Living With Environmental Change

Terrestrial Biodiversity Climate Change Impacts

Report Card 2012 -13

The Terrestrial Biodiversity Climate Change Impacts Report Card provides an overview of how climate change is affecting UK biodiversity and potential future changes based on the latest scientific evidence and understanding.[1] The project has been overseen by a working group of senior scientists, and both the card itself and the review papers that support it have been peer-reviewed to ensure scientific rigour and that the consensus view of the scientific community is represented. In total over 40 scientists from more than 20 different research and conservation organisations have contributed to this Report Card.

The Report Card shows where observed changes in UK biodiversity are likely to have been caused by changes in the UK climate over recent decades ('What is happening'). It also assesses potential future impacts of climate change on biodiversity ('What could happen').

The Report Card covers the following topics:

- Headline messages
- Confidence assessments and causes of change
- UK climate
- Key trends
- Ecological processes
- UK animals and plants
- UK terrestrial habitats
- UK coastal habitats
- Extreme events
- Regional variations
- Implications for people
- Adapting to climate change

[1] *The Report Card is based on 15 technical review papers, each commissioned to provide in-depth analyses of specific topics. The key findings from these papers are presented in the Report Card.*

Headline messages

- There is strong evidence that climate change is already affecting UK biodiversity. Impacts are expected to increase as the magnitude of climate change increases.
- Many species are occurring further north and at higher altitudes than in previous decades, including some species which have colonised large parts of the UK from continental Europe.
- Recent rates of change in distributions differ between species. Some species, including many plants, are intrinsically slow to disperse and fragmentation of habitat may contribute to some species spreading more slowly than would be expected from climate change alone.
- Warmer springs in recent decades have caused a trend towards many biological events (e.g. flowering, budbreak, laying and hatching of eggs) occurring earlier in the year. The rates of change vary among species, which may alter the interactions between species.
- There is evidence of changes in the composition of plant and animal communities, consistent with different responses of different species to rising temperature.
- Species differ in their responses to variation in precipitation. The effects of climate change are less certain for precipitation than for temperature, but potential changes could lead to substantial changes in biodiversity and ecosystems.
- Some habitats are particularly vulnerable to climate change; the risks are clearest for montane habitats (to increased temperature), wetlands (to changes in water availability) and coastal habitats (to sea-level rise).
- Climate change exacerbates the risk that non-native species (including pests and pathogens) may establish and spread.
- We expect there to be regional differences in the impact of climate change on biodiversity, reflecting different species, climate, soils and patterns of land use and management.
- The protected area network, which includes Sites of Special Scientific Interest and National Nature Reserves, will continue to have a valuable role in conservation although there will be changes in populations, communities and ecosystems at individual sites.
- Climate change will interact with, and may exacerbate, the impact of other continuing pressures on biodiversity, such as land-use change and pollution.
- Extreme weather events, such as droughts and floods, have clear impacts on ecosystems and the ecosystem services they provide; climate change may alter the frequency and severity of such events.

Confidence assessments and causes of change

An important issue in presenting climate change impacts is to communicate how much confidence we can have in any particular piece of evidence. Some research results are quite clear, whereas others are subject to greater uncertainty. Contributing authors were asked to provide an assessment of confidence for each of the headline messages provided in their technical papers. A version of the confidence scales developed by the Intergovernmental Panel on Climate Change (IPCC) was used to capture the amount and quality of the evidence supporting the statement and the level of agreement between different sources. Confidence increases where there are multiple, consistent, independent lines of high-quality evidence.

Our understanding of what is already happening is based on current and past observations. Our ability to detect trends in the data is determined by the amount of data available and how representative they are. If there are very few data, or the data are only for one part of the country, confidence in the observation is low compared to a national dataset that has been collected over many years. The UK has some of the best monitoring data in the world for a range of different species and habitats. There are particularly good data for birds and butterflies, and the timing of life-cycle events such as egg laying and flowering of plants has been well recorded. However, some other groups, including some mammals, are relatively poorly recorded, which makes it more difficult to be confident about identifying trends.

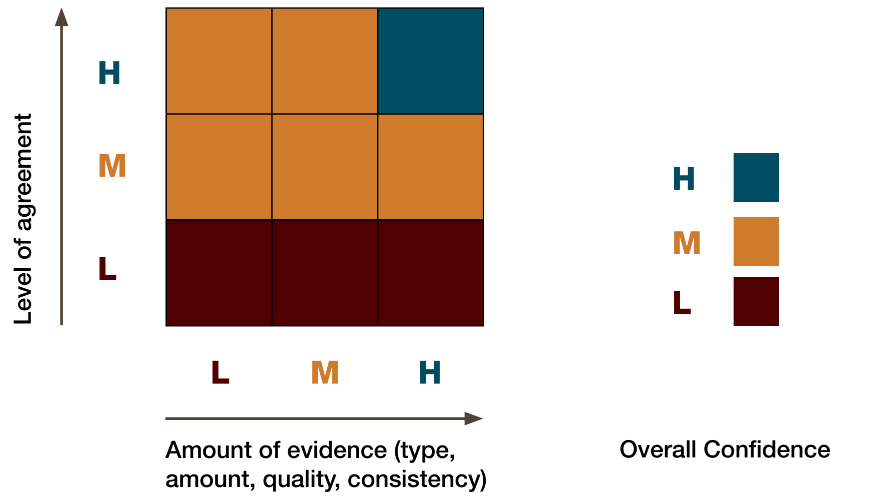
A further complication is that a range of non-climatic factors are also affecting the natural world, including changes in land use and management, air pollution and animal and plant diseases. Scientists therefore have to take account of the probability that climate is the cause of change rather than one of these other variables. Evidence that climate is the cause of change includes understanding the processes by which climate affects plants and animals and testing other plausible causes of change. There are also a range of 'field experiments', which artificially raise temperatures or manipulate water supply to plots of vegetation in order to empirically test the effects of climate on biological communities and soils.

In assessing the effects of past and present changes in climate, this Report Card deals with the relationship between observed changes in meteorological data and biological data. It does not address the causes of climate change itself – for example, the relative importance of elevated greenhouse gas emissions from human activity and natural causes – which have been extensively dealt with elsewhere.

The descriptions of potential future change are based on a variety of types of evidence, including understanding of the mechanisms by which climate affects plants and animals, field experiments and a variety of computer models.

They are qualitative assessments that indicate a direction of travel rather than quantitative predictions. Whilst climate models project changes in temperature with reasonable confidence, the complexities of ecological responses and the interactions with other non-climate pressures mean that there is a large range of possible future outcomes. This is compounded for other climate variables, such as rainfall, where there is less certainty in future projections. Where we are not able to anticipate specific changes, we simply present evidence of ecological sensitivity to climate variables which may plausibly change in future.

The Report Card has simplified the assessments to provide an overall confidence level of high (H), medium (M) or low (L). Low confidence results are still based on evidence and still reflect expert judgment.



Our climate is already changing. In some cases, changes can be at least partly linked to the influence that people are having on the climate system. In other cases, we may be able to detect a trend but are not yet able to say what is causing it. It is particularly difficult to attribute the cause of changes at the scale of the UK, where the climate is naturally very variable and there are other influences on the climate system. It is even harder to look at changes in the frequency and severity of extreme events. By their nature they are rare occurrences and so there are limited observational data to study.

This section summarises the changes we have already seen and describes how we expect the climate to change in future.

What has happened

- Global and European temperatures have risen in recent decades and a large part of the warming can be attributed to human-induced climate change. In the UK, temperatures at many locations warmed, with the number of days warmer than 20°C having increased and the number of days colder than freezing having reduced in recent decades.
- Rainfall in the UK is highly variable from month to month and year to year, making it difficult to detect or attribute the cause of long-term trends. For the UK as a whole, recent decades have been getting wetter but this does mask a lot of regional and seasonal differences and may be part of natural variability. There are also signs that a greater proportion of rain is falling in more intense events.
- In the last decade or so, a number of extreme months or seasons have occurred in the weather record. In some cases, such as the European heat wave of summer 2003, there is evidence that human influence has changed the odds of such warm events happening.
- Mean sea-levels are continuing to rise around the coast of the UK, driving an increase in extreme sea-levels.
- The magnitude and duration of winter river flooding has increased over the last 30 years, but a longer record is required to establish what is driving this change.
- Clear patterns of change in the occurrence of droughts have not been observed.
- 2012 was the second wettest year in the UK national record dating back to 1910, and just a few millimetres short of the record set in 2000. It featured a dry January to March which exacerbated a significant two-year drought, but this was followed by record rainfall in April and June. Summer 2012 was the second wettest for the UK overall and there were further periods of intense rainfall in the autumn and early winter. At present it is still unclear if humans have altered the odds of a year like 2012 occurring more frequently but this is an active area of research.

What may happen

Projections of how the climate of the UK may change in future decades depend on levels of past and future greenhouse gas emissions. On top of the projections of the long-term trends in warming, our weather will continue to be highly variable. For example, we will still get cold winters but the frequency of them is likely to reduce as the decades pass.

- Temperatures across the UK are likely to warm at a faster rate than during the last few decades. A hot summer, like that of 2003, may happen on average every other year by the 2040s and be considered cool by the end of the century.
- A greater proportion of rainfall may fall in intense events. In the long-term, it is also likely that summers in the UK will get drier and winters will get wetter on average, although the annual average rainfall may not change greatly across the UK. However, there could be other influences of a changing climate which may override this expected pattern on shorter timescales.
- River flooding is expected to increase in magnitude and frequency through the century, but the scale of these increases is unclear.
- Increases in short-duration droughts are possible, but there is little agreement on changes in longer droughts.
- Sea levels will continue to rise and are likely to at a faster rate than we have observed in the last century. There is evidence that some current projections may underestimate the amount of sea-level rise in coming decades.

This information is based on the UK Climate Projections 2009 reports, together with more recent publications. Full references are available in a separate online document.

High Confidence ■ H
Medium Confidence ■ M
Low Confidence ■ L

A number of general indicators of climate change impacts, particularly rising temperatures, can be identified across a wide range of species and habitats. These range from changes in individual species life-cycle timing through to changes in species distribution and composition of many ecological communities. The fact that common patterns can be identified across contrasting species and situations contributes to high confidence in some of these findings.

Changes in timing of life cycle events (phenology)

Mossman, Franco & Dolman

Sparks

What is happening

Spring events have advanced, including flowering and leafing of plants, egg laying in birds and earlier emergence of insects. ■ H

Higher temperature advances phenology or timing of natural events in many species of plants and animals. Changes over the last century are consistent with changes in temperature. The extent of this effect is species- and even genotype-specific. ■ H

Temperature is not the only influence on phenology. Studies have shown that changes in nutrients, day length and water supply, and increases in carbon dioxide, can also have an impact on some species. ■ M

Some evidence shows that phenological changes are affecting the synchrony between predators and prey, host plants and pollinators and are also affecting symbiotic relationships. ■ L

There has been a delay in the timing of autumn events such as leaf fall, although the pattern is less consistent than for spring. ■ L

What could happen

Further changes in climate may increase present trends and increase the risk of a breakdown in synchrony between phenological events in different species, affecting the complex network of interactions between species, for example between predators and prey or between plants and their pollinators. ■ L

Curlew nest with eggs © *Natural England*

Range shifts

Ellis

Neaves *et al.*

Pateman

Pearce-Higgins

Changes in the range margins of many animal species are consistent with recorded increases in temperature; good data is available for a range of groups including birds, butterflies and dragonflies. ■ H

Available data show that for most southerly distributed animal species in the UK, there has been a northwards shift, and to a lesser extent a shift to higher altitudes, over 20–25 years. Average shifts have been 31–60 km at rates of 13.7–24.8 km per decade; the altitudinal range margins have shifted 25 metres uphill at a rate of 2.8–10.1 metres per decade. ■ M

Rates of change in species range margins differ; most are not moving as fast as the change in temperatures we have seen in recent decades. ■ M

Species will continue to shift their distribution northwards and to higher altitudes in response to increasing temperatures. ■ M

Interactions between species will influence the patterns of species shift in newly climatically suitable areas (e.g. agricultural management may inhibit the establishment of plant species beyond current margins in some locations). ■ M

Species that are unable to shift distribution to keep pace with climate change may experience reduction in their range extent and local extinction. Barriers to movement include distance between isolated habitats such as mountain tops, and habitats fragmented by land use. ■ M

What is happening

Range shifts – continued

Ellis

Neaves *et al.*

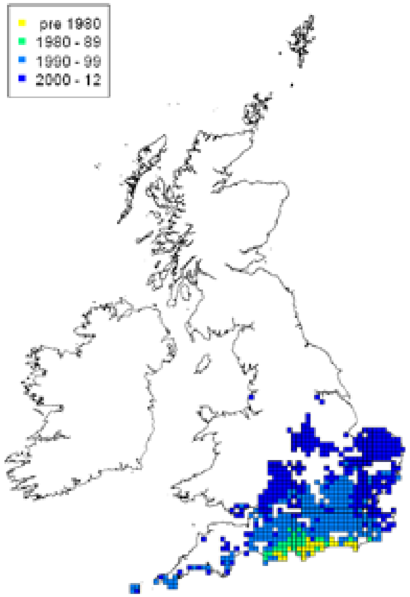
Pateman

Pearce-Higgins

Genetic adaptation is helping some species to expand their range by increasing dispersal ability or altering species interactions (e.g. brown argus butterflies have started to use a new food plant, wild geranium). ■ **M**

There are fewer studies examining changes in distributions of northerly distributed animal species, compared to southerly distributed species. Three of four northern butterfly species have retreated northwards and to higher elevations (e.g. the mountain ringlet). ■ **L**

There are fewer examples of plant species distributions shifting compared to animals. ■ **L**



Long-winged conehead cricket: a species spreading northwards – year of first recording © Bjorn Beckmann/BRC

Adonis blue butterfly © Natural England/Peter Wakely

Long winged conehead cricket © David Browne

What could happen

Because there are more species with northern range margins than southern ones in the UK, more species may increase than decrease in the UK. However, those species expanding in the UK may be declining elsewhere in their ranges across central or southern Europe. ■ **M**

Expanding species will tend to be those with a relatively warm, southerly distribution (e.g. stone curlew, Adonis blue butterfly). Species that will tend to lose climate space across the UK are those typical of cold areas, including common scoter, black grouse, arctic–montane bryophytes and lichens. ■ **M**

Species with limited dispersal abilities are unlikely to keep pace with climate change and are likely to be at greater risk than those that disperse easily. ■ **L**

Black grouse © Edmund Fellowes/BTO

What is happening

Community composition

Carey

Mossman, Franco & Dolman

Pearce-Higgins

There have been some shifts in community composition, consistent with effects of recent warming, among birds and some invertebrates. Southerly distributed or lowland species have tended to increase in abundance, while northerly distributed and upland species have declined. ■ M

Warming has been associated with a general increase in species diversity among butterflies and birds (e.g. during the period 1994–2006 when average annual spring temperatures increased by 1.4°C, the diversity of the bird community increased by 8%). This reflects the fact that many British birds and butterflies are southern species requiring relatively high temperatures. ■ M

There is some evidence that increasing temperatures are contributing to an overall decline in specialist species with narrow habitat preferences, while generalist species with broader habitat preferences are increasing. This is leading to less variety in biological communities and habitats, and land-use change and nutrient availability will also be a major driver of this. ■ L

What could happen

Many communities may retain a 'mix of species' similar to the present day but their relative abundance will change. Some species may disappear from some locations and be replaced by others. ■ M

Flower-rich upland hay meadow upper Weardale © Rebecca Barrett/North Pennines AONB Partnership

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Non-native species and colonisation

Hulme

Mossman, Franco & Dolman

The patterns of introduction of non-native species since 1800 are mainly consistent with the growth of international trade and long-distance transport. However, climate change and evolution have favoured the spread of some species once established. ■ H

Warming is likely to have facilitated a number of recent natural species colonisations in the UK (e.g. damselflies such as the southern emerald). ■ M/■ L

Southern emerald damselfly © Dave Smallshire

The risks posed by non-native invasive species, including pests and pathogens, may be increased in future due to shifts in climate suitability (particularly mild winters). However, other factors such as land-use change and interactions between species through competition and predation may have a more significant role in controlling their establishment and dispersal rates. ■ M

It is very difficult to predict which species will become invasive. Potential non-native species that may establish themselves in the near future include the North American corn western rootworm (with the UK currently on the edge of its climatic range), the tiger mosquito, and escaped horticultural plants such as succulents and cacti. ■ M

The colonisation of new plant species may also lead to shifts in host plants for insects and other invertebrate species; this has been observed in gardens with cultivated plants. ■ L

Pests and diseases

Doswald & Epple

Evans & Pearce-Higgins

Hulme

Mossman, Franco & Dolman

What is happening

Disease caused by recently emerging pathogens (e.g. the oak processionary moth) has had a major impact on UK tree species. ■ **H**

Increases in temperature contributed to the spread of bluetongue virus in Great Britain. The virus is carried by the biting midge *Culicoides imicola*, a southern European species which is currently spreading north. ■ **M**

Rust fungus on Norway spruce © Forestry Commission/Barry Lambsdown

What could happen

Climate change will increase the risk of plant diseases due to a northward range expansion of pathogenic organisms and their vectors. ■ **H**

Climate change will increase the suitability of the UK climate for a number of non-native forest pathogens (including ones that impact on a wide range of native plant species), such as warmth-loving thermophilic rust fungi. ■ **H**

Central and southern Britain, particularly areas close to saltmarshes, could be suitable for vivax malaria, but malaria returning to the UK is not thought to be a serious threat within the next 50 years. ■ **M**

The overall impact of fungal diseases on UK arable crops is unlikely to increase in severity in response to climate change, as the increases of some diseases will be matched by declines in others. ■ **L**

Rising temperatures will make the climate in the UK suitable for an unknown number of invertebrate pests whose dispersal will be helped by international trade, particularly the timber and horticultural trade. ■ **L**

Climate change may contribute to bird population declines by increasing the effects of diseases and parasites. However, the size of this risk is not known except for red grouse, where the gastro-intestinal nematode is likely to increase in warm, wet conditions, leading to a reduction in red grouse fertility and abundance. ■ **L**

High Confidence ■ H
Medium Confidence ■ M
Low Confidence ■ L

Animals and plants respond on a year-by-year basis to changes in weather patterns and other environmental variations that affect the survival, timing and success of reproduction, growth and migration. They are also influenced by interactions between species through, for example, the food chain, competition, pests and diseases, and pollination. Changes to these ecological processes will also influence genetic diversity and evolutionary change.

Migration

Evans & Pearce-Higgins

Morrison & Robinson

Sparks

What is happening

There has been a tendency for many summer migrant bird species to arrive earlier in recent years, with the advance greater for those with shorter migration distances than for intercontinental migrants, and greater for early arriving species than later arriving species. ■ H

Migratory insects are arriving with increasing frequency and this is leading to new species becoming resident in the UK. ■ H

A number of wildfowl and wader species have declined significantly in their abundance in the UK. For example, between 1997/98 and 2007/08, winter populations of Bewick's swan declined by 44%; these birds are now wintering further north and east in other parts of Europe, partly in response to winter warming, although land-use change may also be responsible. ■ M

Spotted flycatcher © Andy Hay (RSPB Images)

What could happen

Because of the dependence of many migratory species on wetland habitats, they would be disproportionately affected by any reductions in seasonal precipitation that lowered water tables, and affected prey availability. ■ M

UK populations of waterfowl and waders are projected to have mixed fortunes due to shifts in wintering locations. For some species, declines in global population size will result from reduced quality of Arctic breeding environments. ■ L

Changes in spring phenology are likely to affect the synchronisation of migration with food availability en route and at breeding grounds. ■ L

Substantial changes in the strength, direction and timings of prevailing winds during migration could have a major impact on some species, particularly birds of prey. ■ L

Many summer migrant birds are sensitive to drought in the Sahel and other climate changes in sub-Saharan Africa, which some climate models indicate will increase in severity. ■ L

Black-tailed godwits © Jill Pakenham/BTO

Species interactions

Ellis

Evans & Pearce-Higgins

Mossman, Franco & Dolman

Newman & Macdonald

Pearce-Higgins

What is happening

A range of experiments have shown that changes in climatic factors affect the growth rates of plant species, altering competitive interactions between species and community composition. ■ H

Recent advances in the phenology of many species in marine, freshwater and terrestrial environments have occurred at different rates within food webs. ■ H

Climate change can alter the impact of plant-eating insects on vegetation by increasing the insect population or the relative timing of insect emergence. Warmer temperatures appear to increase aphid populations, with subsequent impacts on vegetation. ■ M

Direct links have been found between summer precipitation and survival of bat species, with higher precipitation associated with greater insect abundance and drier springs and summers having a negative effect on population numbers. ■ M

What could happen

Range shifts and species colonisation are likely to give rise to novel combinations of species and complex changes in food-web interactions between, for example, plant species and herbivores, parasites and hosts. ■ M

Food-chain mismatches are most likely to be an important mechanism for climate change impacts in highly seasonal species that depend on a synchronised food peak (e.g. the link between an abundance of caterpillars and the reproductive success of some woodland bird species). ■ M

Changes in climatic conditions will alter how different species compete for the same resource in an ecosystem (e.g. food or living space), leading to shifts in community composition. The greatest impacts and changes are likely on the southern range margins of northern species. ■ M

An increase in small rodent populations arising from warmer winters is likely to positively impact on their raptor and owl predators. ■ L

Genetic diversity and potential for genetic adaptation

Neaves *et al.*

What is happening

Populations of many species are genetically adapted to local conditions, including climate. ■ M

Heavily fragmented landscapes have hampered the movement of genes between populations in many species, restricting opportunities for evolutionary adaptation to climate change. ■ M

Climate-driven changes in phenology, species distributions and population sizes are already influencing the levels and distribution of genetic diversity (i.e. the variation of genes found within a population or species, and the raw material for natural selection). ■ M

Genetic variation in some populations is enabling adaptive responses to environmental change (e.g. in the comma butterfly). ■ L

What could happen

For many species, the rate of evolution is unlikely to match that of climate change. Adaptive genetic responses are likely to be limited where genetic diversity is low or lost, or where gene flow between populations is restricted because of low reproductive rates or long generation times. ■ M

Evolutionary (genetic) adaptation to climate change is possible and may allow some species to remain in places where the climate would otherwise become unsuitable or to colonise new areas. ■ L

Reproductive processes

Evans & Pearce-Higgins

Newman & Macdonald

What is happening

Many bird species have better breeding performance during a mild spring. ■M

Warming is reducing the winter chilling required by some plant species, leading to delayed flowering and reduced subsequent reproductive success. Around one-fifth of 384 species studied in Oxfordshire between 1954 and 2000 demonstrated delayed flowering due to reduced winter chill. ■L

Song thrush © Mike Richards (RSPB Images)

What could happen

Warmer temperatures and extended growing seasons will lead to more reliable and frequent fruiting of some southern plant species near their northern limits (e.g. the small-leaved lime). ■M

Climate change will influence the efficiency of pollination in different ways for different species and places. ■L

Climate change may reduce the ability of seed bank longevity by changing soil moisture and temperatures, with increased exposure to soil moisture rather than temperature being the dominant factor. ■L

Species are likely to be more vulnerable to climatic stressors at key stages in the life cycle (e.g. in mammals, mating period, pregnancy, weaning, dispersal and hibernation). ■L

Hazel catkins © Natural England/Peter Roworth

High Confidence ■ H
Medium Confidence ■ M
Low Confidence ■ L

There are 35 terrestrial mammals, 12 reptile and amphibian species and about 300 birds that are native to the UK. There are at least 24,000 species of insects in the UK, together with thousands of other invertebrate species that have not been quantified. There are just over 2950 vascular plant species (flowering plants, conifers, ferns, horsetails and clubmosses) in the UK, over 1000 bryophytes (mosses, liverworts and hornworts) and around 2000 green algae species. Climate affects each species individually but it is possible to identify some general patterns showing change in life-cycle events, population numbers and distribution and behaviour.

Birds

Evans & Pearce-Higgins

Pearce-Higgins

What is happening

Warmer winters in the 1990s and early 21st century increased the survival rates of some resident bird species, contributing to population increases. ■ H

Population trends of a number of UK bird species, including birds with high conservation interest such as the black grouse and golden eagle, demonstrate a sensitivity to high spring rainfall during the breeding season (causing reduced reproductive success and poor chick condition). ■ M

Bird populations such as the song thrush, blackbird, ring ouzel and golden plover that rely on invertebrates associated with wet conditions are negatively impacted by increasing summer temperatures and drought. ■ M

Bird ranges in the UK have shifted northwards but have lagged behind changes in the distribution of isotherms (temperature contours). ■ M

Warming has been associated with an increase in the diversity of bird communities, and in particular with increasing generalist populations. Populations of southerly distributed species have tended to increase more than those of northern species. ■ M

Snow bunting © Julian Dowse/ Natural England

What could happen

Increased winter temperature is likely to increase the overwinter survival rate and therefore abundance of many UK resident bird species. ■ M

Species most associated with cool temperatures are likely to be most vulnerable to climate change, particularly those with a narrow thermal niche (e.g. ptarmigan, dotterel and snow bunting are currently restricted to the summits of the highest Scottish mountains and suitable climatic conditions will disappear by the end of the century under many standard climate change projections). ■ M

Climate change may affect migrant species populations as they are particularly susceptible to climatic effects on breeding and to changes in the timings of natural events, wintering sites and migration routes. They may be especially vulnerable to changes in the timings of natural events, such as the earlier peaks in availability of insects before they arrive at their breeding grounds. ■ L

Increased winter rainfall would reduce the ability of some small birds to survive overwintering due to reduced food availability and greater energy expenditure. ■ L

Male blackbird © Julian Dowse/ Natural England

	What is happening	What could happen

What is happening / What could happen

Reptiles and amphibians

Dunford & Berry

What is happening

Changes in the timing of life-cycle events have been identified and related to increased mean temperatures. Monitoring of the common frog shows congregation, spawning and hatching are happening earlier. ■ **H**

Reductions in frog and toad populations are consistent with low summer rainfall and consequent lower soil moisture during the drier summers between 2003 and 2006, alongside loss of suitable habitats and habitat fragmentation. ■ **M**

Common frog © Natural England/ Steve Hiner

What could happen

Some reptiles and amphibians, including the smooth snake, natterjack toad, and common toad, could gain climate space. This would allow northward range expansion, although this would depend on their ability to move between habitat fragments. ■ **L**

Common lizards, smooth newts and adders are projected to lose suitable climatic conditions across England under many climate change scenarios, but may expand into Scotland. ■ **L**

Adder © Natural England/Peter Wakely

Mammals

Newman & Macdonald

What is happening

Mammals that rely on hibernation, such as hedgehogs, dormice and bats, have reduced their period of hibernation during warmer winters. This can have consequences for their body condition, breeding success and survival rates. ■ **M**

Warmer winters have increased breeding success and/or overwinter survival of mammals, including red deer and Soay sheep, badgers, rabbits and hares. ■ **M**

Juveniles are often more vulnerable than adults to extreme events, such as spring drought, flooding and colder winters, which may have a subsequent impact on populations. ■ **H**

Periods of drought affect the survival of worm foragers such as badgers, moles and hedgehogs. ■ **M**

What could happen

Variation in how mammals respond to current average and extreme climatic conditions suggests that species will show a diversity of responses to climate change. ■ **M**

Climate changes may affect bat populations through changes in their yearly hibernation cycle, breeding success and food availability. Bat species that are associated with colder climates in northern latitudes could be more severely affected by climate warming, with some local extinctions possible by the end of the century. ■ **L**

Milder winters will potentially result in increasing populations of some mammals. ■ **L**

Insects and other invertebrates

Mossman, Franco & Dolman

Pearce-Higgins

What is happening

A number of invertebrates have colonised the southern UK from Europe in recent years and are expanding their range northwards – especially flying species of Hymenoptera (wasps, bees and ants) and Odonata (dragonflies and damselflies). ■ **H**

Climate warming has resulted in northward range shifts of many southern and common British invertebrates, including dragonflies and damselflies, butterflies, woodlice and millipedes. ■ **H**

Spring and summer life-cycle events are advancing, with earlier flight periods for spring species of dragonfly and damselfly, earlier appearance of some species of hoverfly, and changes in reproductive development of southerly species of limpet. ■ **H**

Increasing summer temperatures have resulted in population increases for many southern generalist butterfly species. There have been declines in northern butterfly species and in populations of some moth species (e.g. the garden tiger moth) in southern England. Increases in aphid populations have been influenced by climate change but also by other pressures such as land-use changes, changes in water quality and increased atmospheric nitrogen deposition. ■ **M**

Garden tiger moth © Mark Parsons

What could happen

Although climate suitability might increase for some species, others that need to shift may not be able to, particularly in fragmented landscapes. ■ **M**

Some invertebrate species may adapt their habitat requirements or evolve to cope with changing conditions. For example, as a result of increases in temperature, the requirements of some warmth-loving species (including some butterflies such as the silver-spotted skipper) for sparse or short vegetation may be reduced as they adapt to taller vegetation providing cooler, shaded microclimates. ■ **M**

Advances in emergence or flight date have the potential to lengthen the season suitable for reproduction; warmer temperatures may result in faster completion of insect life-cycles at northern latitudes. This may lead to additional generations of insects but there is no evidence relating to the viability of these, if access to food and vulnerability to occasional early frost events is taken into account. ■ **L**

Silver-spotted skipper butterfly © Natural England/Michael Hammett

Plants

Carey

Ellis

Evans & Pearce-Higgins

Pateman

Sparks

What is happening

Flowering dates have advanced by 2–13 days over the last 250 years. ■ **H**

In the UK, there are fewer examples for plants than for animals of changes in distributions in the last century that can be confidently attributed to climate change. ■ **H**

Many semi-natural plant communities are relatively resilient to climate change: there are examples of isolated arctic–alpine and montane species that have survived for millennia in climatically marginal situations. ■ **M**

Flowering of most species has advanced because of warmer springs (H), but reduction in winter chill has delayed the flowering of some plant species. ■ **M**

Growth rates of many UK trees are limited by drought. Droughts, in particular the one in 1976, have resulted in the death of trees, with beech and silver birch being particularly vulnerable, as is the non-native sycamore. ■ **M**

Cold microclimates such as on north-facing slopes, provide a buffer for some plant species, including bryophytes and lichens, against macroclimatic change. ■ **M**

There is evidence of some plant species spreading northwards in response to increasing temperatures. There are also indications that climate change may be starting to influence the composition of some plant communities, for example in the Scottish Highlands. ■ **L**

Spring gentian © Natural England/ Neil Pike

What could happen

As the extent of climate change increases, change is likely to start to become apparent in plant communities and species distributions. Montane and arctic–alpine species are threatened by climate change, as more warmth-loving species colonise these habitats. Examples include bryophytes such as *Andreaea nivalis* and *Marsupella arctica*, and to a lesser extent *Racomitrium lanuginosum* and lichen-rich ericaceous heath communities primarily found in Scotland and dependent on late-lying snow-beds. This may compound pressures from other environmental changes such as pollution and heavy grazing. ■ **H**

Warmer winters will benefit many plant species, increasing their abundance and allowing expansion into new areas. However, for some other species, winter warming will offset advances in spring green-up as winter chill requirements are not met for flower or seed development, reducing their reproductive success. ■ **M**

Beech trees © Natural England

High Confidence ■ H
Medium Confidence ■ M
Low Confidence ■ L

The UK's plant communities are classified into 17 broad habitat types and, at a finer level of classification, 65 'priority habitats' were identified as the most important for conservation under the UK Biodiversity Action Plan and subsequent initiatives. Some of the UK's most iconic landscapes and habitats are potentially vulnerable to climate change, including montane, wetland, heathland and some types of woodland habitats.

Montane

Carey

Ellis

What is happening

There is evidence that rising temperatures have contributed to changes in the composition of montane vegetation in the Scottish Highlands, including a decrease in arctic–alpine species. ■ M

What could happen

Mountain top plant communities are composed of species adapted to low temperatures; these species are likely to decline in response to rising temperature, particularly as a result of increasing colonisation and competition from other upland species more typical of lower altitudes. ■ H

Snow-bed communities are vulnerable to reduced snow cover during warmer winters. ■ H

Grasslands and heathlands

Carey

Sparks

What is happening

Following dry summers there is an increase in plants that colonise bare ground, such as the prickly ox-tongue and field thistle. ■ H

Increasing temperatures have promoted earlier spring greening of grasslands and a longer growing season. ■ H

Axe Edge Moor © Natural England/Peter Wakely

What could happen

Lowland heath in southeast England is threatened by reduced precipitation and by increased fire risk, and could be replaced by dry, acid grasslands. ■ M

Upland heathlands are vulnerable to wildfire; fire risk may well increase with warmer conditions and any seasonal decrease in precipitation. This could affect the composition and structure of moorland ecosystems. ■ M

Reduced summer rainfall and increased evaporation and transpiration could change the species composition of plant communities in wet lowland and floodplain meadows. ■ M

Changes in precipitation patterns may alter the composition of wet plant communities, such as purple moor grass and rush pasture. Wetland bryophyte species with a southerly distribution may be particularly vulnerable. ■ M

What is happening

Wetlands

Carey

Ellis

Morrison & Robinson

Pearce-Higgins

Periods of low rainfall have hampered the management of lowland fens. ■ M

Wigeon are one of the wildfowl which occur in their thousands on the flood plain meadows of the Lower Derwent Valley National Nature Reserve © Natural England/Peter Roworth

What could happen

Reduced precipitation in summer months may adversely affect wetland habitats, with lowland fens particularly likely to be under increasing threat in southeast England. ■ M

Drying out of wetland habitats may have major impacts on migratory birds, many of which are dependent on these areas at some point in their life cycle. ■ M

Computer models indicate that a long-term decline in actively growing peatlands would be expected under current climate projections. Eastern and southern areas are more vulnerable than those to the west and north. Blanket bogs are vulnerable to surface drying in summer leading to fires and erosion, resulting in the release of carbon and changes in their vegetation. ■ H

Woodland

Carey

Ellis

Sparks

Leafing has advanced by 2–3 weeks since the 1950s in response to increased temperatures and this may be having a negative impact on woodland flora, particularly spring-flowering species. ■ M

Thorpe Wood bluebell carpet © Natural England/Peter Wakely

Lowland beech and yew woodlands are likely to be affected by summer drought, as are wet woodlands on seasonally inundated soils in southeast England. ■ M

Pests and diseases (both those that are currently present in the UK and those that may be introduced) represent a major threat to woodlands. These threats may be increased by interactions with the direct effects of climate change on tree function. ■ M

By 2080, because of the lack of suitable climatic conditions, Scots pine, characteristic of native pinewoods, could disappear from the UK apart from in northeast Scotland , under some projected climate changes. This may lead to the habitat becoming progressively invaded by deciduous tree species such as birches and oaks. ■ L

Ground flora in deciduous woodlands may change due to earlier leafing of the tree canopy as a result of rising spring temperatures. ■ L

Changes in woodland structure could have an important effect on epiphyte (plants that grow on other plants, particularly trees) communities. ■ L

High Confidence ■ H
Medium Confidence ■ M
Low Confidence ■ L

Fifteen coastal and intertidal habitats have been identified as UK Biodiversity Action Plan priority habitats. Twenty habitats for which the UK has special responsibility are listed under the EU Habitats Directive, including coastal lagoons, grey dunes and dune slacks, estuaries, vegetated shingle banks, machair and vegetated sea cliffs. Coastal habitats in the UK are also of international importance for wintering populations of waders and small losses of habitat could have major negative impacts on their populations. Coastal habitats are treated separately here because of the additional threat that rising sea-levels pose, making them particularly vulnerable to climate change, compounded by other pressures such as land-use change and coastal development.

Coastal and intertidal habitats

Gillingham

Mossman, Grant & Davy

What is happening

Losses of saltmarsh have been substantial (e.g. 50% of saltmarsh was lost along the south coast of England between 1971 and 2001); sea-level rise combined with hard sea defences ('coastal squeeze') is a major contributing factor to this loss. ■ H

Increased air and sea surface temperatures have resulted in changes in the range sizes and distribution of a number of coastal animals. Warmer-water species are shifting northwards (e.g. the molluscs *Osilinus lineatus* and *Gibba umbilicalis*). ■ H

Where southern and northern species with similar niches occur, there has been a relative increase in abundance of the southern species. *Coelopa piipes*, a coastal strandline fly with a southern distribution, has expanded its UK range northwards and become more abundant at the expense of the previously dominant northerly species *C. frigida*. ■ H

Warmer temperatures have resulted in changes in the timings of life-cycle events of a range of species, with the rates of change observed in marine species being greater than those observed in terrestrial and freshwater species. Warmer sea temperatures have advanced the timing of spawning of the intertidal bivalve *Macoma balthica*, resulting in a mismatch in timing between the bivalve and the phytoplankton it feeds on. ■ H

What could happen

Projected rises in sea level will have significant impacts by accelerating the natural erosion of coastal and intertidal habitats, and changing the pace and nature of natural geomorphological processes. Soft cliffs and the vegetation that grows on them will be particularly affected, especially in the south and east of England, where sea-level rise will be the greatest. ■ H

Coastal species and habitats will be subject to further coastal squeeze where coastal defences are maintained or enhanced, or hard infrastructure exists, preventing natural habitats rolling back inland. ■ H

Projected future losses in the extent of saltmarshes and mudflats will have significant impacts on overwintering bird populations and invertebrates. ■ H

Rising sea-levels and coastal squeeze will result in conflict between the need to maintain intertidal and coastal habitats (such as dune systems) by allowing the natural movement of coastlines and through managed realignment and the need to protect valuable inland coastal habitats, such as grazing marsh and saline lagoons. ■ H

Coastal grazing marshes, raised bogs and saline lagoons are all threatened by increases in salinity due to increased inundation of sea water during storm tides and flooding. This will ultimately cause their transformation into saltmarsh or other intertidal habitat. ■ M

Coastal freshwater habitats including grazing marsh and lowland raised bog, which account for 3.5% of the total area of English Sites of SSSIs, are at risk from inundation by sea water. ■ M

Climate projections indicate that the UK is likely to experience an increased number of extreme weather events. Observations, to date, show that events such as flooding and drought can have significant effects on biodiversity. Many (but not all) are localised and will have short-term impacts. However, if in the future the intensity and frequency of extreme events increases, or events are combined (e.g. drought followed by a major flood event or storm surge), the cumulative impact could in some circumstances reach a 'tipping point' where habitats and species distribution or populations are irrevocably changed. The uncertainty associated with projections of the frequency and intensity of extreme events mean that it is not possible to provide a confidence rating other than low for these events individually, but collectively they pose a major risk to biodiversity and ecosystem function.

What do we know now?

Drought and heat waves

Carey

Evans & Pearce-Higgins

Newman & Macdonald

Pearce-Higgins

Spring droughts can reduce the survival of young mammals and birds, and plants.

Some trees are more sensitive to drought than others, including beech, birch and sycamore. Changes in woodland structure and composition were reported following the 1976 drought.

Most, but not all, butterflies are more abundant in warm, dry summers, although there may be negative impacts the following year.

Upland birds that feed on invertebrates such as crane fly larvae, which are sensitive to drought conditions, have declined more than species with other food sources.

An increased number of extensive moorland fires, affecting areas of peat, was associated with dry springs and summers between 2003 and 2006.

During summer drought in the mid-1990s, lowland or southerly distributed ground beetles tended to increase while northerly and upland species tended to decline.

Heat stress can affect bird populations. For example, great skuas breeding on Shetland spend more time bathing in response to heat stress and less time at their nests, so more chicks are killed by predators.

What might this mean in the future?

An extreme drought could lead to widespread death of sensitive tree species and a change in the character of some British woodlands.

Reduced soil moisture could adversely influence breeding success or survival rates of ground-feeding bird species, particularly those which feed on invertebrates whose abundance is influenced by soil moisture or those that require moist, easily penetrable soils to get food.

Spring drought could reduce the breeding success of mammals such as badgers and moles, which need earthworm prey at a crucial time of juvenile development.

Reduced water flow in rivers would adversely affect mammals such as water voles, otters and mink.

Plants flowering at the end of summer may be more vulnerable to the impacts of drought and heat stress, as they will benefit less from projected increases in winter rainfall than species that flower in the early part of the year.

Otter © Natural England/Michael Hammett

Heavy rain events and flooding

Evans & Pearce-Higgins

Newman & Macdonald

What do we know now?

Flooding has a negative impact on almost all mammals, except bats, and on ground-nesting birds with free-ranging chicks. When large areas of land are inundated, nests and burrows are flooded causing the young to drown or die from chilling.

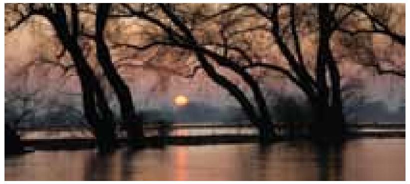
High rainfall during the pre-breeding season can also reduce parental foraging opportunities, thus reducing body condition and subsequent reproductive success.

Heavy rainfall in the breeding season can affect reproductive success. In west Scotland, golden eagle populations declined by 25% during a period when there was a significant increase in May rainfall.

What might this mean in the future?

Extreme heavy rain events may reduce the breeding success of birds and mammals, including the harvest mouse.

Localised flooding may lead to loss or change of habitats, particularly where there is saline intrusion.



Winter floods in the Lower Derwent Valley National Nature Reserve © Natural England/Peter Roworth

Frost and snow events

Ellis

Evans & Pearce- Higgins

Mossman, Franco & Dolman

Between 1990/91 and 2007/08 there was an observed decline in snow-patch extent in Scotland, resulting in snow-bed bryophyte vegetation shifting towards upland grassland with an increasing abundance of highland rush and a reduction in snow-bed liverworts.

Late lying snow-bed on the East Drumochter Hills © Lorne Gill/SNH

Snow-beds are expected to be among the most vulnerable habitats to climate change, with snowfall predicted to decline in montane areas by 65–80% by 2080.

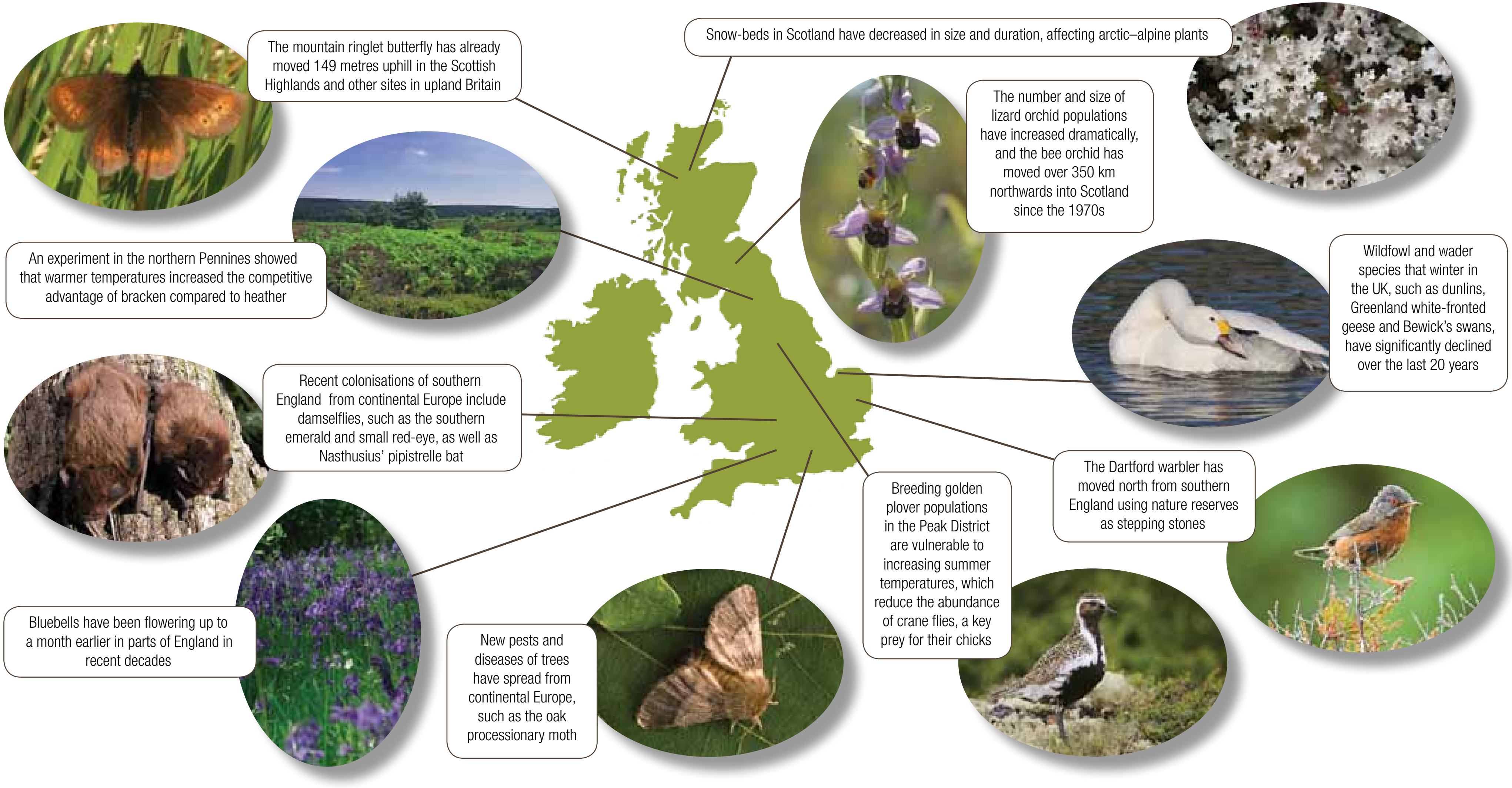
If spring vegetation starts to emerge earlier driven by climate change, leaf buds and blossom could be at greater risk of frost damage if they advance more quickly than that of the last frost dates.

Some species of insects have cold-tolerance mechanisms that are triggered by exposure to cold conditions; higher temperatures in early winter may therefore increase mortality if the winter becomes more severe later.

Woodwalton Fen National Nature Reserve © Natural England/Peter Wakely

Regional variations in observed changes to UK biodiversity that may be climate change related

This map provides ten local examples to illustrate the regional contrasts in the impact of climate change. In the past, land-use change and pollution have had a more significant impact than climate change on habitat loss, degradation and fragmentation, and have been a key factor in changes in species distribution and community composition. Climate change will have a greater effect in the future, when changes in regional variation are likely to be more marked.



Implications for people

High Confidence ■ H
Medium Confidence ■ M
Low Confidence ■ L

Biodiversity is important to people, and the value placed by society on the natural environment and its wildlife is demonstrated by the significant number of protected areas in the UK. These include SSSIs, Special Areas of Conservation and National Nature Reserves, as well as National Parks and other landscape designations. Biodiversity is not just a key component of our landscape and natural heritage but also provides us with critical services such as pollination, carbon sequestration, hazard control and genetic diversity. This section provides some examples of how climate change effects people's use and management of the natural environment. (Food and timber services will be covered in the Agriculture and Forestry Report Cards.)

	What is happening	What could happen
Hazard control Doswald & Epple	Recent heavy rainfall events have resulted in a number of landslips. ■ H	Natural flood and mudslide protection offered by vegetation will be tested due to the increases in frequency and intensity of extreme events, especially in areas where ecosystems are already degraded. ■ M
Pollination Doswald & Epple	Climate-driven mismatches in phenology of plants and their pollinators have been observed, although so far, there are no observations of climate-driven mismatches between these species due to changes in distribution. ■ M	The complete disruption of pollination services in the UK as a result of climate change is unlikely. Plant pollinator networks are complex, involve multiple species interactions between generalists and specialists, and have been shown to be resilient to disruptions. There may however be specific incidences of disruption to pollination. ■ L
Carbon sequestration Doswald & Epple	Periods of drought may have resulted in the loss of soil carbon from UK organic soils over the last 20 years as a result of higher respiration rates. ■ L	Climate change could alter the balance between carbon uptake and loss; the net effect would be different in different habitats and circumstances. Extreme events such as persistent drought or fires present a direct threat to carbon stores, particularly in peatlands. ■ L
Protected areas Gillingham	Many invertebrate species in the UK have disproportionately colonised protected areas in spreading northward, facilitating their range expansion. ■ H Up to now other land-use pressures and pollution, rather than climate change, have been the main causes of species decline in individual protected areas. ■ M	The vulnerability of protected areas to climate change will vary depending on their size, their location and the type of feature for which they are designated, but climate change will pose an increasingly important risk to some (e.g. coastal, wetland and montane sites). ■ H The management of protected areas for nature conservation means that they will continue to perform an important role in protecting diversity even if the species for which they were originally designated move to new areas. ■ M Representation of habitats and species typical of northern latitudes in protected areas will decrease, while representation of those more typical of southern latitudes will increase. ■ M

Adapting to climate change

This Report Card shows an emerging picture of changes taking place in the UK's biodiversity and ecosystems that are consistent with the impacts of climate change. It also shows that much more change is on the way, even on the most conservative interpretation of the climate change projections now available. The need to adapt conservation and land management to minimise the risks and take advantage of opportunities that climate change brings is now widely recognised.

The starting point for effective adaptation is to promote the natural resilience of ecosystems. This includes increasing the number, size and condition of protected sites and improving the linkages between them. It also includes identifying and protecting particular areas or sites where species may be able to survive – for example cooler, north-facing slopes. In other cases active management may allow species to be maintained, for example by changing grazing regimes to favour threatened species. Good management of ecosystem processes, such as restoring the natural development of coasts and rivers, can also increase resilience. However, some change is inevitable, and it is important to accommodate change in conservation planning and to be proactive in managing for the best of the possible outcomes; for example, it may be better to accept and facilitate the spread of a threatened species to new locations rather than to attempt to maintain it *in situ*.

It is important to recognise that, while we have a good evidence base to identify and respond to the impacts of climate change, there remain gaps in our knowledge. Ongoing research and monitoring remain important to understanding the emerging nature of climate change impacts.

Further advice on climate change adaptation for biodiversity

Adaptation is the subject of active development and the following resources provide a good introduction and further guidance:

- National Adaptation Programme (NAP).
- Climate Ready.
- Northern Ireland Adaptation Programme.
- Adaptation Scotland.
- England Biodiversity Strategy Climate Change Adaptation.
- Conserving Biodiversity in a Changing Climate: Guidance on Building Capacity to Adapt.
- Climatic Change and the Conservation of European Biodiversity: Towards Adaptation Strategies.
- Natural England Climate Change Resources.

Technical papers and contributors

This Report Card is a summary of 15 technical papers that were commissioned from leading experts. Each technical paper covered a separate topic and was peer-reviewed by experts. The technical papers, which include supporting evidence and sections on knowledge gaps and confidence assessments, can be accessed using the links below.

Published papers 2013

1. Oliver T, Roy D, Interactions between climate change and land-use impacts: addressing attribution problems
2. Newman C, Macdonald D Implications of climate change for UK mammals
3. Mossman H, Franco A, Dolman P Implications of climate change for UK invertebrates (excluding moths and butterflies)
4. Gillingham P, Implications of climate change for SSSIs and other protected areas
5. Carey P, Impacts of climate change on terrestrial habitats and vegetation communities of the UK in the 21st century
6. Pateman R, The effects of climate change on the distribution of species in the UK
7. Pearce-Higgins J, Evidence of climate change impacts on populations using long-term datasets
8. Ellis E, Implications of climate change for UK bryophytes and lichens
9. Hulme P, Non-native species
10. Mossman H, Grant A, Davy A, Implications of climate change for coastal and intertidal habitats in the UK
11. Morrison C, Robertson R Implications of climate change on migration
12. Sparks T, The implications of climate change for phenology in the UK
13. Doswald N, Epple C Overview of climate change implications for ecosystem services
14. Evans K, Pearce-Higgins J Mechanisms driving UK biodiversity responses to climate change: assessment and indicators
15. Neaves L, Whitlock R, Piertney S, Burke T, Butlin R and Hollingsworth P, Implications of climate change for genetic diversity and evolvability in the UK

Dunford R and Berry P Climate change modelling of English amphibians and reptiles: Report to Amphibian and Reptile Conservation Trust (ARC-Trust)

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Report Card Working Group

The delivery of this Report Card was overseen by a working group, who also undertook peer-reviews of the technical reports. The members are: Mike Acreman Centre for Ecology and Hydrology (CEH), Pam Berry (University of Oxford), Richard Bradbury (RSPB), Iain Brown (James Hutton Institute/ ClimateXChange), Mary Christie (Scottish Natural Heritage), Humphrey Crick (Natural England), Brian Huntley (Durham University), Chris Thomas (University of York) and Clive Walmsley (Natural Resources Wales). Mike Morecroft and Lydia Speakman (Natural England) led the project as Working Group Chair and Project Manager respectively.

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