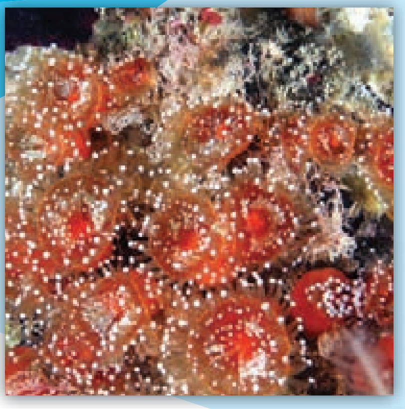
Biodiversity and Climate Change

– a summary of impacts in the UK



INTER-AGENCY CLIMATE CHANGE FORUM

Cyngor Cefn Gwlad Cymru
Countryside Council for Wales

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JNCC
Joint Nature Conservation Committee

Inter-Agency Climate Change Forum

The Inter-agency Climate Change Forum (IACCF) of the UK statutory nature conservation agencies comprises the Countryside Council for Wales, Natural England, Northern Ireland Environment Agency, Joint Nature Conservation Committee and Scottish Natural Heritage. The IACCF aims to provide strategic direction for UK and international work on climate change and nature conservation undertaken by the JNCC and the country agencies.

Countryside Council for Wales

The Countryside Council for Wales champions the environment and landscapes of Wales and its coastal waters as sources of natural and cultural riches, as a foundation for economic and social activity, and as a place for leisure and learning opportunities. It aims to make the environment a valued part of everyone's life in Wales.

Natural England

Natural England is here to conserve and enhance the natural environment, for its intrinsic value, the wellbeing and enjoyment of people and the economic prosperity that it brings.

Scottish Natural Heritage

Scottish Natural Heritage (SNH) is a government body established to secure conservation and enhancement of Scotland's unique and valued natural heritage – the wildlife, habitats and landscapes that have evolved in Scotland through long partnership between people and nature. SNH advises on policies and promotes projects that aim to improve the natural heritage and support its sustainable use. Its aim is to help people to enjoy Scotland's natural heritage responsibly, understand it more fully and use it wisely so it can be sustained for future generations.

Northern Ireland Environment Agency

The Northern Ireland Environment Agency takes the lead in advising on, and in implementing, the Government's environmental policy and strategy in Northern Ireland. The Agency carries out a range of activities, which promote the Government's key themes of sustainable development, biodiversity and climate change. Our overall aims are to protect and conserve Northern Ireland's natural heritage and built environment, to control pollution and to promote the wider appreciation of the environment and best environmental practices.

Joint Nature Conservation Committee

The Joint Nature Conservation Committee (JNCC) is the statutory adviser to Government on UK and international nature conservation. Its work contributes to maintaining and enriching biological diversity, conserving geological features and sustaining natural systems.

JNCC delivers the UK and international responsibilities of the four country nature conservation agencies - Council for Nature Conservation and the Countryside, the Countryside Council for Wales, Natural England and Scottish Natural Heritage.

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Biodiversity and Climate Change in the UK

Introduction

Climate change is a reality. In the UK, temperatures on land have risen by as much as 1°C since 1980 and coastal sea surface temperatures by roughly 0.7°C over a similar period. Sea level around the UK has risen by 10cm since 1990. The UK has experienced eight of the ten warmest years on record since 1990 (Met Office 2009). These trends are projected to continue (UKCP09); at what rate and by how much primarily depends on the volume of greenhouse gases released into the atmosphere around the globe (IPCC 2007).

Climate change affects biodiversity in many ways (Hopkins *et al*. 2007, Walmsley *et al*. 2007). Impacts on species include changes in distribution and abundance, the timing of seasonal events and habitat use and, as a consequence there are likely to be changes in the composition of plant and animal communities. Habitats and ecosystems are also likely to change character by, for example, showing altered water regimes, increased rates of decomposition in bogs and higher growth rates in forests.

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.

Biodiversity also has an important role in climate change adaptation and mitigation. For example, soils, forests and oceans hold vast stores of carbon. The way managed habitats are used will affect how much of that carbon is released in gaseous form into the atmosphere. How we address climate change and maintain healthy ecosystems so that they provide ecosystem goods and services essential for human well-being is now a key challenge for society. Understanding the on-going impacts of climate change on ecosystems is an essential prerequisite to addressing this challenge. This booklet collates recent evidence about the known interactions between climate change and biodiversity.

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Black Wood of Rannoch
© Michael B Usher

Terrestrial and Freshwater Ecosystems

Background

Soil erosion © Barbara Jones/Countryside Council for Wales

The UK has a broadly oceanic climate, with warm summers, mild winters and relatively high rainfall. There is, though, significant regional variation in climate, with marked gradients related to latitude, longitude and altitude. Regional climate has a major influence on biodiversity. So, for example, arctic-alpine species (such as ptarmigan, *Lagopus mutus*) are found at high altitudes in the Scottish Highlands, whereas Mediterranean species (such as land quillwort, *Isoetes histrix*) thrive in south-west England and Steppe species (such as the stone curlew, *Burhinus oedicnemus*) are found in eastern England.

A considerable amount of carbon is stored in the terrestrial environment. Forests and woodlands, which cover 12% of the total UK land area (Broadmeadow 2004), hold the majority of carbon stored in above ground vegetation, estimated to be around 130 megatonnes (Mt) (Broadmeadow & Ray 2005). Organic soils are estimated to lock up around 5,100 Mt (Dawson & Smith 2007) of carbon, most of which is held in the form of peat. Peatlands cover 14% of the total UK land area, mainly in the uplands (Dawson & Smith 2007). Typically, undamaged peatlands accumulate about 0.25 tonnes of carbon per hectare per year (Nayak *et al*. 2008).

Ptarmigan © Stuart Elsom 2010/www.stuartelsom.co.uk

The way habitats are managed can affect greenhouse gas emissions. Habitat management therefore has an important role in climate change mitigation. Deforestation can release large volumes of carbon depending on how the wood is used. Growing trees sequester carbon which remains stored even when the tree stops growing until it decays or is burnt (Brainard *et al*. 2003). Damage to peatlands caused by drainage, over-grazing or burning can lead to the loss of large amounts of carbon as organic matter. Newly drained peatlands can release 2-4 tonnes of carbon per hectare per year for the first 2-4 years after ploughing (Holden 2005). However, peatlands can be restored through sympathetic management leading to sequestration of atmospheric carbon (Moors for the Future Partnership 2007).

Climate change in terrestrial and freshwater environments

Meteorological records show that between 1961 and 2006, annual average temperatures in the UK have typically risen between 1.0 and 1.7°C, with the largest increases in south and east England and the smallest in Scotland. Over the same period, there are some indications, at least in parts of the UK, of an increase in average winter precipitation, a decrease in average summer precipitation, and increased storminess (Jenkins *et al*. 2009).

An analysis of the best available data from rivers in England and Wales shows an upward trend in mean annual river water temperatures over the last 35 years, with greater rises in the lower reaches of rivers, particularly in southern England (Hammond & Pryce 2007). In Scotland there is evidence that small streams have shown an increase in winter temperature maxima (Langan 2001). Overall evidence suggests that headwaters are warming in winter and spring, whereas the lower reaches are warming in summer (Hammond & Pryce 2007).

Climate change projections for the UK indicate that average temperatures and winter precipitation will both increase, and summer precipitation will decrease, especially in the south (Murphy *et al*. 2009). In freshwater systems the most potentially significant effect of this will be an increased risk of deoxygenation associated with hotter summers and lower rainfall (Everard 1996). Middle and lower river sections and standing waters are thought to be most at risk (Conlan *et al*. 2007a). Greater fluctuations in climate are also likely to result in altered water levels that will change local hydrological conditions, impacting on habitat suitability and connectivity between habitats (Conlan *et al*. 2007a).

Nitrate leaching from upland catchments to surface and groundwaters is more likely under a changing climate with increased runoff events and higher temperatures having implications for water quality (Wessel *et al*. 2004).

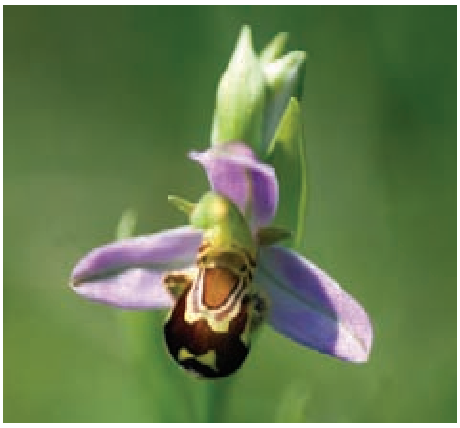
Impacts of climate change on terrestrial and freshwater biodiversity

Assessing the impacts of climate change on terrestrial and freshwater biodiversity is not easy, as plants and animals are influenced by other pressures, such as atmospheric pollution and land use, and different factors can work in combination to bring about change. However, changes are beginning to be observed across a range of species and habitats in the UK that have been related to climate change.

Climate change has significant impacts on hydrology which will ultimately result in changes to habitat composition and distribution. In the short-term, changing rainfall patterns with drier summers causing lowering of the water table and drying out of upland soils, combined with more frequent extreme rain events, are increasing soil erosion. A recent study on organic soils has indicated climate change and associated hydrology changes, as the most significant causes of erosion of organic soils and peat, along with over-grazing pressure. The study indicated that at the national scale, erosion has impacted on around 14% of blanket bog in Northern Ireland and some 35% of blanket bog in Scotland (Lilly *et al*. 2009).

Freshwater ecosystems are very vulnerable to climate change because the metabolic rates of organisms and overall rate of productivity of ecosystems are

River Eye © Peter Wakely/Natural England



Bee orchid © Christopher Moncrieff/Dreamstime

Cladonia coccifera © Lorne Gill/Scottish Natural Heritage

directly regulated by temperature (Clarke 2009). The effects of climate change appear to be variable between river types, with species rich, unpolluted (non-acidified) shallower rivers and their biodiversity most at risk (Conlan 2007b). It is particularly important to recognise that aquatic ecosystems will be affected not only by climate change directly, and by the physicochemical changes that may follow, but also by any catchment scale land management responses such as building hard flood defences.

One of the primary observed impacts of climate change upon species within the UK has been a northward movement of many warmth-loving species, and some retreat of northerly distributed species. There have also been concomitant changes in abundance observed in some cases. Some key examples are outlined below.

- Analysis of distribution data for a range of vertebrate (e.g. amphibians, freshwater fish and mammals) and invertebrate groups (e.g. damselflies, spiders and millipedes) has shown range extension northward and uphill in Britain over approximately 25 years in response to the changing climate. For example, out of a total of 329 species with range limits in Britain analysed across 16 taxa, 275 species shifted northwards at their range margin and 52 shifted south. The same analysis showed that 227 species shifted to higher altitude and 102 species shifted to lower altitude. The average northwards shift across all species was 31-60 km and a mean increase in altitude of 25m (Hickling *et al*. 2006).

- Some plant species are increasing in range in the UK, in ways consistent with climate change, particularly short-lived pioneer species (such as prickly lettuce, *Lactuca serriola* and annual mercury, *Mercurialis annua*) associated with urban habitats and the transport network. Such species tend to be those that are readily dispersed and respond rapidly to conditions that favour them, e.g. where land has been disturbed (Braithwaite *et al*. 2006). For most species there is not yet enough evidence to link range change with climate change; it is hard to distinguish between the different factors affecting distribution and attribute them to any one cause. It is suggested that climate change has been responsible for southern species associated with neutral and calcareous grasslands (such as bee orchid, *Ophrys apifera* and field madder, *Sherardia arvensis*) faring better than northern ones (Braithwaite *et al*. 2006).

- Long-term monitoring of mountain vegetation is showing a general decline in the cover and frequency of some specialist arctic-alpine lichen and plant species in mountain-top environments, including *Alectoria nigricans*, *Cetraria aculeata, Cetraria islandica, Cladonia arbuscula, Cladonia coccifera, Cladonia uncialis, Ochrolechia frigida* (all lichens), trailing azalea, *Loiseleuria procumbens*, dwarf willow, *Salix herbacea*, stiff sedge, *Carex bigelowii* and starry saxifrage, *Saxifraga stellaris*. However, some species appear to be increasing in cover and frequency, but, as in the case of heather, *Calluna vulgaris*, these are species which are predominantly of lower altitude and are adapted to less severe environmental conditions (Britton *et al*. 2009).

- A review of data on bird distribution has found that after controlling for overall population expansions and retractions, the northern margins of many species have moved further north by an average of 18.9 km between 1980 and 1999. This shift corresponded with a period of climatic warming which might be one of the factors behind these trends (Thomas & Lennon 1999).

- Summer warming may have driven recent large declines in ring ouzel, *Turdus torquatus* populations. Although there is little evidence of significant differences in productivity between stable and declining populations (Burfield 2002), analyses of long-term population data from southern Scotland highlight negative effects of summer warming, in addition to climate effects from the Moroccan wintering grounds. The observed rate of summer warming is sufficient to account for the observed decline, which may be mediated by reduced food abundance at the end of the breeding season affecting post-fledgling and over-winter survival rates (Beale *et al*. 2006). Ongoing research is currently examining in more detail the mechanisms for this decline.

- Many species of butterflies have shown changes in distribution and abundance in recent decades. Since the 1970s many mobile species of the wider countryside (such as the comma, *Polygonia c-album* and Essex skipper, *Thymelicus lineola*) have spread northwards (consistent with increasing temperatures). However, climate change also appears to have led to the loss of some populations of northern species, including mountain ringlet, *Erebia epiphron* (Franco *et al*. 2006). In contrast, species that are highly specialised in terms of habitat and/or food plant requirements, such as marsh fritillary, *Euphydryas aurinia* have mostly declined as negative responses to habitat loss appear to have outweighed positive responses to climate warming. The dual forces of habitat modification and climate change are likely to cause specialists to decline, leaving biological communities with reduced numbers of species and dominated by mobile and widespread habitat generalists (Fox *et al*. 2007).

- Since 1980, 34 of 37 British species of damselfly and dragonfly have expanded their range northwards by an average of 74km (Hickling *et al*. 2005). One species, the small red-eyed damselfly, *Erythromma viridulum* has established itself in the UK spreading throughout South East England and as far north as the Humber (Hickling *et al*. 2005). Milder winter temperatures are thought to be the most likely factor driving this change.

- Carabid species (ground beetles) have shown significant trends over time with numbers increasing in the south-east but decreasing elsewhere. Analysis suggests the trends are associated with rising air temperature. The uplands have shown more pronounced temperature rise and more northerly populations might be more vulnerable to impacts of such warming (Morecroft *et al*. 2009).

Comma butterfly, Derbyshire © Helen Baker

Elm bud © Michael B Usher

There is increasing evidence for changes in the timing of many natural events which are closely correlated with changing temperature. For example, many plants are coming into leaf and flowering earlier in the year, migratory birds are arriving earlier in the UK and leaving later, butterflies are appearing earlier in the spring, and many birds are laying eggs earlier in the year. These phenological changes may mean that the life cycles of some species are no longer synchronised with those of species on which they depend (e.g. food plants and prey species) with potential changes in competitive advantage arising between species (Morecroft *et al*. 2009, Sparks *et al*. 2006).

Small red-eyed damselfly © Damian Pinguey 2007

Blackthorn © Ellie Crane

Golden plover © Markus Horsch

There is a wealth of information on the timing of these events including more than 3 million records, some dating back to the 18th Century gathered by the UK Phenology Network. Other large, long-term records exist for plankton , birds, butterflies, aphids and moths. Recent analysis of over 25,000 phenological trends for 726 species, including plankton, plants, insects, amphibians, fish, birds and mammals show that more than 80% of trends between 1976 and 2005 indicate earlier seasonal events (Thackeray *et al*. 2010). On average the timing of reproduction and population growth has advanced by more than 11 days, but change has accelerated in recent decades. There are large differences in response between species. Of particular ecological importance is the slower overall change in timing of events among predators compared with prey species. Some other studies that have identified phenological responses are outlined below.

- Recent trends towards warmer spring weather have advanced laying dates for a range of upland bird species (Moss *et al*. 2005). For example, golden plover, *Pluvialis apricaria* breeding and the emergence of their cranefly prey have roughly advanced at similar rates to temperature increase. However, recent analysis suggests that late summer (August) warming has a strong negative impact on the magnitude of cranefly emergence in the following year. This effect is strong enough to cause detectable fluctuations in a golden plover population, with declines occurring two years after a hot summer, mediated through poor chick survival in the intervening year, and therefore low levels of subsequent recruitment (Pearce-Higgins *et al*. 2009). As craneflies are a key food source for a wide range of upland birds, these results have wide implications.

- In Northern Ireland there is evidence that climate change is affecting survival of Atlantic salmon, *Salmo salar*. One of the key changes in the life cycle of the salmon is when they undergo physiological changes in the spring of their 2nd to 4th year to become smolt which then migrate from freshwater habitats to the sea. Data from the River Bush show that in 2007 this change occurred two weeks earlier than it did in 1997. The earlier date of smolting is strongly correlated with a substantial decline in marine survival rates. Low survival rates of early smolts might arise because earlier migration means the fish experience a greater than usual difference between sea and river temperature (Sier & Scott 2009).

- The Environmental Change Network's monitoring of the common frog, *Rana temporaria* has shown phenological changes associated with climate change. Frog spawning dates can be radically different between different parts of the UK (e.g. Cornwall and Scotland) but annual variation in spawning dates at a particular location tends to be low. Analysis has shown key events in frog reproductive cycles (congregation, spawning and hatching) are now occurring earlier and take place over a longer period. Observed trends appear to be linked to rising mean temperatures (Sier & Scott 2009). Assessment of this data with monitoring of other British amphibian species shows all are breeding earlier in response to rising temperatures (Beebee 1995).

Common frog © Katharina Wittfield/Dreamstime

Dollaghan trout © Northern Ireland Environment Agency

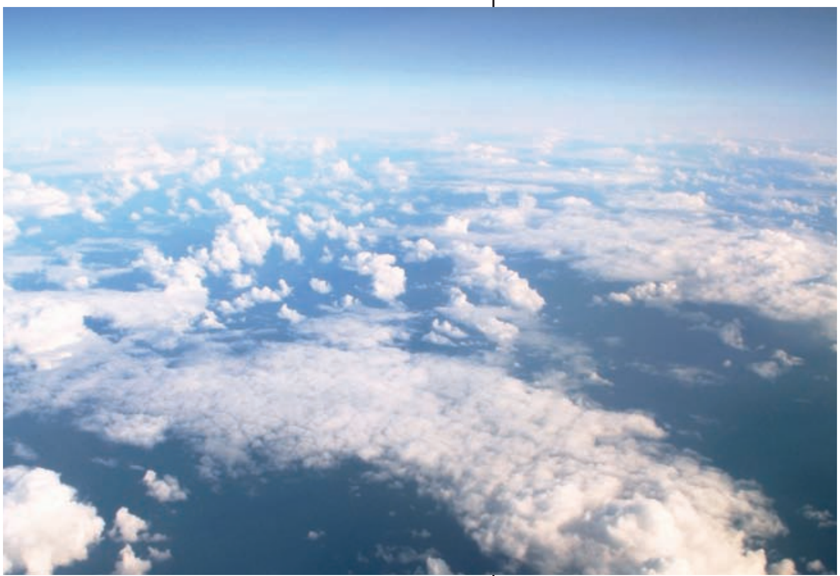
While most impacts have been recorded in relation to individual species, there is already evidence that shifts in community composition are occurring. For example, long-term monitoring of stream macroinvertebrates at Llyn Brianne between 1981-2005 has shown that winter temperature changes linked to both global climate change and the North Atlantic Oscillation (NAO) are responsible for significant changes in communities (Durance & Ormerod, 2006). Over the 24 years of this study stream temperatures adjusted for NAO rose by 1.4-1.7°C. In circumneutral moorland streams there were 'core' species present over a wide temperature range and others characteristic of the cooler or warmer years respectively.

Marine and Coastal Ecosystems

Background

The UK is an island nation, and the total area of its marine waters is 867,000 square kilometres: over three times its land area. The UK's seas support a rich fauna and flora, with a much greater taxonomic diversity than on land.

Oceans are a major driver of the Earth's climate, operating over time periods of decades to centuries. Ocean climate is largely defined by its temperature, salinity, ocean circulation patterns and the exchange of heat, water and gases (including carbon dioxide) with the atmosphere. The UK's seas range in climate from the warm temperate waters of the south-west approaches, to deep sub-arctic waters between the Faroe Islands and Norway.



Atlantic clouds © Adriano Castelli/Dreamstime

Climate change in the marine environment

Marine air and sea surface temperatures (SST) have been rising at a similar rate to land air temperature, but with strong regional variations.

Average sea surface temperatures around the UK coastline increased by 0.7°C over the past three decades (Met Office 2009), while sea surface temperatures at the continental shelf edge have increased by between 0.12°C and 0.29°C over the past century (Defra 2005). Since the 1980s, marine air and sea surface temperatures in the UK have been rising at a rate of 0.2 - 0.6°C per decade with stronger warming in the south-east than in the north (MCCIP 2008). Surface waters to the north and west of the UK have become relatively more saline since the 1970s. Deep waters of the North Atlantic have freshened over the past 40 years (MCCIP 2008).

Global sea level rise is largely a result of thermal expansion of the world's oceans and ice-melt from glaciers and ice sheets, both as a result of climate change. Recent research figures suggest global rates of sea-level rise of 3 mm/year between 1993 and 2003 – more rapid than the average rate over the preceding 40 years (1.8 mm/year from 1961-2003) (IPCC 2007). Sea-level around the UK rose by about 1mm/year during the 20th Century, corrected for land movement. The rates for the 1990s and 2000s have been higher than this. Sea-level changes around the UK show considerable regional variation due to land movement after the last glaciation, with greater rises in the south-east compared to elsewhere (Defra 2005).

The world's oceans absorb around 25% of atmospheric carbon dioxide produced by human activity. This has caused acidification of marine waters as carbon dioxide uptake has led to a 0.1 unit reduction in the pH of surface sea water that is equivalent to a 30% increase in the concentration of hydrogen ions. If global emissions of carbon dioxide continue to rise on current trends then the average pH of the oceans could fall by 0.5 units (equivalent to a three-fold increase in hydrogen ions) by 2100. The pH of the oceans is probably lower than for hundreds of millennia and the rate of change is 100 times greater than at any time over this period (The Royal Society 2005, Ocean Acidification Reference User Group 2009).

Impacts of climate change on marine biodiversity

Rising sea temperatures and acidity appear to be associated with various changes in biodiversity in UK marine and coastal ecosystems. Climate driven changes to salinity, wind, waves and currents are also having an impact (MCCIP 2008, Turley *et al*. 2009).

- In the north-east Atlantic, both warm-water and cold-water plankton have moved northwards by approximately 1000 km (MCCIP 2008). Such changes could have important consequences for other marine wildlife, especially fish larvae and subsequently fisheries stocks (Edwards *et al*. 2008), including cod, *Gadus morhua* (Beaugrand *et al*. 2003).

- In the North Atlantic large changes in the ratio of the cold water copepod *Calanus finmarchicus* and the warm water species *Calanus helgolandicus* have been observed. In addition to changes in the relative abundance of these plankton, the overall *Calanus* biomass is declining: between the 1960s and 1990s, there has been an overall decline in biomass of approximately 70%, which has important consequences for other parts of the food chain, especially fish larvae and consequently fisheries stocks (Edwards *et al*. 2008).

Calanus finmarchicus © Daniel Mayor 2007, Oceanlab ®

- Data analysis strongly suggests that climate-driven changes in the food chain have had acute negative impacts on breeding seabirds on Britain's North Sea coast. Poor sand-eel, *Ammodytidae* productivity is associated with warmer sea-surface temperatures (Arnott & Ruxton 2002). Low breeding success of kittiwakes, *Rissa tridactyla* and of other species such as common guillemot, *Uria aalge* that feed on sand-eels, have occurred with increasing frequency in recent years (Frederiksen *et al*. 2004 & Frederiksen *et al*. 2007), which is thought to be linked to the relationship between temperature and sand-eel productivity.

Triggerfish © Peter Leahy/Dreamstime

- Warm-water fish, algae and invertebrates have increased in abundance in UK seas and have extended their ranges around northern Scotland and eastwards through the English Channel. For example, warm-water species such as tuna, *Scombridae*, stingrays, *Dasyatidae* and triggerfish *Balistes sp*. have increased in the waters of southern Britain (MCCIP 2008). Conversely, there is evidence for a decrease in abundance in some cold-water species, such as the acorn barnacle, *Balanus perforatus*, dabberlocks alga, *Alaria esculenta* and the zooplankton species *Calanus finmarchicus*.

- Since the mid-1980s, wintering populations of several species of wader occurring in internationally important

Oystercatchers © Joe Gough/Dreamstime

numbers in the UK, including curlew, *Numenius arquata* oystercatcher, *Haematopus ostralegus* dunlin, *Calidris alpina* and ringed plover, *Charadrius hiaticula* have over-wintered on eastern estuaries in response to increasing mean winter temperature (Austin & Rehfisch 2005). Climate change projections indicate that populations of some wader species may decline considerably in the future and may lead to a situation where Britain no longer holds internationally important populations of species such as ringed plover, *Charadrius hiaticula*, sanderling *Calidris alba*, purple sandpiper, *Calidris maritima* and ruddy turnstone, *Arenaria interpres* (Rehfisch *et al*. 2004). Numbers of some wader species on some Special Protection Areas (SPAs) in the UK are already dropping below the thresholds for site selection contained in the SPA selection guidelines, such as is the case for dunlin on the Severn SPA (Maclean *et al*. 2008).

- As in terrestrial ecosystems, climate change may be exacerbating the spread of some invasive non-native species (e.g. Chinese mitten crab, *Eriocheir sinensis* and japweed, *Sargassum muticum*) in UK waters (MCCIP 2008).

- With rising sea levels and increased coastal erosion intertidal areas, rich in invertebrate sediment communities, are being squeezed with consequences for over-wintering wildfowl and waders and their feeding (Kendall *et al*. 2004).

Duddon Estuary sand dunes © Paul Glendell/Natural England

Rising sea levels and increased storminess are affecting coastal habitats such as saltmarsh, sand dunes, shingle and cliffs . This can alter the distribution of sediment and so potentially affect natural habitat processes and their ability to adapt to climate change (MCCIP 2008). In some cases, climate change is contributing to habitat loss through a process known as ‘coastal squeeze’, as coastal habitats are unable to move inland in response to rising sea levels because of fixed man-made structures such as seawalls.

Chinese mitten crab © Christian Fischer

Conclusion

This brief synopsis presents evidence of a wide range of observed climate change impacts on UK biodiversity, and the potential for further climatic changes in future. The potential scale of climatic change within the UKCP09 projections (Murphy *et al*. 2009) suggests that future impacts are likely to be far greater than those seen so far. This makes the continued monitoring of climate change impacts through initiatives, such as the Environmental Change Network, UK Phenology Network and Continuous Plankton Recorder Survey, that have contributed to this synopsis, all the more important. In addition, further systematic analysis and communication of the impacts of climate change through projects such as BICCO-Net that utilise existing biodiversity data should be a priority. Understanding the extent and nature of impacts on biodiversity is an important prerequisite to developing a truly adaptive approach to nature conservation under a changing climate.

In compiling the evidence of climate change impacts, important ecological principles emerge for conserving biodiversity in a changing climate. Firstly, diverse biological communities are more likely to adapt to climate change and climate variability than impoverished ones (Balvanera *et al*. 2006, The Royal Society 2008, Secretariat of the Convention on Biological Diversity 2009). Secondly, studies looking at the long-term persistence of species have shown that where there is high genetic diversity the ability to remain in a given area is significantly enhanced (Campbell *et al*. 2008). How these processes work is still poorly understood as an ecosystem's ability to withstand disturbance and either resist or return to its former state may also depend on other factors. Understanding the complex interplay between climate change impacts and the way the natural environment responds to such changes is now essential not only for nature conservation, but also the continued delivery of ecosystem services, which are important for communities and livelihoods.

Flower meadow © Tt/Dreamstime

Key Sources of further information

BICCO-Net - Biodiversity Impacts of Climate Change Observation Network
www.bicco-net.org

BRANCH - Biodiversity Requires Adaptation in North West Europe under a CHanging climate
www.branchproject.org

Countryside Council for Wales
www.ccw.gov.uk

Joint Nature Conservation Committee
www.jncc.gov.uk

MCCIP - Marine Climate Change Impacts Partnership
www.mccip.org.uk

The Met Office
www.metoffice.gov.uk/climatechange

MONARCH - Modelling Natural Resource Responses to Climate Change
www.ukcip.org.uk

Natural England
www.naturalengland.org.uk

Northern Ireland Environment Agency
www.ni-environment.gov.uk

Scottish Natural Heritage
www.snh.gov.uk

UKCIP - UK Climate Impacts Partnership
www.ukcip.org.uk

UK Phenology Network
www.naturescalendar.org.uk

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Biodiversity and Climate Change – a summary of impacts in the UK

Climate change is a reality. In the UK, temperatures on land have risen by as much as 1°C since 1980 and coastal sea surface temperatures by roughly 0.7°C over a similar period. Sea level around the UK has risen by 10cm since 1990. The UK has experienced eight of the ten warmest years on record since 1990. These trends are projected to continue; at what rate and by how much primarily depends on the volume of greenhouse gases released into the atmosphere around the globe.

This brief synopsis presents evidence of a wide range of observed climate change impacts on UK biodiversity, and the potential for further climatic changes in future.

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