committee,[41] especially in the case of legally protected species, where special permits will be required.

36 www.ukbap.org.uk/GenPageText.aspx?id=105
37 www.apis.ac.uk
38 www.brc.ac.uk
39 www.nbn.org.uk
40 Bainbridge I.P. et al. (2003) Re-introduction of the white tailed eagles (Haliaeetus albicilla) to Scotland. In: Thompson D.B.A. et al. (eds) Birds of prey in a changing environment. The Stationery Office, Edinburgh; Barnett L.K. & Warren M.S. (1995) Species Action Plan: Large Blue Maculinea arion. Butterfly Conservation, Wareham; Carter I. et al. (2003) Re-introduction and conservation of the red kite (Milvus milvus) in Britain: Current threats and prospects for future range expansion. In: Thompson D.B.A. et al. (eds) Birds of prey in a changing environment. The Stationery Office, Edinburgh.
41 Joint Nature Conservation Committee (2003) A Policy for Conservation Translocation of Species in Britain. Joint Nature Conservation Committee, Peterborough. pp30.

5b Respond to changing conservation priorities

As resources for conservation are limited, conservationists have traditionally prioritised the conservation of rare and threatened species and habitats. This has been reflected by added legal protection and conservation focus for those species included in the UK Biodiversity Action Plan (UK BAP), Annexes of the EU Habitats or Birds Directives, Schedules of the Wildlife and Countryside Act or in Red Data Books. Site managers often focus their efforts on the basis of such status.

Under a changing climate, the range and abundance of many species will change, a process already well documented for many species groups. For some species and habitats special conservation measures may become inappropriate over time, as climate change means they become more abundant. A warming climate may offer many of the BAP species with southern distributions the potential to spread northwards and occupy a wider range of localities. Conversely, some currently common species may decline due to their sensitivity to climate change and will need to be prioritised. As a result of these changes, reviews of conservation priorities such as the BAP will need to take account of changing conservation status.

A phenomenon almost certainly linked to climate change is the recent colonisation of the UK by species found on the near continent of Europe. Over time populations of these and other species newly found in the UK may decline in mainland Europe due to climate change, and UK populations may become of international importance. Hence, these species should begin to be considered in UK conservation target setting.

Suggested actions

Respond to the changing status of species at UK level by adapting conservation targets and Habitat and Species Action Plan priorities. Given that impacts of climate change will not be uniform across the UK, it will be equally important to recognise and respond to the changing status of species regionally through LBAPs and within site management plans.

6 Integrate adaptation and mitigation measures into conservation management, planning and practice

An approach to conservation management on individual sites has been developed over several decades, which requires the identification of clear targets for habitats and species and the removal of obstacles to their achievement.[42] With data from regular monitoring the effectiveness of management practices, such as grazing, can be reviewed, and if necessary amended. It is now essential that conservation management planning also incorporates consideration of climate change impacts at its initiation or review. There is a need to move from management largely focused on selected species and habitats towards much greater emphasis on the underlying physical processes that are essential to the maintenance of biodiversity on the site.

In the light of available evidence there should be an increased scrutiny in management planning of:

- *Water regimes*, as rivers, lakes, ponds and wetlands will require more active management in those parts of the UK where droughts are expected to increase in frequency;

42 Alexander M. (2000) Guide to the production of management plans for protected areas. Conservation Management System Partnership, Aberystwyth; Alexander M. (2005) Management planning: the adaptable approach. Conservation Land Management 3(1), 13-16; Walmsley C.A. (2005) The 21st Century challenge: adapting to climate change. Conservation Land Management 3 (4), 12-14.

- *Fire control and management*, as increased summer droughts may mean habitats in which summer fire is currently absent or rare could become prone to fire; generally summer fire may increase;

Fire Break, near Denny Bog, Hampshire
Credit: Natural England, Photographer: Peter Wakely

- *Livestock management and cutting regimes*, as the longer growing season may increase the amount of herbage available to be grazed, and earlier dates for cutting of hay meadows, verges and other habitats may become appropriate. In areas with increased summer drought lack of water for livestock and reduced plant growth may limit summer grazing or mean changes in the type of stock used;
- *Erosion and deposition of sediments* along rivers due to flooding and along the coast due to sea-level rise is likely to be of greater importance due to more intense rainfall events and the greater frequency of storms expected in the future;
- *Increased control of alien species* that threaten to become invasive as a result of climate change at an early stage in their establishment or spread.

In some cases these factors are under the control of an individual land manager, as for example grazing and cutting regimes. Others, however, such as water management and alien species control, may need to be dealt with by land and water managers at landscape or regional scale, for example through LBAPs and catchment management plans. Many of the impacts that climate change may have on sites in the near future, such as summer drought and flood, are already encountered albeit less frequently, and suitable techniques for their management are available so that action can be taken.

There is likely to be more focus on mitigation through land use practices in future, particularly preventing loss of carbon and where possible increasing its storage. Most of the terrestrial carbon in the UK is in the soil and measures to reduce modification of soils – for example remedying the adverse effects of drainage on peat soils, or managing vegetation to minimise organic-rich soil disturbance – should be incorporated into management plans.

A large proportion of the carbon stored in UK soils and vegetation is within Protected Areas and other high-quality wildlife sites, especially in peatlands, and their management is a significant responsibility for land managers. There has, however, been very little quantification of the way in which conservation management practices impact upon carbon in the soil and vegetation. Such knowledge is urgently needed in order to ensure that they do not result in the increased release of greenhouse gases and, where possible, do result in carbon being removed from the atmosphere.

Suggested actions

Conservation management plans should be revised to take account of the impacts of climate change in particular incorporating consideration of adaptation measures as outlined above and the retention or further capture of carbon within habitats where possible.

Conclusion

This document sets out the type of actions that can be taken now to promote adaptation of biodiversity in a changing climate. Uncertainty about how climate change will unfold or what the response of species and habitats will be must not prevent us from taking such actions urgently. However, these measures may be overwhelmed by events if we do not at the same time tackle the main cause of climate change: our ever-growing global emissions of greenhouse gases. The implementation of these actions will provide evidence of their effectiveness and assist their future review and refinement. Even setting aside climate change, taking on board the key guiding principles contained within this guidance will greatly benefit biodiversity conservation. The challenge is that their use as an integrated package of measures will require far greater collaboration both amongst conservationists and with other sectors.

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