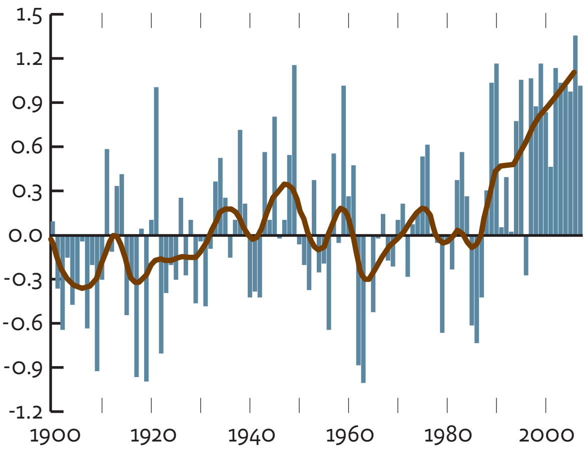
5.2 Climate change

5.2.1 The current situation

There is now overwhelming consensus that climate change is taking place at both global and UK levels (Figure 5.1, Tables 5.1 and 5.2), and that human activities, predominantly the burning of fossil fuels and changes in land-use, have increased the atmospheric concentrations of greenhouse gases (Intergovernmental Panel on Climate Change (IPCC) 2007). The principal greenhouse gas, carbon dioxide, increased from the pre-industrial (1750) level of 280 parts per million (ppm) to 383 ppm by 2007. Methane concentrations have increased by over 1,000 parts per billion during the last 200 years. The increasing concentration of greenhouse gases in the atmosphere has, through the enhanced greenhouse effect, led to an increase in global and UK temperatures.

Figure 5.1 Changes in central England temperature from 1900 to 2007



Changes in CET annual values (bars) from 1900 to 2007 relative to the average over the 1961-90 baseline period (about 9.5°C). The line empasises decadal variations. Source: UKCIP 2008.

5.2.2 Implications for the natural environment

Change in climate has already resulted in a wide range of changes to the natural environment. Amongst the most significant are:

5.2.2.1 Phenology

Seasonal events in spring and summer are occurring earlier: for example first leafing dates of trees (oak leafing has advanced three weeks in the last 50 years), flight times of moths and butterflies, egg-laying dates of birds, first spawning of amphibians, first appearance of hoverflies and earlier fruiting of species such as blackberry *Rubus fruticosus* (Beebee 1995; Crick & Sparks 1999; Hopkins *et al*. 2007; Sparks *et al*. 1997; Woiwod 1997). There is evidence that some populations of the pied flycatcher *Ficedula hypoleuca* are declining because breeding has failed to keep pace with earlier peak caterpillar abundance, resulting in reduced reproductive rates (Both *et al*. 2006). Such breakdown of synchronisation between inter-dependent species may become more widespread.

Table 5.1 Observed changes in global climate

Component of climate	Observed change in global conditions
Average temperature *	• Rate of warming 1956-2005, 0.13°C per decade • Rate of warming 1980-2005, 0.20°C per decade
Temperature extremes	• Widespread reduction in the number of frost days in mid-latitudes • Increase in the number of warm extremes (day and night) • Decrease in the number of cold extremes • Increased frequency and magnitude of heat-waves
Precipitation	• Significant increases in precipitation for many regions (including northern Europe), whilst at the same time there has been long-term drying in others (including the Mediterranean); • Heavy rainfall events are increasing in most regions (including northern Europe) even in regions were there is an overall drying • Snow cover is decreasing in most regions especially in the Northern Hemisphere spring
Sea level	• Global sea-level rise is accelerating and is now about 3 mm/yr

* 2005 and 1998 were the two warmest years in the global temperature record since observations began in 1850. Eleven of the warmest years on record have occurred during the last 12 years (1995-2006 NEEDS update for 2007).

(Source: IPCC, 2007)

Table 5.2 Observed changes in UK climate

Component of climate	Observed change in global conditions
Average temperature	• 1°C rise in Central England temperature* since 1950 • Rate of warming increasing in all regions • 2006 was the warmest in the 358-year record, with an anomaly of 1.35°C above the 1961-90 baseline. 2007 was the second warmest year on record. †
Temperature extremes	• Widespread reduction in the number of frost days in mid-latitudes • Increase in the number of warm extremes (day and night) • Decrease in the number of cold extremes • Increased frequency and magnitude of heat-waves
Precipitation	• Little observable evidence for change in rainfall totals • Increased winter rainfall intensity in all English regions • Decreased summer rainfall intensity in all English regions
Sea level	• Sea-level rise approximately 1 mm/yr ‡

* The Central England temperature record provides us with the longest continual observational daily temperature data (1659-present).
† July 2006 was the warmest month on record with a mean temperature of 19.7°C. September 2006 was the warmest September on record; autumn 2006 was the warmest autumn; and April 2007 the warmest April. May 2006 to April 2007 was the warmest 12 month period on record.
‡ Taking account of changes in the vertical elevation of the British Isles

(Source: Jenkins *et al*. 2007)

5.2.2.2 Range change and habitat preference

Migratory, southern and northern species are all having their ranges affected by climate change. Migratory species have changed their patterns of movement. This has been particularly notable among wading birds that breed in the Arctic but winter on the coast of England. Fewer have been found on the milder south-west coast because warmer winters mean birds are now able to winter further north and east, nearer to their Arctic breeding sites (Austin & Rehfisch 2005).

Many warmth-loving species at the northern edge of their range are extending northwards, or onto higher ground. This includes a very wide range of vertebrate and invertebrate species (Hickling *et al*. 2005, 2006; Hopkins *et al*. 2007; Warren *et al*. 2001). However, not all are expanding their range: natterjack toad *Bufo calamita* and scarce emerald dragonfly *Lestes dryas* have not spread as expected (Hickling *et al*. 2005, 2006). Many species at the northern edge of their range utilise a wider range of habitats further south in Europe (Thomas *et al*. 1999). The silver-spotted skipper butterfly *Hesperia comma* has begun to breed in a wider range of grassland types in England, mirroring its behaviour further south in Europe, due to increased temperatures (Davies *et al*. 2006). A similar pattern is shown by other species (Thomas *et al*. 2001).

In contrast, some species reaching their southern limit in the UK, such as the mountain ringlet butterfly *Erebia epiphron*, are retreating northwards or are being lost from lower ground (Franco *et al*. 2006).

5.2.2.3 Species abundance

Even where species have not changed their distribution there is evidence that their abundance has changed due to climate change. This has already been observed amongst butterflies, moths and plants of woodland and grassland (Conrad *et al*. 2004; Dunnet *et al*. 1998; Kirby *et al*. 2005; Roy *et al*. 2001).

5.2.2.4 Habitat and ecosystem change

It is difficult to interpret causes of habitat and ecosystem change. For example, European forests have increased their above-ground biomass, with tree productivity increasing in recent decades. But, in addition to climate change, this is thought to be due to a combination of other factors including increased carbon dioxide in the atmosphere and greater atmospheric nitrogen deposition (Cannell 2002). Increased rates of decomposition in bogs, and consequent increases of dissolved organic material in streams and rivers, may be partly linked to climate change, though it is not clear that this is the main driver (Bardgett 2005; Montieth *et al*. 2007).

5.2.2.5 Sea-level rise

Areas of intertidal habitat have already been lost due to sea-level rise, particularly on the low-lying coasts of south-east England where significant losses of saltmarsh have been recorded from 12 Special Protection Areas (Royal Haskoning 2006).

5.2.2.6 Extreme weather events

It is difficult to find evidence for change driven by extreme weather events, such as flooding, drought and storms, as they are relatively rare and unpredictable. However, there are indications that they may already be a significant cause of change. The tidal surge on the east coast of England in November 2007 caused widespread inundation of freshwater habitat by salt water, and not all such areas will return to their former freshwater state. Major disruption to the footpath network on the east coast also occurred, some of it resulting in long-term loss of access. In woodlands, drought has been shown to cause change in tree composition (Peterken & Mountford 1996), and major storm damage to woodlands may also be increasing in frequency (Quine & Gardiner 2002).

5.2.3 Forward look

5.2.3.1 Expected climate changes during the 21st century

Globally, emissions of greenhouse gases from man-made sources continue to increase. IPCC studies predict that concentrations of carbon dioxide in the atmosphere could reach between 500 ppm and 1,000 ppm by 2100. Taking account of all greenhouse gases, and converting their global warming effect into equivalent concentrations of carbon dioxide, means that by 2100 the total concentration of carbon dioxide-equivalent could be between 600 ppm and 1,550 ppm and the global mean temperature could increase by between 1.1°C and 6.4°C .

In England, it is expected that annual mean temperatures will increase by between 0.1°C and 0.5°C per decade, with rates of summer warming most pronounced in the south-east. Little overall annual change in total precipitation is expected, although it could reduce in inland areas. Winter precipitation is expected to increase by 5-15%, while summer precipitation is expected to decrease by 10-50%.

The predictions in Table 5.3 show, for three time-slices this century, how temperature and precipitation are expected to become more extreme. Other key climate changes and sea-level rise are also predicted (Table 5.4).

Table 5.3 Predicted weather extremes in England

	2020s	2050s	2080s
Mean temperature			
A hot '1995 type' August (+3.4 °C)	1%	20%	63%
A warm '1999 type' year (+1.2 °C)	28%	73%	100%
Precipitation			
A dry '1995 type' summer (37% drier than average)	10%	29%	50%
A wet '1994/95 type' winter (66% wetter than average)	1%	3%	7%

The percentage of years expected to experience a range of extreme seasonal anomalies across southern UK for the UKCIP02 medium-high scenario.

(Source: Hulme *et al*. 2002)

Table 5.4 Other expected changes in England's climate

Component of climate	Observed change in conditions
Diurnal temperature range *	• Decrease overall, especially in winter • Increase in summer
Snowfall	• Reductions in snowfall amounts and the number of days with snow on the ground
Soil moisture	• Decrease in summer and autumn in the south-east • Increase in winter and spring in the north-west
Sea level	• Sea-level rise approximately 1 mm/yr **

* The difference between the daytime maximum and nighttime minimum temperatures
** Taking account of changes in the vertical elevation of the British Isles

(Source: UKCIP, 2008)

Table 5.5 sets out the expected range of sea-level rise in a number of English regions by the 2080s. By this period, the sea level in eastern England is currently expected to have risen by between 22 and 82 centimetres relative to the 1961-90 average.

Table 5.5 Expected sea-level rise in selected English regions by the 2080s

Region	YH	EM	EE	L	SE	SW
Expected 2080s net sea-level change (cm)	15-75	20-80	22-82	26-86	19-79	16-76

(Source: Hulme *et al.* 2002)

The major impact of sea-level rise would occur when it combined with weather events to create a storm surge. These surges are expected to become higher and more frequent. A major storm surge with a height of 1.5 metres, currently expected once every 120 years, would, by the end of the century, be expected once every 7 years. (Hulme *et al*. 2002).

5.2.3.2 Implications of further climate changes for biodiversity and landscapes

As climate impacts upon nearly all aspects of the natural environment, producing multiple and complex effects, it is possible to foresee only some of the likely changes. From observation of current change, climate projections and experiments, the following likely future changes can be identified:

Sea-level rise

We can expect to see further major sea incursions inland during storms, particularly on the south and east coasts of England. In a truly natural landscape, such change need not be damaging, as the habitats will re-establish further inland as the sea level rises. However, existing coastal development, often defended by sea walls, prevents inland migration of habitats and species. If measures such as managed retreat are not adopted in low-lying areas, there may be widespread losses of intertidal and coastal habitats. Coastal defences will come under greater threat and become increasingly unsustainable.

In the coastal zone, sea-level rise may also result in the direct loss of freshwater habitats such as reedbeds and wet grasslands, including feeding and roosting areas for internationally important flocks of migratory birds. Such freshwater sites may be converted to saline habitats, with subsequent loss of freshwater species and feeding birds (ABP Marine Environmental Research Ltd 2003).

Phenology

The degree to which changes in the timing of seasonal events will further affect wildlife is uncertain. Some of these phenological changes may give more favourable conditions for growth and reproduction. However, where species are inter-dependent, differences in seasonal response to climate may mean natural relationships break down: for example between insect-eating birds and their prey, or flowers and their insect pollinators. Migratory birds that breed in England may be particularly at risk (Lemoine & Böhning-Gaese 2003). Changing climate may also mean that the timing of management, such as grazing and cutting, also shifts. This may impact adversely upon some species (Hopkins *et al*. 2007).

Northern and upland species

Computer modelling suggests that northern and upland species, such as the black grouse *Tetrao tetrix* and oblong woodsia fern *Woodsia ilvensis*, will decline and may become extinct in England. This could be as a result of the total loss of areas with a climate similar to those they occupy today; alternatively suitable sites may exist but be far away from sites now occupied, making dispersal to those new areas unlikely (Walmsley *et al*. 2007).

Southern species

It is expected that many southern species, such as the greater horseshoe bat *Rhinolophus hipposideros* and silver-spotted skipper butterfly *Hesperia comma*, may extend their range northwards in England as the area with suitable climate expands (Walmsley *et al*. 2007).

However, some warmth-loving species may be unable to spread to new habitats because they have poor powers of dispersal and suitable sites are rare. These species may at first increase their population size locally as climate changes, but eventually may become extinct as the climate there becomes inhospitable (Travis 2003; Warren *et al*. 2001).

Even species not at the edge of their range may be unable to disperse due to the highly modified and fragmented nature of many of England's landscapes, where there are many barriers to their spread, such as intensively managed farmland and major roads.

Fire

More droughts will make the countryside increasingly vulnerable to wildfire. Many heathlands and grasslands already undergo uncontrolled burning, and fire frequency is likely to increase. It may be that habitats not normally subject to accidental fire, such as broadleaved woodlands and bogs, may suffer from fire in the future (Hopkins *et al*. 2007), causing major change in their structure and species content. Where upland heathland is burned as part of management for driven grouse shooting, a distinctive 'patchwork' landscape has developed. Climate modelling suggests that, from the late-21st century, red grouse *Lagopus lagopus* may no longer occur within upland England. This is likely to result in a smaller area of heather routinely burned, bringing about further changes in upland landscapes (Huntley *et al*. 2007).

Grazing management

Open habitats such as fens, grasslands and heathlands have traditionally been managed by grazing. More summer droughts, in particular, may mean that grazing is no longer possible due to die-back of vegetation and a lack of drinking water for animals (Hopkins *et al*. 2007). It is increasingly likely that the spread of diseases (eg bluetongue) related to climate change will reduce livestock numbers and restrict movement, altering grazing patterns.

Freshwaters

Complex changes may occur to standing and running waters. Groundwater levels will fall, and more ponds may be prone to drying out in summer. There may be wider draw-down zones (areas of shore affected by fluctuating water levels) around lakes and reservoirs. The impact of climate change on the few deep lakes in England is difficult to assess, although rare cold-water species such as the vendace *Coregonus albula* are likely to be at increased risk. Changes to freshwater plant and animal communities may be very complex and difficult to predict (McKee *et al*. 2002a, 2002b; Monteith *et al*. 2007; Moss *et al*. 2003). The potential impacts of climate change on river systems are also likely to be highly complex and may include more frequent and extreme low flows in summer, and higher river flows in winter (Arnell 2004). Changing flow is likely to alter the form of river beds, banks and flood plains and, over time, the shape of the river valley itself; although the pattern of change is also likely to be strongly influenced by land use (Macklin and Lewin 2003).

Recreation

Climate change is expected to have complex impacts on recreation. The limited snow- and ice-based recreation in England is likely to completely disappear, but higher temperatures may extend the season for most other outdoor recreation and tourism (Viner 2006). More frequent drought may close parts of the countryside to visitors due to high fire risk, with potentially severe impacts upon local economies (Peak District National Park Authority 2007). More heavy rainfall events may mean that river and stream crossing points become hazardous, making some remote areas inaccessible.