5 Pressures and risks

5.1 Introduction

England's natural environment is not static – millennia of complex changes have given us our landscapes, habitats and wildlife of today. Changes have been long-term and short-term, natural and man-made. They range from the impacts of centuries of agricultural activity to the effects of the enormous economic growth of the last 100 years and the recent effects of individual extreme weather events.

This chapter provides a summary of the major drivers of change, then examines the key pressures that have major direct effects on the state of our natural environment. These pressures arise from climate change, invasive species and diseases; how we allocate land and the sea to different uses; how we manage land, sea and freshwater; and pollution.

For each of these pressures, we describe the current situation and the implications for the natural environment. We provide a brief forward look at the risks to England's natural environment from these pressures in the immediate future, based on current understanding of their pace and direction.

5.1.2 Major external drivers of change

Social, technological, environmental, economic and political factors provide the context for the pressures directly affecting our natural environment.

5.1.2.1 Social factors

Social issues are increasingly dominated by population change. Population in England increased steadily through the last century and will grow further, with a projection of 60.4 million in 2031 compared with 50.8 million in 2006 (National Statistics 2006). It is also predicted that there will be a higher proportion of older people among the population and more single-person households. The trend of higher population increase in southern and eastern England is expected to continue, leading to further demands for housing, transport and infrastructure development there. Increased migration introduces some uncertainty and could lead to unexpected demands on infrastructure and extra pressures for housing in both rural and urban areas.

Improved health and increased longevity will continue, but these are accompanied by trends such as increased obesity rates. Obesity coupled with inactivity is costing £10 billion per annum in England alone (Department of Health 2008; Cabinet Office 2002). Poor diet and unhealthy lifestyles (for example, seven out of ten people do not exercise enough) lead to more people having long-term health problems. Such people are less likely to be engaged with the natural environment. There is also evidence that physical health needs to be accompanied by improvements in mental wellbeing – one in four people consult their GP over their mental health. The natural environment has a crucial role to play in providing space and opportunities for engagement, understanding and re-connection. There remains a section of society still suffering from poverty and deprivation in which these physical and mental issues are at their most acute and access to the natural environment is limited.

Leisure time has increased and there is a significant amount of direct contact with the natural environment. Annually there are 74.8 million visits to England's National Parks (National Parks Portal 2008) and over 16 million visits to National Nature Reserves (see Chapter 4). Leisure time is expected to increase further as people's average age and prosperity go up. At the same time younger people spend less time outdoors, so there is an emerging generation who have little engagement with, or direct knowledge of, the natural environment.

5.1.2.2 Technological factors

The enormous changes in agricultural technology since the Second World War, for example in pesticides, plant breeding and mechanisation, continue to have a major impact on England's natural environment. Genetic engineering is a significant emerging technology that could have a profound influence on climate change issues, for example by using engineered micro-organisms to capture and convert carbon dioxide, or to produce biofuels. However there are concerns over the potential effects of genetically modified organisms on biodiversity and landscapes.

5.1.2.3 Economic factors

Economic drivers are increasingly influenced by climate change, described in the Stern Review (HMSO 2006) as 'the greatest and widest-ranging market failure ever seen'. The development of carbon pricing (placing a financial value on likely emissions) is already affecting decision-making, notably on energy generation. Global economic issues are driving trade liberalisation, better regulation and influencing investment in education and research as the UK seeks to increase its competitiveness and productivity in the face of global competition. There is also risk and uncertainty over global food production, in part driven by biofuels replacing food crops on agricultural land, which may lead to higher food prices. England's natural environment is thus increasingly affected by efforts to both respond to climate change and sustain UK economic growth.

5.1.2.4 Political factors

The domestic political will to tackle environmental issues has increased protection for our biodiversity and landscapes. This has been increasingly driven by action at European and wider international levels, notably over agricultural policies (for example the shift in the European Union's Common Agricultural Policy towards delivering environmental gains) and global arrangements (for example the Kyoto Protocol for reducing emissions of greenhouse gases; and the World Trade Organisation seeking to remove market barriers). Current Common Agriculture Policy reform will move to a more market-based approach for agriculture, which may provide opportunities as well as risks. The European Union's Common Fisheries Policy has been unsuccessful in halting biodiversity loss.

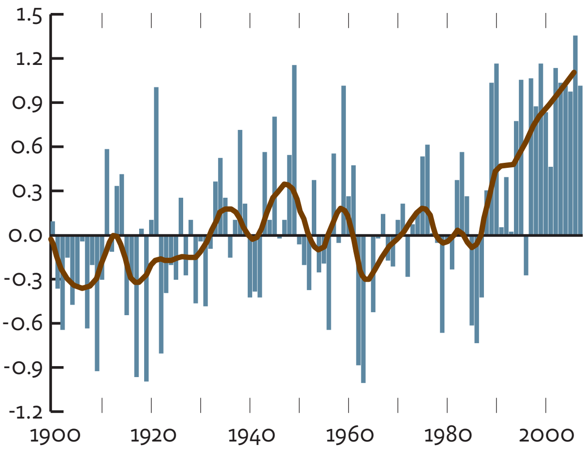
Action at national level is being accompanied by moves to devolve more political power in England to regional and local levels. This gives an opportunity to deliver a quality natural environment for the whole of England that also reflects local distinctiveness and local people's needs.

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.

5.3 Invasive species and diseases

Invasive species and disease can have significant effects upon the natural environment, affecting the existence or integrity of some species and habitats. For example, the native red squirrel *Sciurus vulgaris* is threatened by disease carried by the invasive grey squirrel *Sciurus carolinensis*. Freshwater habitats are particularly vulnerable where, for example, vigorous invasive plants such as Japanese knotweed *Fallopia japonica* can reduce biodiversity. Diseases such as foot and mouth have effects on livelihoods and ecosystems and can disrupt public access. The effects of climate change will be to increase the risks from new invasive species and diseases affecting the natural environment, and to alter the risks associated with existing invasive species and diseases.

5.3.1 The current situation

5.3.1.1 Invasive species

Non-native species have been introduced to England over thousands of years, either deliberately for social or economic reasons such as forestry, agriculture and horticulture, or by accident: for example Dutch elm disease *Ceratomyces ulmi* was introduced in imported timber. Most non-native species are benign and only a small proportion becomes invasive, although why some do so and others do not is unclear. It is also not well understood why some introduced species, present for many years at low levels, subsequently expand rapidly and become invasive.

5.3.1.2 Diseases

A large number of diseases can affect plant and animal biodiversity. Examples of those posing a direct risk include squirrel poxvirus, crayfish plague, bluetongue and avian influenza:

- A study of squirrel poxvirus infection in red and grey squirrels (Sainsbury *et al*. 2000) showed that 61% of apparently healthy grey squirrels have been exposed to the virus. In contrast, only 3% of red squirrels were found to have antibody to it, but 75% of those with the antibody showed clinical signs of squirrel poxvirus-associated disease. This suggests that the virus causes little or no disease in greys, but is highly pathogenic for reds. In addition, the study found evidence that the highest risk of the virus affecting red squirrel is in areas currently shared with grey squirrels.

- The invasive non-native signal crayfish *Pacifastacus leniusculus* is displacing the native white-clawed crayfish *Austropotamobius pallipes* by carrying the fungal crayfish plague, to which the native species is susceptible (eg Alderman 1993).

- The first case of bluetongue disease in the UK was detected in September 2007 and it began circulating between the local animal and midge population in East Anglia. The disease has now spread to other parts of southern and eastern England.

- Avian influenza reached the UK in April 2006 but, since then, only a few isolated cases in wild birds and poultry have been detected.

5.3.2 Implications for the natural environment

5.3.2.1 Invasive species

Invasive non-native species have an impact on biodiversity by displacing or preying upon native species, by destroying habitats, or by introducing new diseases or parasites. The most direct implications are the threats of predation on, and competition with, native species. For example, water voles *Arvicola terrestris* have declined as a direct result of predation from invasive non-native mink *Mustela vison*. Ground-nesting birds and seabird colonies can be damaged by predation from non-native species, especially on islands. The slipper limpet *Crepidula fornicata* (pictured) is an example of an invasive marine species that modifies the local environment by allowing mud deposition through faecal accumulation, making it less favourable for other native species and having an economic effect on commercial oyster beds.

Invasive non-native species can also affect ecosystems more widely. River catchments are particularly vulnerable to invasive aquatic species: these include signal crayfish and Australian swamp stonecrop *Crassula helmsii*. Along riverbanks, dense monocultures of plants such as Himalayan balsam *Impatiens glandulifera* and Japanese knotweed can crowd out native species, affect the appearance of riverine landscapes, prevent access to riversides, and impede the flow of water thereby exacerbating flood risk. When these invasive species die down in winter, they leave the river banks bare, exposing them to increased soil erosion. In the marine environment, the Chinese mitten crab *Eriocheir sinensis* is a voracious predator threatening many native species. Also, it burrows in soft sediment estuarine banks and, in high densities, can reduce their effectiveness as flood defences.

5.3.2.2 Diseases

In addition to the direct risks to wildlife, the management of disease-carrying organisms can also present indirect risks. For instance, insecticide control of the vectors of Lyme disease and bluetongue may affect non-target terrestrial and aquatic invertebrates. If restrictions are placed on livestock movements or livestock numbers as part of disease control during major outbreaks, such as that of foot and mouth in 2001, changes in grazing regimes can drastically affect terrestrial ecosystems and landscapes as well as farming practices and livelihoods. Such restrictions can also reduce public engagement with the natural environment.

5.3.3 Forward look

Climate change is likely to increase the impact of invasive species through:

- more non-native species arriving and becoming established in England;
- those currently restricted to southern England spreading north; and
- both new and established species becoming invasive.

It is also likely that some diseases, or the invasive species that carry them, will spread as seen, for example, with bluetongue: milder winters with fewer consecutive frost-free days, may extend the season of activity of the adult midges that carry the disease and allow its spread, despite control measures. Increasing global trade and movements of people also increase the chances of species reaching and becoming established in England.

5.4 Use of land and sea

Current changes in the use of England's land and sea present both threats and opportunities to the natural environment. We look at the impacts of three drivers of change in land and sea use: energy generation and the demand for alternative renewable sources, development, and the growing demands for water.

5.4.1 Energy generation

5.4.1.1 The current situation

Since 1990, energy demand in the UK has increased by an average of 0.7% per annum (DTI 2006). In 2006, 90% of the UK energy supply was derived from fossil fuels (coal, petroleum and natural gas), 8% was provided by nuclear generation, and renewable sources produced 2% (DBERR 2007).

The Government's long-term environmental goal for energy policy is to cut the UK's carbon dioxide emissions by 60% by 2050. Part of the response to this is to increase renewable energy generation. The domestic target of 10% of electricity supply from renewable energy by 2010 is now superseded by the EU target of 20% of energy consumption from renewable sources by 2020.

There are five major sources of energy considered in this section: bioenergy, wind energy, wave and tidal energy, fossil fuels and nuclear power.

Bioenergy is generated from plant material and agricultural waste such as manures and slurries. All are used to produce heat, electricity and transport fuels, and can help mitigate climate change, improve fuel security by reducing reliance on imports, and contribute to rural economies. We consider two aspects of bioenergy affecting the natural environment: a) biofuels derived from agriculture, and b) other biomass sources such as short-rotation coppice. Landfill and sewage gas is also classed as bioenergy but its production does not have the same level of impact on the natural environment.

Liquid biofuels (renewable transport fuels) in England come from either starchy crops which produce bioethanol, such as wheat and sugar beet, or oil-producing crops such as oilseed rape, which produce biodiesel. Biomass sources include woody energy crops, grasses, agricultural and forestry residues, and other organic wastes.

The UK has one of the largest potential wind energy resources in Europe. Wind could provide around 18% of the UK's total electricity, but in 2006 produced less than 2%. There is a trend towards the use of larger, off-shore wind farms.

The UK also has the largest wave and tidal resource in Europe, which could provide a considerable proportion of its renewable power. Tides as a source of energy have the advantage of being highly predictable and regular. Technical development, however, is still in its early stages.

In terms of fossil fuels, the UK Continental Shelf oil and gas production, though declining, still supplies 75% of our total energy needs and investment is expected to rise over the next 10 to 15 years. Coal production has declined since the 1970s and most new or recommissioned power stations use gas. Over the next decade, a number of older power stations are to be decommissioned and new facilities built; these new power stations are likely to be more efficient.

All but one of the UK's existing nuclear power stations will be decommissioned by 2025. The Government is encouraging new-build nuclear energy generation. A new generation of power stations, if built, could start production by around 2020.

5.4.1.2 Implications for the natural environment

The production of bioenergy presents a range of opportunities as well as risks. Bringing currently unmanaged woodlands into active management to produce woodfuel can improve their biodiversity and amenity value; introducing new arable crops that require lower levels of herbicides, pesticides and fertilisers may provide positive opportunities for wildlife to flourish. Perennial crops for biomass can benefit farmland soils as they remain undisturbed for the productive lifetime of the crop (up to 20-30 years) and require no pesticides or fertilisers once established. Crops such as short rotation coppice introduce structural variety and can benefit more generalist species and enhance the landscape if low impact management strategies are adopted (Wildlife and Countryside Link 2007). In particular short rotation coppice sustains large numbers of invertebrates and provides habitat for small birds and mammals.

However, biofuel crops need to be sited appropriately to avoid water stress (DBERR 2007) and the risk of erosion or damage to archaeological sites. During establishment and removal (pictured) they can have an intrusive effect on traditional landscapes. They can also displace wildlife closely associated with former crops or land uses. If perennial crops such as short rotation coppice are introduced, plants, invertebrates and birds of open farmland, such as lapwing and skylarks, may decline.

Biofuel production can lead to substantial short-term reductions in carbon emissions, but can replace other land uses that have a higher value for landscapes or biodiversity. It can also impact upon fertility and the use of pesticides and water in the same way as any other arable crop. Importing and consuming biofuels grown in other countries may have major impacts upon their environmental quality and may lead to release of sequestered carbon from land not previously intensively managed.

Onshore wind energy developments can have impacts from the turbines themselves and from their infrastructure requirements. Poorly sited wind farms can cause severe problems for birds through disturbance, habitat damage or collision with turbines. Turbine and track construction can cause habitat disturbance and biodiversity loss. Drainage and construction of roads and grid connections may impact on the hydrology of upland peat-based soils potentially causing release of sequestered carbon. The landscape and visual impacts of large-scale wind energy developments can be substantial, as they tend to be sited in prominent, open locations.

Offshore wind energy impacts include loss, damage and disturbance of habitats and species during construction and operation. Important seabed habitats may be damaged or lost as a result of pile and cable installation. Populations of seabirds or waterfowl could be at greatest risk if they are displaced from shallow water feeding areas or if they collide with turbines. Large, clustered developments can have a range of potential cumulative effects on mobile species such as birds and marine mammals. Installations close to the shore may also affect the surrounding seascape, and also have local environmental impacts where transmission lines come ashore. There are possible benefits to marine species from reducing commercial fishing where there is offshore development, but this may increase pressures elsewhere.

The majority of the potential locations for tidal and wave energy projects are designated or proposed SPAs or SACs. For example, the Severn Barrage proposal is likely to be highly detrimental to the special interest of the Severn Estuary, affecting the geomorphology, saltmarshes, underwater reefs and migratory fish.

Fossil fuel exploration, extraction, processing and transportation can have adverse, pervasive and long-term environmental impacts. These include toxic and harmful inputs to the atmosphere, marine environment, soils and aquatic systems. Nitrogen oxides are a significant contributor to eutrophication (see Section 3.6).

While nuclear power offers a significantly reduced carbon footprint compared with burning fossil fuels, the siting of plants has a direct effect on the natural environment. Most current sites are on or near designated sites (SSSIs, SACs and SPAs) with most also being on or near the coast. Through land take, new development can impact on the size and integrity of significant habitats and species, and have a considerable visual impact on low-lying coastal landscapes. More specific impacts include:

- Effects on marine ecosystems, notably the warming of coastal/estuarine water and the entrapment of marine biodiversity in cooling intake pipes.
- The risk of unintentional release of long-lived radioactive isotopes, for example through sabotage or accidental release.
- Disposal of radioactive wastes from normal operations. Current policy is to keep wastes in above-ground temporary storage, but there is now a long-term plan to reduce risks further through disposal deep underground.
- The disposal of radioactive isotopes from the reactor core after decommissioning (isolation is required for up to 130 years).

5.4.1.3 Forward look

Biomass crops and production techniques are developing rapidly and it is not yet clear how they will impact on the natural environment or how much the increased global demand for biomass will lead to significant changes in land use for these crops in England. If biomass were to provide 3% of the UK's energy needs, this would require an additional 1.2 million ha of short rotation coppice willow *Salix* and elephant grass *Miscanthus x giganteus* (Land Use Consultants 2007); yet only 7,448 ha were planted between 2001 and 2007.

It is estimated that 20 to 30% of the UK's arable land would be needed to meet the current UK Government target of replacing 5% of our transport fuel use with biofuels (National Farmers Union 2006). However, simple extrapolation of the area of land required to meet, for example, the EC Directive on Biofuels may not predict change accurately. For example, the development of second generation biofuels may change the estimates of crop areas required. The biofuels market will be global and production will come from countries and regions that have the most suitable conditions and can produce fuel at the lowest cost. Production in these areas, however, may also have the greatest overall impact upon the global natural environment.

Offshore windfarm development has the potential to impact on the natural environment. As required under the EC Habitats and Birds Directives, Natural England is currently advising on the selection of a series of marine Special Areas of Conservation (SACs) to protect subtidal sandbanks and reefs around the English coast and Special Protection Areas (SPAs) for important aggregations of seabirds (Figure 5.2). There is considerable overlap between the areas being considered for designation and the potential windfarm sites (Figure 5.3), and the sandbank sites are likely to be favoured by windfarm developers.

Figure 5.2 Indicative areas of search for marine SPAs in England

Source: Natural England, 2008

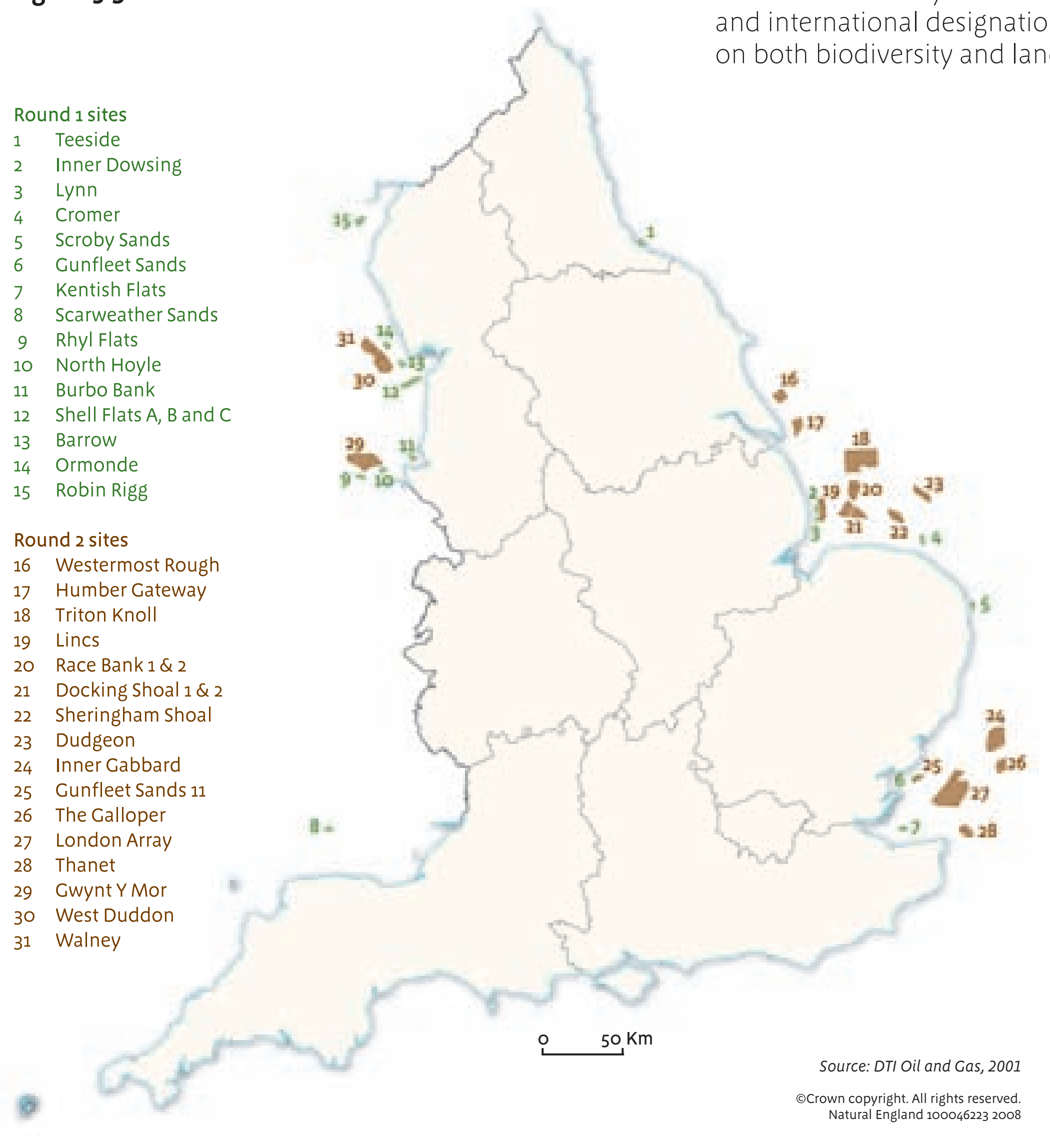
The Government's plans announced in December 2007 aim to provide the UK with 33gW of offshore wind power by 2020. This huge expansion has the potential to lead to further significant impacts on England's marine environments.

The environmental impacts of developing tidal and wave technologies are not well understood and need further investigation. Large-scale tidal barrages, such as the Severn Barrage proposal, would have substantial impacts. Other options such as tidal lagoons and tidal stream technologies are likely to have fewer risks for the natural environment. Wave devices are also likely to have less impact, though moving underwater parts may be a risk to cetaceans and fish. Depending on location, wave and tidal energy could also impact on habitats and species that rely on high-energy environments for their survival.

In terms of fossil fuels, there will be a large increase in the gas network (new pipelines and terminals) and storage investment over the next five years. Any further construction of coal-fuelled power stations will require carbon capture and storage to prevent an increase in greenhouse gas emissions.

Any new development of nuclear power capacity is expected to be adjacent to existing nuclear power stations, the majority of which are in coastal locations and therefore likely to be close to areas with national and international designations, with potential impacts on both biodiversity and landscapes.

Figure 5.3 Potential wind farm sites



Source: DTI Oil and Gas, 2001

5.4.2 Development

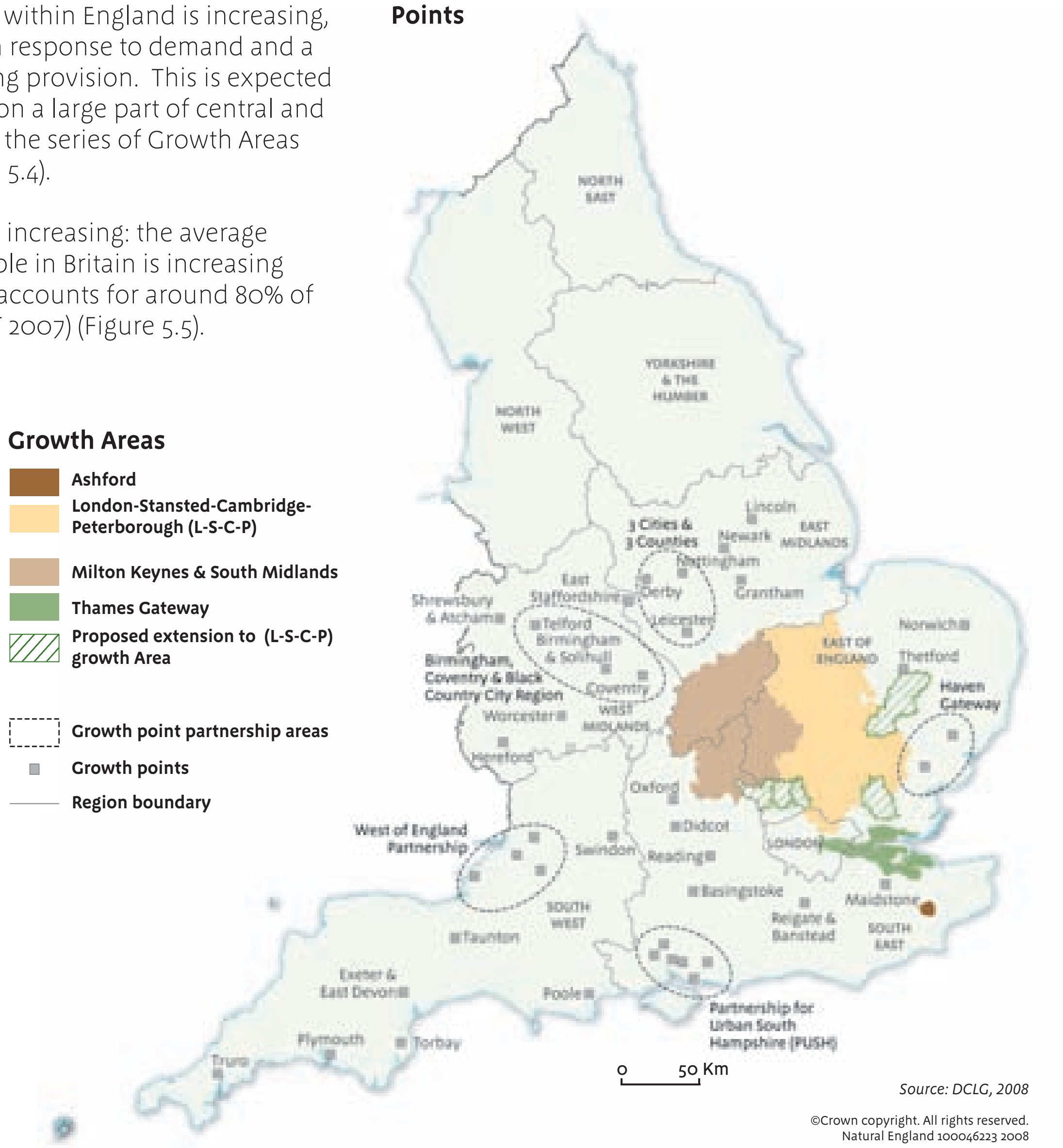
5.4.2.1 The current situation

Land with settlements or transport infrastructure (for example roads and railways) covers about 2.3 million ha, almost 10% of the total land surface of Great Britain. Within rural England, the area of developed land has increased by about 4% since 1990, largely at the expense of agricultural land (Defra 2006a). While the planning system has increasingly prevented adverse impacts on biodiversity, large-scale development in rural areas continues to change its landscape character. Between 1998 and 2003 substantial greenfield development has occurred near many urban areas, notably at key growth points, but also in former coalfield belts.

The pace of development within England is increasing, particularly for housing in response to demand and a historic shortfall in housing provision. This is expected to have a dramatic effect on a large part of central and southern England though the series of Growth Areas and Growth Points (Figure 5.4).

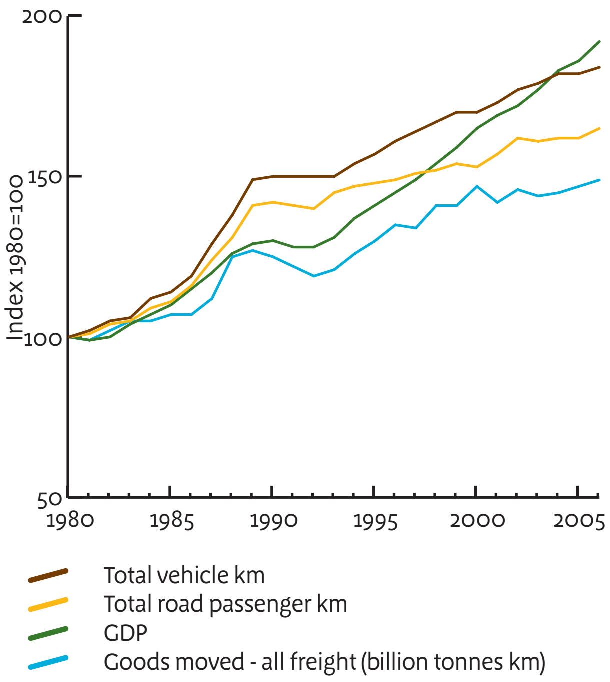
All forms of travel are also increasing: the average distance travelled by people in Britain is increasing every year, and car travel accounts for around 80% of the distance travelled (DfT 2007) (Figure 5.5).

Figure 5.4 Location of Growth Areas and New Growth Points



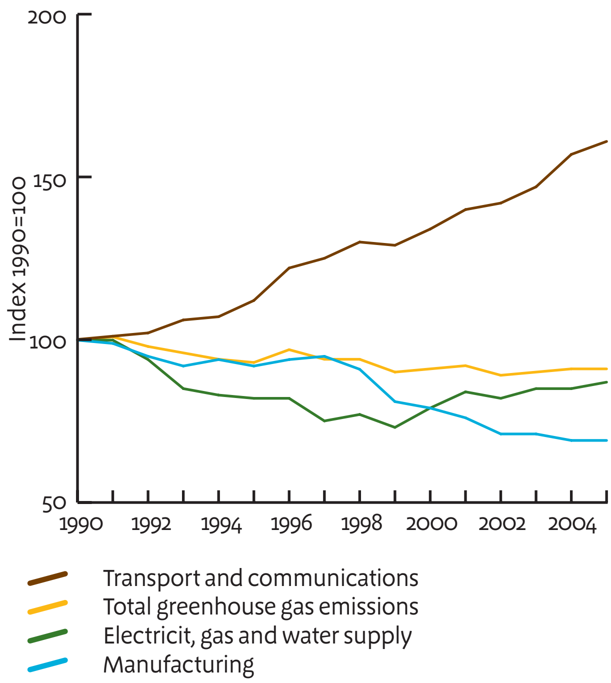
Source: DCLG, 2008

Figure 5.5 Growth in traffic, passengers, freight and GDP in GB, 1980-2006



(Source: DfT, 2007)

Figure 5.56 Changes in greenhouse gas emissions, 1990-2006



(Source: DfT, 2007)

5.4.2.2 Implications for the natural environment

Development has a direct effect on the natural environment by taking land and profoundly affecting landscapes, particularly when it takes place on greenfield sites. Most development outside existing urban areas has occurred on agricultural land; of all development between 2000 and 2003, 29% took place on agricultural land, with a further 5% occurring on other non-urban land (Defra 2006a).

Transport and development are having an effect on tranquillity. The area of countryside disturbed by noise and visual intrusion rose from 26% in the 1960s, to 41% in 1990 and 49% in 2007 (CPRE 2006). South-western England is rapidly becoming less tranquil, and the south-eastern half of England remains the least tranquil.

Transport growth has also led to a substantial increase in transport-related greenhouse gas emissions (Figure 5.6).

Housing and infrastructure development has a range of indirect effects. It can increase the demand for transport. Even the relatively small amount of land-take for transport has contributed to habitat fragmentation, disturbance and pollution. Air travel is increasing, creating pressures for airport expansion, and there is continued expansion of ports to handle larger ships and more shipping traffic.

Development also increases the demand for materials, notably for mineral extraction from both terrestrial and marine environments. This can directly affect biodiversity and landscapes and also have indirect effects on water tables and water quality through processes such as excavation, drainage and washing. Decommissioned extractive industries can provide sites for waste disposal through landfill, creating potential for air and water pollution, considerable visual impact and other effects on the environment as waste is transported.

Other indirect effects of development include impacts on floodplain management through increased rates of water runoff. There are also increased risks associated with switching rural or mixed-use land to more urban uses such as housing (or industrial) development: large-scale development in particular can increase disturbance and damage to remaining habitats and landscapes, increase their fragmentation, and decrease the habitat connectivity necessary to adapt to the risks of climate change.

5.4.2.3 Forward look

Development can offer opportunities as well as risks. Decommissioned quarries and other extractive sites can provide land for habitat creation and create a positive impact on the natural environment. Sustainably built and managed housing development can give people the chance to experience the natural environment and so derive benefits for their health and wellbeing as outlined in Chapter 4. Sustainable development can also provide ecosystem services, for example helping to directly manage environmental threats such as flooding and adapting to climate change. The plans for flagship 'eco-towns', with low or zero carbon footprints, sustainable transport provision and accessible green space provision, may help realise these benefits. Well-designed transport links can also provide 'green infrastructure' or locally accessible green space, with green landscaping in built-up areas forming part of traffic-calming and home-zone approaches. For long-distance routes, the Sustrans network (Sustrans 2008) illustrates how transport corridors can be converted for green access.

Figure 5.7 Groundwater bodies at risk from abstraction pressures in Anglian Water region

5.4.3 Water abstraction

5.4.3.1 The current situation

Water is abstracted from surface water and groundwater sources for a range of activities, of which public water supply and electricity generation are the most important by volume. The impacts of abstraction on the natural environment can be on the volume of water available or on the quality of the water left after abstraction (for example increased temperature, increased nutrient concentration or reduced dilution).

5.4.3.2 Implications for the natural environment

By removing water from the natural surface or ground resource, abstraction puts the organisms that depend on it at risk. This affects a wide range of habitats, from woodlands (where groundwater constantly replenishes the large evapotranspirative losses from trees) to those habitats that directly depend on the availability of large quantities of water;

- **Rivers:** Reduced flows in rivers can reduce and degrade available habitat, and restrict migration of many species including fish such as salmon. Many species have specific requirements in terms of water depth, current velocities and substrate types that are affected by abstraction. Reduced flows result in less effluent dilution and increased concentrations of pollutants such as nutrients. Water temperatures also increase, further increasing algal growth and reducing oxygen availability.

- **Lakes, reservoirs and ditches:** Lower water levels reduce the amount of habitat, increase nutrient problems through reduced flushing, can reduce spawning habitat for fish and can destabilise the open water ecosystem. Repeated rapid draw-down of water through abstraction can result in lifeless marginal zones due to the hostile hydrological conditions.

- **Fens, wet woodlands and wet heathlands:** Reduced groundwater and surface water supply dries out wetland soils and makes them less suitable for a range of characteristic plant and animal assemblages.

- **Wet dune systems:** Increased abstraction lowers water levels in marshy areas, reducing the water available for characteristic species.

- **Peatlands:** Increased abstraction lowers water tables and increases soil aeration and oxidation, leading to loss of accumulated organic matter. Drying out can thereby shift peat soils from carbon sink (sequestrating) to carbon source (releasing), exacerbating the effects of climate change.

Under the Water Framework Directive, the risk to groundwater bodies from abstraction pressures have been identified. Figure 5.7 identifies the extensive areas at risk in the Anglian Water region.

5.4.3.3 Forward look

Climate change will increase the risks associated with water abstraction. Predicted warmer and drier summers, with reduced rainfall and increased evapotranspiration, will increase water demands from the natural environment – compounded by further abstraction to meet public demand. The increased intensity of winter rainfall storms will mean greater run-off and consequently less effective aquifer recharge, which may reduce the water available for the following summer.

Population increases and other social changes, such as more single-person households (see Section 5.1.2.1), will increase the demand for water. These effects will be most apparent in south-eastern England, the driest part of the country, exacerbating existing impacts and further jeopardising water-dependent habitats and species that require adequate water to adapt to the impacts of climate change.

5.5 Land and sea management

The way we manage our land and seas to produce food and raw materials has a profound impact on the natural environment. Some 80% of the area of England is managed either for agriculture or forestry (Figure 5.8), and much modern land management is intensive and specialised. For some areas, however, neglect (where the current level of management is very low or management has ceased altogether) rather than intensification, now impacts on the environment. In our seas, intensive commercial fishing has significantly changed populations and ecosystems.

5.5.1 Agriculture

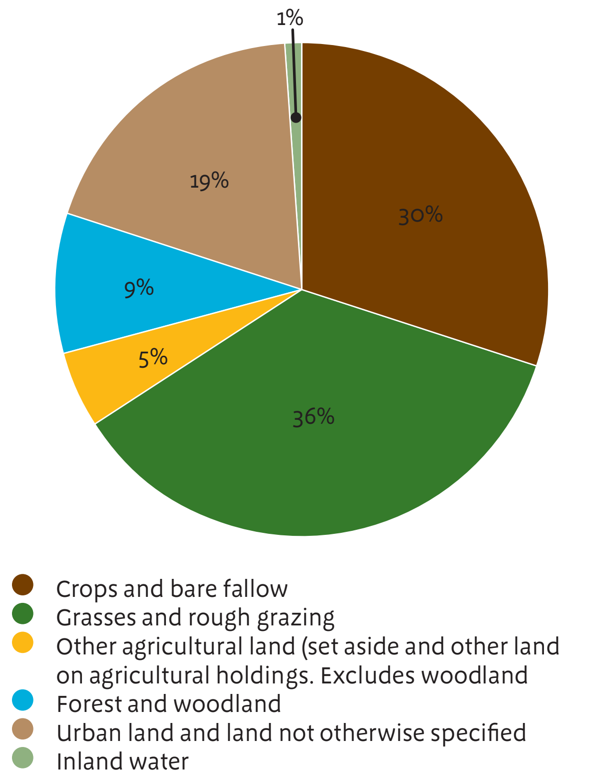
Most modern agriculture is based upon intensive land use. Systems have become specialised, with increasing numbers of farms concentrating on a small number of products to increase efficiency. This combination of intensification and simplification has led to landscape change, habitat degradation and loss, reduction or loss of species, and damage to soils. Key threats to the natural environment arising from intensive modern agriculture include nutrient input; overgrazing in the uplands encouraged by the previous subsidy regime; and drainage, which is a hangover from past subsidies and management, especially on upland blanket bogs.

5.5.1.1 The current situation

Agricultural land covers 71% of England's land area. Between 1996 and 2006, the area of agricultural land fell by 1%. The area of crops fell by 4% in the same period and rough grazing also fell by 4% (although grassland increased by 5% and forest and woodland by 14%) (Defra 2006a). Development for housing and infrastructure was a significant factor in this agricultural contraction: around 5-6,000 ha of rural land is currently converted to urban development annually (Defra 2005e).

Agricultural land in the lowlands is more versatile than in the uplands, and the mix of farming enterprises more liable to change. In recent years arable farming has been more profitable due to factors such as restriction of worldwide supply and the expanding domestic biofuel market. Numbers of grazing animals have declined as increases in regulation and feed prices have forced out smaller livestock producers. This has led to less diverse farming: there are fewer mixed, small or low-intensity farms.

Figure 5.8 Broad land uses in England



England total land area = 13.3 m ha

(Sources Defra, Ordnance Survey, Forestry Commission, Forest Service)

5.5.1.2 Implications for the natural environment

Intensification of agricultural land has led to the loss of some habitats and landscape features. Drainage has destroyed wetlands, and the demise of mixed farming systems in particular has also led to the loss of other features such as hedgerows, field margins and orchards. In addition, radical changes in management can result in damage to habitats, such as fertiliser application on species-rich grassland. Other impacts include soil compaction, erosion and loss of organic matter, which reduces soil capability for carbon sequestration. Conversion to arable land from other uses can also increase the rate of water runoff, contributing to erosion, greater sediment load in rivers and increasing the likelihood of flooding.

Prior to policy changes in the late 1980s and 1990s, which stemmed the rate of intensification, 97% of lowland unimproved grassland was lost between 1930 and 1984 (Fuller 1987), and 20% of hedgerows were lost between 1984 and 1990 (Petit *et al*. 2003).

Increased grazing pressure has also changed upland landscapes and their biodiversity. Here the impacts on shallow, relatively infertile soils ranged from increased erosion to loss of biodiversity, particularly the highly valued landscape dominated by heather and other dwarf shrubs. These trends have been exacerbated by over-intensive burning, either to aid game production (though traditional regimes can sustain typical upland landscapes) or to control coarser grasses to improve stock grazing. Other adverse impacts include draining, liming, ditch-digging and re-seeding. These impacts have had a significant effect on upland peatlands: 74% of upland heathland by area is designated SSSI and of this 29% remains in unfavourable condition; 69% of blanket bog is designated SSSI and 30% is in unfavourable condition. As well as the impacts on biodiversity, eroded peat affects the landscape, water run-off and quality, and restricts access. There are also implications for climate change due to carbon emissions from the eroded peat. Over half of the UK carbon is stored in peat, and the majority of peat in England and Wales (over 80%) is in the uplands (Holden *et al*. 2007).

Agriculture has had a profound effect on BAP priority habitats, with 11 of the 15 declining habitats doing so at least partly as a result of agricultural practices.

Intensive fertiliser and pesticide application affects field margins and boundaries. Intensive stock rearing leads to run-off from slurry and manure, and can have a pervasive effect on watercourses and open water through the leaching of excess nitrates and phosphates. It is also a source of atmospheric pollution (particularly nitrogen), which has a significant effect on terrestrial wildlife (see Section 5.6).

In the lowlands, and particularly in the south-east of England, agricultural change has led to under-management of areas valuable for biodiversity and landscapes, which can be difficult to reverse. Often small fragments of land have been left isolated, and they are then not economic or practical to manage. The lack of management leads to development of rank vegetation and eventually scrubbing up of grassland and heathland. Small areas are also more vulnerable to impacts from surrounding areas; for example changes in water level on adjacent land leading to drying out of wetland habitats such as lowland fen.

5.5.1.3 Forward look

A number of factors will affect agriculture and its impacts on the natural environment. The future direction of the Common Agricultural Policy following the current 'healthcheck' could have a major effect as the agricultural industry becomes more market-led. The outlook is currently difficult to judge. It may provide opportunities to find beneficial alternative uses for land no longer economically viable for agriculture, but may also signal the prospect of further intensification. This may depend on whether cereal commodity prices continue to rise, impacting on food prices and affecting the amount of arable land and the crops grown. The likely introduction of genetically modified organisms and other biotechnology may have direct effects from the introduction of new crops, and indirect effects on biodiversity through modified strains of existing crops requiring different patterns of herbicide or pesticide use. The impacts of biofuel and biomass crops have been outlined in Section 5.4.

The decline in lowland and upland stock farming, driven by regulation, economics and the risk of disease, is expected to continue. This will lead to continued neglect of some lowland habitats, such as grassland and heath, and the undergrazing or abandonment of some upland areas and habitats such as hay meadows, which are dependent on traditional upland livestock systems.

Climate change may gradually impact upon production: warmer summers may result in the introduction of new crops or strains of existing crops and higher productivity of some existing crops.

5.5.2 Forest and woodland management

5.5.2.1 The current situation

Woodland cover has increased, particularly since 1947, from a low of around 5% of England's land area in 1900 to around 9% now (Forestry Commission 2006b). This was mostly through conifer planting. However, since 1985 the earlier clearance of ancient woods and conversion of native woodland to plantations has been partly reversed under the Forestry Commission's Broadleaves Policy by replacing conifers with native broadleaves. New planting of woodland continues with a total of 3,174 ha in 2006/07 (Forestry Commission, 2007b).

The emphasis on timber production as an output from forestry and woodland management has been decreasing for the last 20-30 years, though there are signs that this trend may be reversing. According to Defra's 2007 Forestry Strategy, we currently harvest only around a quarter of the annual growth of timber from our native woodland and only 60% from our conifer forests each year. Woods are increasingly being managed for biodiversity, access and amenity – non-timber based woodland businesses, such as those involving recreation and tourism, are equivalent to around 16% of the value of all timber and woodland management in England. The Forestry Commission estimates that there were 222 million visits to woodland in 2002/03 (see Section 4.2.2).

5.5.2.2 Implications for the natural environment

Not all woods need to be actively managed, but there are lost opportunities from the current under-management of woodland in terms of lowered sustainable production and declines in some key species, and many woods have become less attractive for recreation. The Woodland Management Grant scheme funding has proved insufficient to bring enough woods into management to meet current BAP targets, and costs of sustainable forestry certification are acting as a barrier to management for many woodland owners. This has a particularly adverse impact on species that depend on open space or young growth because under-management and abandonment reduce the structural as well as the species' diversity within woods; it also reduces their amenity value. Additionally, overgrazing by deer is having significant effects by limiting natural regeneration and damaging existing young trees and shrubs and ground flora with consequent impact on the diversity of woodland plants and birds. There have been major changes to woodland shrub layers as a result of deer browsing (e.g. Kirby 2003a).

In the public sector, management of the Forestry Commission's estate has provided benefits for biodiversity and access. These have extended beyond semi-natural woodland habitats. For example, rotational felling within conifer plantations, in themselves of limited biodiversity value, can create valuable breeding habitat for bird species such as woodlark and nightjar (see Section 3.5.3).

The risks of woodland being under-managed have increased due to poor returns from wood and timber (related to low world timber prices and often poor quality of the current tree crops) combined with perceived burdens of regulation and insufficient incentive through grants etc. In addition, woodland management may not be the primary objective for some private owners who value their woodland for other reasons, for example because it provides privacy.

Increasingly economic and other factors are also militating against further forestry expansion. In particular, rising food or energy crop prices are discouraging farmers and other land managers from making land available for new woodland. The cost and complexity of establishing wooded urban green space limits the creation of new woods while, especially in the south-east, urban and infrastructure development continues to erode the ancient woodland resource.

5.5.2.3 Forward look

Continued climate change is likely to have effects on our woods though these are as yet not completely understood. The introduction or spread of further pest and diseases could have drastic effects on individual species and thus on our landscapes and biodiversity. There are also opportunities for climate change mitigation – woodland can sequester carbon more rapidly than an equivalent area of peatland.

If demand for wood-fuel and fibre increases, opportunities could be created for the natural environment. The Forestry Commission estimates that there is the potential by 2020 to harvest 2 million tonnes annually of currently unharvested material: this biofuel would power the equivalent of 250,000 homes per year (Forestry Commission 2007a). While bringing neglected woodland back into management would provide benefits for biodiversity and people, there would be risks of localised over-intensive management. Consequently, there would need to be careful planning of how any expansion of harvesting takes place.

New development, green space provision and leisure could lead to further opportunities to provide new woods and access to and use of existing woods. Benefits will be greatest where forestry is closely integrated with agriculture, environmental conservation, energy, transport and social agendas such as the proposed creation of 'eco-towns'. The Community Forests programme (see also Section 4.4.3) has shown how this can be done: since 1990, over 10,000 ha of new woodland have been planted, more than 27,000 ha of existing woodland have been brought under management and 16,000 ha of woods and green space have been opened up for recreation and leisure (England's Community Forests 2005).

5.5.3 Sea fisheries

5.5.3.1 The current situation

Fishing is the most widespread and significant exploitative activity in the marine environment. The most common methods involve towed fishing gear such as trawls or dredges pulled through water. Depending on the species to be caught, these can be either demersal (towed on the seabed) or pelagic (towed clear of the seabed). In shallower, inshore waters, static fishing methods are more common, such as the use of baited pots or traps, baited hooks on set lines and fixed nets.

At present, most fishery management is based on the size and distribution of stocks of individual fish species. Management of fisheries to keep stocks above a 'safe biological level' puts limits on fish numbers caught, the gear that can be used, and the number of fishing days. In north-west European waters, fisheries management has largely failed to meet this objective, leading to fewer fish being available for fishermen to catch and the effects on populations outlined below.

5.5.3.2 Implications for the natural environment

There have been very significant impacts on marine species (especially fish) populations, particularly through targeting large and long-lived species, advances in technology and the intensity of fishing.

In addition, there are the unintended effects of fisheries activities such as by-catch that further reduce populations of key species.

Since 1990, at least 70% of overall UK fish stocks have declined in their reproductive capacity and have been harvested unsustainably. The situation varies widely between species. In 2005, only 65% of assessed UK fish stocks (largely whitefish) were fished sustainably and only 35% of fish stocks around the UK were at full reproductive capacity (Defra 2004a). In 1998, UK vessels landed £137 million of cod and haddock (about 25% of UK landings by value), but this fell to just £70 million in 2002 (Cabinet Office 2004). Recent changes in stocks of commercially fished species are given in Table 5.6.

Table 5.6 Changes in stocks of key fish species, 1996-2004

Location	Species	% Change in stock level (1996-2004)
North Sea	Herring	+300%
	Haddock	+50%
	Plaice	+5%
	Cod	-50%
NE Atlantic	Mackerel	0%

(Source: ICES, 2006)

Though these major impacts on fish stocks are largely due to towed fishing methods, static techniques may have significant localised or wider impacts on vulnerable species and populations. For example, mono-filament gill nets are highly effective at catching slow-growing species of fish such as sharks or rays, which can be difficult to catch with towed gear because of seabed topography, and hence may have major impact on their populations.

By-catch, the inadvertent capture of non-target species, is a major problem and can affect nearly all marine species: animals living on the seabed, mammals, reptiles (such as turtles) and seabirds. It can occur during active fishing, or as a result of 'ghost fishing' (see below). Two forms of fishing gear towed on the seabed (demersal gear) are particularly damaging. By-catch can constitute up to 60% of the fish caught in beam trawls (where chains may be used to disturb fish from sediment), and up to 40% of those caught in otter trawls (which travel over rocky sea beds and can crush seabed organisms) (Commission of the European Communities 2007).

Set gears are also responsible for by-catch. There are numerous records of birds and cetaceans becoming entangled in static nets (Dayton *et al* 1995). Even gear no longer in use can have an effect: in 'ghost fishing', organisms become entangled in snagged or lost gear (including torn nets, lost crab and lobster pots) made from non-biodegradable materials. More evidence is needed about its impacts on marine species.

Fishing affects marine ecosystems in complex ways, and establishing precise cause and effect can be difficult. However, if a major part of a marine food web is removed or severely depleted by fishing, it is likely that several other component species will be affected as their competitors, predators, or food sources are removed. Cod stocks are a good example. Full-sized cod prey on smaller species such as herring, which compete for food with small cod. However, fishing has reduced the number of older, larger cod. Cod can live for approximately 40 years but, as a result of fishing, only 10% of the individuals in the North Sea are more than one or two years old and less than 0.5% are five years old or more. This skewed age structure also leads to the selection and survival of smaller, faster-maturing individuals. The long-term effects of such genetic shift are unknown, and more evidence is needed on whether it reduces fish species' resistance to further environmental changes. Conversely, other species, such as prawns, scallops and lobsters, whose predators (mainly fish) have been greatly reduced in abundance by fishing, thrive today in the much more sparsely populated seas that surround England (Roberts & Thurstan unpublished).

Numerous studies have shown that the physical effects of using benthic fishing gear reduce both species richness and productivity in most marine seabed types (eg Kaiser *et al*. 2002). The reefs of Lyme Bay are a good example of the damage that can be caused. The hauling of set nets and pots, particularly across reefs, affects less of the seabed than mobile fishing gears, but they may be locally significant in areas with communities of long-lived fauna particularly those of high conservation value (Gray *et al*. 2006).

5.5.3.3 Forward look

The English fishing fleet is now much smaller than in the past yet technical efficiency means these impacts on marine biodiversity will continue (JNCC 2008b). It seems likely that the current adverse effects on fish stocks and the marine environment will continue unless there is significant reform of the Common Fisheries Policy. This requires a long-term approach to management of fish stocks, the adoption of both an ecosystem approach to management and the precautionary principle, reduction in overall fleet capacity, environmental protection requirements and a reduction in by-catch. Common Fisheries Policy measures agreed in late 2007 have focussed on protecting cod stocks and reducing discards.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5.6 Pollution

Pollution presents a wide range of pressures and risks to the natural environment. This section considers two of the more significant areas of risk: nutrient enrichment and toxic chemicals.

5.6.1 Current situation

5.6.1.1 Nutrient enrichment of terrestrial and aquatic habitats

Nutrient enrichment can lead to excessive growth of plant life in aquatic and terrestrial habitats, adversely affecting species and ecosystems – this process is known as eutrophication. Nutrient enrichment can arise from diffuse or specific point sources. The two principal sources of nutrient enrichment causing concern are phosphorus and nitrogen compounds entering freshwater and coastal water systems, and atmospheric nitrogen deposition which affects terrestrial as well as aquatic habitats.

In the freshwater environment, phosphorus loads in heavily populated catchments come largely from domestic and industrial sources (for example sewage treatment works). In contrast, in more rural areas loads come mainly from diffuse agricultural sources (particularly run-off from fields and also leaching through soils), although small point sources (such as septic tanks) can have significant local effects (Carvalho *et al*. 2005). Agriculture's contribution to phosphorus loading varies regionally from almost 50% in the West Midlands to less than 20% in the Thames catchment (White and Hammond 2007). In terms of the nitrogen load in freshwater systems, nationally diffuse agricultural pollution accounts for 60% and sewage treatment for another 32% (ADAS 2007). Coastal waters are subsequently influenced by these freshwater sources when they enter the sea, as well as by direct point and offshore sources.

Phosphorus and nitrogen loads have been reduced through improved treatment at major sewage works under the Urban Waste Water Treatment Directive and (for SACs and SSSIs) under the Habitats Directive and national legislation. There has been a decline nationally in direct inputs (from point sources such as sewage outfalls) of phosphorus by 50% and nitrogen by 35% to coasts and estuaries since 1990 (Defra 2005a). However, riverine inputs to coasts and estuaries, mostly dominated by diffuse sources, have not decreased and there is growing recognition of the need to tackle such sources (for example Johnes, 2000, Mainstone *et al*. 2008).

The main atmospheric sources of eutrophication are oxides of nitrogen (NO_X) from industry and transport and ammonia, principally from agriculture. Ammonia forms an increasing proportion of nitrogen deposition in the UK, now accounting for 47% of the total (RI Smith, pers comm., Hall *et al*. 2006b). These ammonia emissions come chiefly from livestock production and have increased substantially in the latter half of the 20th century due to agricultural intensification. Emissions of the other main source, oxides of nitrogen, have decreased by 48% since their peak in the 1970s and the main source is now the transport sector, which contributes 39% of total emissions (National Atmospheric Emissions Inventory, 2008). Natural soil processes also emit NO_X. This may account for 2-23% of the total in Europe (NEGTAP 2001), and is likely to increase under climate change.

Across the UK, the average atmospheric nitrogen deposition (to 2001) of 14.5 kg N ha^{-1} y^{-1} is around ten times higher than in the 19th century (NEGTAP 2001). The greatest deposition is in upland areas and parts of south west England and East Anglia where it may be more than double the average, reflecting patterns of rainfall, and road transport and agricultural emissions.

Nitrogen deposition also plays a role in acidification and is now proportionately more important than sulphur compounds (SO_X) in causing the acidification of upland soils and freshwaters. Background sulphate levels in air from the Atlantic, largely due to emissions from shipping, have recently formed an increasing proportion of UK sources.

5.6.1.2 Toxic chemicals

The toxic chemicals that enter the natural environment on a daily basis include pesticides, herbicides and veterinary medicines, and industrial and other chemicals. In addition, accidental releases can result in major pollution incidents (Environment Agency 2006a), and pesticides and other biocides are still deliberately used in illegal poisonings of wildlife (Barnett *et al*. 2007).

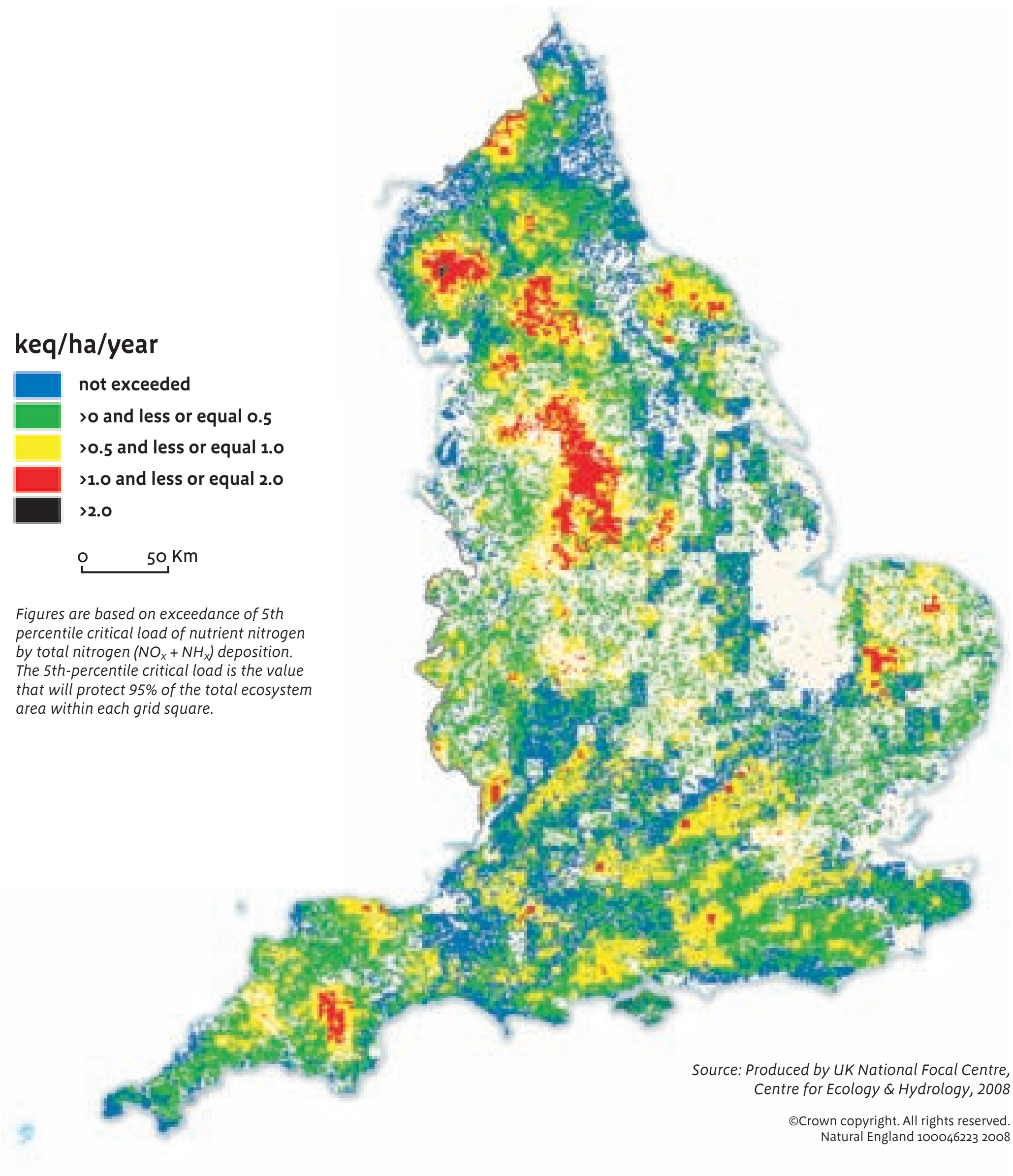
Ground level ozone is a global toxic atmospheric pollutant of growing concern, with potentially harmful effects on plant communities and agricultural crops (Morrissey *et al*. 2007). It is formed in the lower atmosphere by complex photochemical reactions between nitrogen oxides (NO_X) and reactive volatile organic compounds in the presence of sunlight. Highest levels tend to occur in the summer and there is large geographical variation across England with the highest concentrations in the South East.

5.6.2 Implications for the natural environment

5.6.2.1 Eutrophication

Eutrophication from atmospheric nitrogen deposition is now one of the major threats to ecosystems at a global level alongside climate change and biodiversity loss (eg the GANE programme (NERC 2005)). The effects of atmospheric nitrogen deposition are usually assessed in terms of exceedence of the 'critical load' (the level of exposure below which there will be no known significant harmful effects on sensitive elements of the natural environment). Critical loads for nutrient nitrogen (combined ammonia and NO_x deposition) are currently exceeded in about 89% of the area of sensitive habitats in England (J Hall pers. comm.; Hall *et al.* 2006b) (Table 5.7) with the uplands being particulary sensitive (Figure 5.9).

Figure: 5.9 Exceedance of nutrient nitrogen critical loads by total nitrogen deposition 2003-2005



Source: Produced by UK National Focal Centre, Centre for Ecology & Hydrology, 2008

Evidence exists for broad-scale vegetation changes due to nutrient deposition (Leith *et al*. 2005, Stevens *et al.* 2004). Studies have shown a general shift toward more nitrogen-tolerant plant species (Preston *et al*. 2003, Countryside Survey 2000, Braithwaite *et al*. 2006), with increases in those characteristic of more nutrient-rich soils and decreases in those characteristic of less fertile habitats. Increased dominance by grasses, especially species tolerant of higher nutrient conditions, has also been observed in the Brecklands, northern England, and the chalk grasslands in southern England. There have also been losses of lower plants, especially in upland areas (NEGTAP 2001).

Atmospheric nitrogen has further effects on plant communities, including through its contribution to acid deposition; direct toxicity of ammonia to sensitive plants; greater susceptibility of plants to feeding by invertebrates; changes in frost and drought tolerance; and changes to mycorrhizal infection rates (Achermann and Bobbink 2003;. Hall *et al*. 2006a). Close to intensive livestock units, concentrations of ammonia can be very high, with serious impacts on designated sites (Pitcairn *et al*. 1998).

Acid deposition (resulting from emissions of sulphur and nitrogen) has caused widespread acidification of acid sensitive soils and waters in the UK, as well as direct damage to sensitive plant species. According to the UK National Focal Centre for critical loads modelling and mapping, critical loads for acidity are exceeded in 71% of the area of sensitive terrestrial ecosystems in England (2003-2005 estimates) (J Hall pers. comm.). Reductions in emissions have resulted in chemical recovery in some acidified freshwaters though biological recovery has been less evident. Large areas of semi-natural habitat are likely to continue to exceed critical loads as diffuse sources of nitrogen contribute to acidity.

Routine monitoring of protected site condition is not specifically designed to assess air pollution and so the impacts of nitrogen deposition on SSSIs are underreported (JNCC 2007a). It is currently reported that air pollution is a reason for 7.8% (16,804 ha) of SSSI area in England being in adverse condition, but this is likely to be a significant underestimate. Table 5.8 sets out the extent of designated sites exceeding critical loads for nutrient nitrogen (Hall *et al*. 2006a).

Table 5.8 Designated sites in the UK exceeding critical loads for nutrient nitrogen

Site type	Area (km^2)*	Exceeded area (km^2)	Percentage exceeded area
SSSIs	21,061	14,191	67.4
SACs	14,625	9,144	62.5
SPAs	12,119	7,081	58.4

* This is the area of designated sites that occur in 1 km grid squares of the UK for which critical loads for terrestrial habitats are mapped
(Source: Hall *et al.*, 2006a)

Table 5.7 Habitats exceeding critical loads for nutrient nitrogen in England 2003-2005

Broad habitat	Habitat area (km^2)	Exceeded area (km^2)	Percentage area exceeded	Accumulated exceedance (keq/year)
Acid grassland	2,620	2,537	96.8	144,845
Calcareous grassland	3,312	2,181	65.9	68,989
Heathland	2,466	2,373	96.2	125,829
Bog	1,007	1,007	100	91,898
Montane	2	2	100	224
Coniferous woodland (managed)	1,719	1,719	100	305,765
Broadleaved woodland (managed)	5,588	5,588	100	1,123,423
Unmanaged woods (ground flora)	2,252	2,252	100	437,381
Atlantic oak (epiphytic lichens)	150	150	100	28,794
Supralittoral sediment	1,183	269	23.1	5,247
All habitats	**20,299**	**18,078**	**89.1**	**2,332,395**

(Source: CEH (J Hall pers comm), 2007)

Major risks to aquatic ecosystems arise from eutrophication due to nutrient enrichment, organic enrichment and increased fine sediment loading. Eutrophication alters the relative rates of plant growth, especially by stimulating algae, with consequences for plant communities and for overall food webs affecting invertebrates, fish, birds and mammals. Indirect impacts include oxygen depletion in the water column and in sediment, and increased turbidity; these indirect impacts often exacerbate eutrophication symptoms.

Most freshwaters in England are affected by nutrient enrichment from human activities with only a few remote upland water bodies remaining near pristine. Through a national assessment programme, the Environment Agency has made a preliminary assessment of areas of highest diffuse pollution risk. About 50% of river stretches (by length) may be at risk of failing Water Framework Directive quality objectives due to diffuse phosphate pollution (Environment Agency 2004c). Seventy per cent of the area of river SSSIs considered to be in unfavourable condition is due to diffuse pollution, mainly from nutrient enrichment due to factors such as run-off and leaching from agricultural land, and 41% is unfavourable due to a range of point-source pollutants, including nutrients. Agriculture is also a significant source of fine sediment which smothers river plants and gravels important for invertebrates and fish spawning. The England Catchment Sensitive Farming Delivery Initiative has begun to reduce agricultural diffuse pollution affecting SSSIs within priority catchments (see Section 6.6.1).

In contrast to rivers, there is less widespread quality monitoring of lakes under the Environment Agency's risk-based monitoring programme. The *Water Framework Directive River Basin Characterisation* report for England and Wales (Environment Agency 2004a) indicated that up to 53% of lakes were at risk of failing to meet good ecological status due to diffuse water pollution. The 1996 Lowland Pond Survey (DETR 1999) showed that at least 50% of ponds are highly degraded and that there is widespread evidence of enrichment and other diffuse pollution impacts. Approximately 80% of a sample of lake SSSIs were affected by eutrophication in 1998 (Carvalho and Moss 1998). This is mainly from phosphorus enrichment, but there is emerging evidence that increased nitrogen may also be having an effect in reducing submerged plant diversity (eg James *et al*. 2005). Other factors such as overstocking with bottom-feeding fish can interact with nutrient loads to cause greater problems.

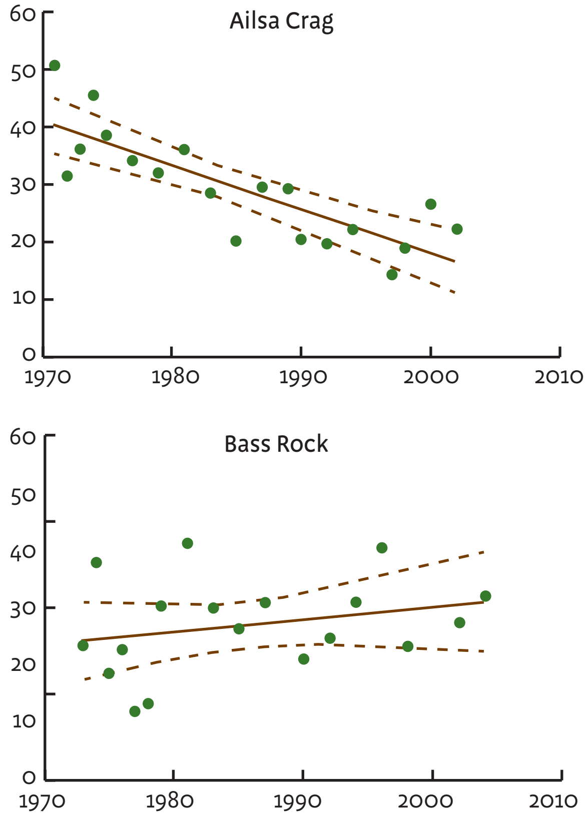
Extensive areas of the coastal waters of England are enriched by nutrients from land-based sources (Defra 2005b). The risk of eutrophication to these waters depends on their vulnerability to nutrient enrichment. Defra has identified 11 sensitive English coastal areas under the requirements of the EC Urban Waste Water Treatment Directive where there are eutrophication risks (partly from point sources) or impacts (Defra 2007h). The largest concentration is in southern England. The Environment Agency's review of Consents programme currently shows that 11 SACs and SPAs, with marine components, (approximately 15% of the England total) are impacted by or at risk from eutrophication.

5.6.2.2 Toxic chemicals
A range of chemicals affect wildlife populations. This can be via direct lethal effects (for example cypermethrin-based sheep dip pollution incidents have impacted upon populations of white clawed crayfish) (Environment Agency 2006a); endocrine-disrupting effects (such as effects on dog whelk due to exposure to tributyl tin; see also below) (Bryan *et al*. 1986, Sayer *et al*. 2006); or indirect food web effects such as pesticide impacts on farmland birds (Boatman *et al*. 2004). However, the risks to biodiversity from some 30,000 chemicals currently in use in the EU (European Commission 2007) are largely unknown.

Despite regulatory actions that have reduced emissions, some persistent, bioaccumulating and toxic substances remain a risk to the natural environment. For example, concentrations of tributyl tin (TBT, an antifoulant used to reduce the build-up of invertebrates such as barnacles on underwater surfaces) are still unacceptably high in some parts of the UK (Environment Agency 2006a), partly due to its persistence in sediments. Risks also remain due to uncertainties in chemicals authorisation processes, which largely involve evaluations of single substances and do not adequately assess the risks from chemical interactions in the natural environment, sublethal effects and their consequences for wildlife populations, or indirect effects such as those on the food chain.

As it is not practicable to monitor all chemicals, monitoring in the environment relies in part on a risk-based targeting approach and using indicators. The Predatory Bird Monitoring Scheme (PBMS 2006) monitors toxic chemicals of concern in predatory birds and their eggs. The PBMS has revealed that, despite controls over industrial and agricultural releases, mercury contamination in gannet eggs has failed to decrease across all UK colonies (Figure 5.10). It has also provided evidence of widespread exposure of predators to second-generation anticoagulant rodenticides (Figure 5.11), thereby highlighting the risk to wildlife from these compounds.

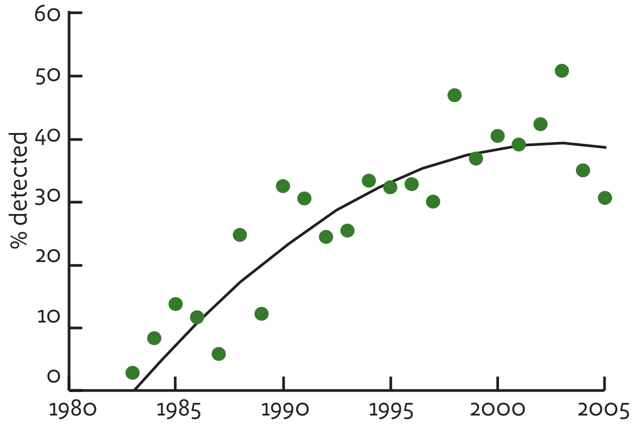
Figure 5.10 Long-term trends in mercury residues in gannet eggs (1970-2002)



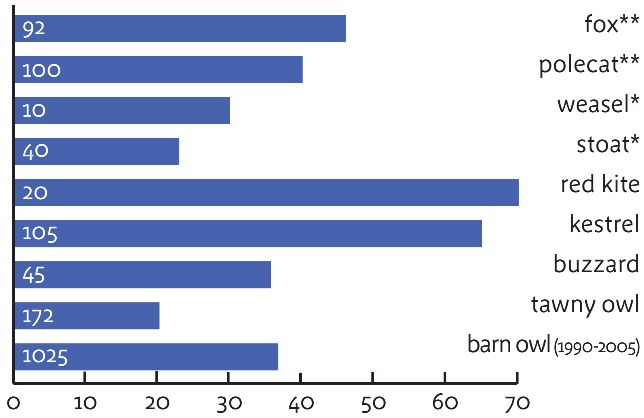
Data are derived from Scottish colonies at Ailsa Craig (west coast) and Bass Rock (east coast). Lines shown are linear relationship (with 95% confidence intervals) between mercury concentration and collection year.

(Source: Shore *et al*. 2006)

Figure 5.11 Changes in exposure of barn owls to second generation anticoagulant rodenticides (SGARs) and exposure footprint for SGARs in predators in the UK



% of barn owls with detectable liver concentrations of one SGAR. Number of barn owls analysed each year is approximately 50. Data from PBMS



% of individuals tested that had detectable liver concentrations of one or more SGAR. Numbers in white indicate number of animals tested

(Sources: PBMS-CEH, 2008, McDonald *et al.* 1998*, Shore *et al.* 2003a, 2003b**)

5.6.3 Forward look

Although significant reductions in emissions of many of the major pollutants have taken place or are planned, risks remain in certain areas. The reductions so far may not sufficiently lower the risk to sensitive habitats and species or to designated sites. For atmospheric pollutants, reductions in point source emissions by 2010 are expected under the EC National Emissions Ceiling Directive. There is no equivalent programme to tackle diffuse atmospheric sources (Fraser and Stevens 2007), although the European Commission is likely to set tighter limits for a range of atmospheric pollutants to be met by 2020. Even with these reductions, critical loads for acidity and eutrophication are likely to continue to be widely exceeded (Hall *et al.* 2006b).

Changes to regulation such as the Water Framework Directive and REACH (Regulation, Evaluation, Authorisation and Restriction of Chemical substances) will improve our understanding of the risks associated with a number of toxic chemicals, and will also aim to phase out, reduce or substitute the most hazardous (European Commission 2007). However, it is likely that most effort will continue to be aimed at controlling single substances, and the environmental risks of complex mixtures will remain unclear.

Population pressure and climate change will affect future pollution risks to the natural environment. Population increase will place further pressures on sewage infrastructure. Likely increased demand for water may result in reduced river flows and water levels, exacerbating the impact of higher nutrient levels in the aquatic environment (Environment Agency 2007a). Climate change projections suggest an increase in intense rainfall events, generating greater surface run-off with associated increased loads of phosphorus and fine sediment. Decreased river flows in hotter, drier summers would reduce flushing capacity and exacerbate the impacts of higher nutrient levels, with increased temperatures stimulating plant growth, and algal build-up resulting in impacts on biodiversity.

The impacts of toxic chemicals on the natural environment are likely to be affected by climate change in a number of ways, both directly (for example higher temperature changing chemical behaviour) and indirectly through changes in use, availability and management of land and water. For example, changes in the occurrence and spread of plant pests and diseases are likely to result in alterations in pesticide usage. Increased storm events and management of water bodies could increase disturbance of historically contaminated sediment in estuaries, increasing risks to aquatic wildlife. The impacts of air pollutants on ecosystems may be modified through climate change in a number of ways, for example, via changes in plant uptake of pollutants, effects on soil microbial activity, and on soil mineralization rates (Defra 2007b). Critical levels for ozone effects on vegetation are already widely exceeded (Coyle *et al.* 2002), and background emissions of precursors in the northern hemisphere are increasing. Ground level ozone concentrations are expected to change in complex ways in response to emission controls and to climate change. Hotter summers may increase the frequency of high ozone episodes (Morrissey *et al.* 2007).

5.7 Overview

Many risks and pressures on England's natural environment are well-documented and their future impacts can be predicted with some confidence, although others are less clear. A large body of evidence makes it clear that pollution remains a major risk and also helps to underpin actions such as on catchment-sensitive farming. We have clear evidence about a range of invasive species and their impacts on the environment. More widely the scale and impact of expected increases in population and development are clear. While we understand the marine environment less well than the terrestrial, the impacts of practices such as commercial fishing on species and habitats are well-documented.

Climate change provides new risks and pressures, both on the natural environment and how it is viewed and managed. It affects other risks: for example, warmer temperatures encourage the spread of new invasive species and diseases. Concerns about climate change affect energy issues, resulting in uncertainties and risks associated with new development and technologies. There are opportunities as well as risks associated with changing land use in response to the growth of biofuels. While a body of evidence is building about the direct effects of climate change, especially on coastal environments, we need a more complete picture of its likely impact under the range of scenarios currently expected. We will need this picture as we shape our vision for the natural environment and the types of land use and land management that will deliver it.

Chapter 5 Pressures and risks

Evidence gaps

Areas where we believe we need more evidence on the condition of England's natural environment, how it is used and the most effective mechanisms to address the challenges we face.

1. **Evidence on the geographical distribution of pressures on the natural environment.**
2. **Evidence on environmental capacity and cumulative impacts from multiple pressures.**
3. **More evidence on the impacts of pressures, including climate change, on the natural environment (terrestrial and marine) at a regional as well as national level; identifying areas most vulnerable to climate change.**
4. **Better, more systematic, recording of non-native invasive species.**
5. **Evidence on uptake of renewable energy options and impacts on the natural environment.**
6. **Evidence on global, national and regional pressures driving land use change.**
7. **Sufficient horizon scanning and futures capacity focussed on the natural environment to identify pressures at an early stage.**