Chapter 3:
The Drivers of Change in UK Ecosystems and Ecosystem Services

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Key Findings*

The majority of human influences have driven a decline in both extent and condition of the ecosystems assessed in the UK National Ecosystem Assessment[1]. The exceptions are Enclosed Farmland, Woodlands and Urban ecosystems, where a number of drivers have caused an increase in ecosystem extent. Typically, economic growth and advances in science and technology, coupled with changes in policy, have increased the area of these ecosystems at the expense of others. Of all drivers, habitat and land use change, pollution and nutrient enrichment, and the overexploitation of natural resources have been consistently identified in this assessment as having a major impact on ecosystem extent and condition and service delivery, possibly reflecting the high proportion of managed land within the UK.

[1] *well established*

Many of the legislative changes that have occurred since 1945 have succeeded in increasing human well-being and limiting ecosystem change. For example, recognition of the negative impacts of poor air quality caused by energy production on human health and well-being, led to the introduction of the Clean Air Act of 1956. This, and others that followed, reduced pollution levels[1]: sulphur deposition in the UK has declined by 70% since the 1970s. There has also been a reduction in the exceedance of critical loads for acidity from 71% to 51% in the same time period. While these indirect drivers were largely driven by the desire to reduce damage to human health, they have also acted to limit potential ecosystem change.

[1] *well established*

In the absence of regulation, market forces, sometimes in combination with production support mechanisms, have led to unsustainable exploitation of natural resources and the prioritisation of a single ecosystem service above others. For example, entry into the European Union Common Agricultural Policy in 1973, coupled with intensive land use, led to overproduction of foodstuffs, and did not foster substantial increased human well-being[1]. Commercial UK marine fisheries also maximised short-term production beyond sustainable levels[1]. However, overexploitation has been addressed by the development of multi-objective policies and changes in the support for agriculture and forestry that reward environmental sustainability. Enforced changes to fisheries regulation policy is also leading to the recovery of some UK fish stocks. For instance, the number of UK fisheries that are at full reproductive capacity and are sustainably harvested has recently increased from 5–10% in the 1990s to 50% in 2008.

[1] *well established*

Key direct drivers of change include: habitat modification as a result of alterations in land use and the use of the marine environment; the overexploitation of terrestrial and marine resources; and air and water pollution. Semi-natural vegetation continued to be converted to agricultural land within the UK from the 1940s to the 1990s[1]. Harvest and resource consumption have had important effects on cultural and supporting services and marine ecosystems, for example through overfishing. Inputs of chemicals and nutrients from agriculture and pollution have had important effects on provisioning, regulating and supporting services, and within many ecosystems, causing, among other things, changes in species composition. To date, non-native, invasive species and climate change are thought to have had relatively little impact on ecosystems and ecosystem services; however, the latter is predicted to be a major driver of future change.

[1] *well established*

The principal drivers shaping ecosystems vary geographically across the UK. Lowland landscapes have become less diverse as farming has become more intensive, large-scale and specialised; whereas the uplands have been subject to high livestock densities and levels of pollution deposition[1].

[1] *well established*

* Each Key Finding has been assigned a level of scientific certainty, based on a 4-box model and complemented, where possible, with a likelihood scale. Superscript numbers and letters indicate the uncertainty term assigned to each finding. Full details of each term and how they were assigned are presented in Appendix 3.1.

There are still significant gaps in our knowledge of what drives ecosystem change and the impacts that changes within ecosystems have on the services they provide. In terms of services, effects on provisioning services are generally well-understood, and are closely followed by our knowledge of effects on regulating services. But much less is known about what affects cultural and supporting services. In many cases, multiple drivers of change are acting on ecosystem service delivery. Often the state of knowledge of the impact of each driver varies, and the combined impact of multiple drivers on an ecosystem service is likely to be difficult to predict.

The direction of change can be successfully guided where strong regulation, legislation and support mechanisms act in conjunction with market forces. Woodland cover has doubled since 1945 in response to Forestry Commission grants and favourable economic and tax conditions[1]. Also, recent agri-environment schemes have been successful in increasing biodiversity in targeted areas: there has been a 145% increase in breeding pairs of cirl bunting (*Emberiza cirlus*) from 1993 to 2009, and a 140% increase of calling male corncrake (*Crex crex*) during the same period[1]. It is often the 'invisible' indirect drivers (e.g. forestry subsidies, demographic change, industrialisation, policy development) whereby society can have the most influence on the direction of environmental change. Therefore, an understanding of the linkage between indirect and direct drivers is critical to any effort to alter or guide the future direction of change.

[1] *well established*

3.1 Introduction

Drivers are the factors, be they natural or human-induced, which cause ecosystem change (Nelson *et al.* 2005). Drivers, as defined by the Millennium Ecosystem Assessment (MA) may be one of two types: direct or indirect. *Direct drivers* have an explicit effect on ecosystem processes (Nelson *et al.* 2005), usually causing physical change that can be identified and monitored (Ash *et al.* 2008). *Indirect drivers* operate more diffusely by altering the level or rate of change of one or more direct drivers (Nelson *et al.* 2005; Ash *et al.* 2008).

It is evident that habitats throughout the UK have changed significantly since the Second World War (WWII; Chapters 5–12). The purpose of this chapter is to provide an overview of the key drivers that have been instrumental in causing such change, and the subsequent effects on the ecosystem services that they provide, while acknowledging that much change may have occurred before this period. Understanding what drives these changes is important in the development of mechanisms, through policy or other means, to influence these drivers and ensure essential ecosystem services can be sustained.

However, it is important to note early on that assessment and management of drivers of change can be complicated for two reasons. Firstly, drivers can affect ecosystem services, and consequently human well-being, at different spatial and temporal scales. Often data may not be available at all scales, or drivers important at one time and place may not be important at a larger (or smaller) scale or over longer (or shorter) time periods (MA 2005b). Secondly, drivers do not act in isolation, but more frequently interact—the pressure from one, exacerbating the impacts of another (CBD 2010). Therefore, an understanding of the linkage between direct and indirect drivers is critical in order to alter or influence future directions of change.

This chapter is structured by first providing an overview of which drivers have had the greatest impact on UK ecosystems and services, and briefly exploring how they inter-relate. We then examine each driver in greater detail, focusing first on the indirect drivers, and second on the direct drivers. For each driver, we will consider trends through time (where possible) and their impact on the extent and condition of the eight Broad Habitats identified by the UK National Ecosystem Assessment (UK NEA) in each of the four constituent countries of the UK (England, Scotland, Wales and Northern Ireland) to provide a picture of how drivers influence the UK as a whole.

As this chapter aims to provide a UK-wide summary of the drivers influencing change, we will, at times, draw on information presented in the habitat and ecosystem services chapters (Chapters 5–16), and may refer the reader to these sections for further details on particular impacts. It should also be noted that this chapter does not include forward projections of how these drivers may change in the future. This is covered in Chapter 25 and Chapter 26, which examines the response of UK ecosystems and their services under six different future sociopolitical and economic ideologies.

3.2 Overview

The combined impacts of various direct and indirect drivers have resulted in significant changes in Broad Habitats throughout the UK since WWII. The key indirect drivers of change which have resulted in significant changes (both positive and negative) in habitats and well-being are:

- Demographic changes
- Economic growth
- Sociopolitical changes, especially in policies
- Cultural and behavioural changes
- Advances in science and technology.

In turn, these have influenced the following direct drivers:

- Habitat change (particularly conversion of natural and semi-habitats through land use change or change in the use of the marine environment)
- Nutrient enrichment and pollution of air, land and water
- Overexploitation of terrestrial, marine and freshwater resources
- Variability and change in climate
- Introduction of invasive alien species.

It is important to understand how these drivers have interacted to bring about change across the UK. These relationships are typically complex; however, we seek to unravel these complexities in this chapter, and provide examples of the interrelatedness of these drivers.

Between the 1940s and 1990s, there was widespread conversion of various semi-natural habitats, such as some grasslands and saltmarshes, to arable land, stimulated by increased demand (due to a growing population and rising wealth) and agricultural production subsidies. Coupled with the intensification of agricultural production and use of agrochemicals, this has resulted in a significant increase in food production. This growth, however, has been at the expense of biodiversity and has caused the degradation of some regulating, supporting and cultural services. Activities other than agriculture, such as the increased demand for water, and air and water pollution from the production and use of energy, have also impacted on UK habitats and ecosystem services.

The drivers described have also interacted in different ways across the UK. For example, lowland landscapes have become less diverse as farming has become more intensive, large-scale and specialised; whereas the uplands have been subject to high livestock densities and levels of pollution deposition. Impacts have changed over time as well, particularly in response to policy changes. For example, while traditional UK and European Union (EU) agricultural production subsidies (such as the Common Agricultural Policy (CAP)) stimulated increased agricultural production, resulting in the conversion of semi-natural ecosystems and the degradation of biodiversity and non-provisioning services, recent reform of such policies means that they now also increasingly support environmentally sustainable practices, particularly through agri-environment schemes. These changes have been linked to, at least in some cases, improving levels of biodiversity and ecosystem sustainability. Falling livestock numbers has also reduced green-house gas emissions.

The direct and indirect drivers vary in their importance in influencing change within and amongst ecosystems and ecosystem services, and in the extent to which their impact is increasing as time goes on. Such patterns could be examined for both types of drivers, but are most easily discerned for direct drivers. In the UK, habitat and land use change, and pollution and nutrient enrichment have had the greatest effect on condition and extent of all habitat types, and are generally thought to have a continuing or increasing impact (**Figure 3.1**). Exploitation of resources has also strongly impacted on all but the Urban and Coastal Margins habitats, as have invasive species, although to a somewhat lesser extent. However, it is thought that the impacts of both these drivers are only going to intensify in the coming decades. To date, climate change has had little impact on ecosystem extent or condition, except in the Mountains, Moorlands and Heaths, Coastal Margins and Marine habitats, where for example shifts in both terrestrial and marine species have been observed (Chapter 4; Chapter 12), yet in all cases it is thought that climate change will be a major driver of change in the future.

In regards to ecosystem services, habitat and land use change, and over exploitation of resources were consistently identified as the major drivers impacting service delivery (**Figure 3.2**). Pollution and nutrient enrichment are also important drivers, although their impact varies both within and between services. Climate variability and invasive species were rarely identified as major drivers of change in ecosystem services, but again, climate change is predicted to be a major driver in the future.

The state of knowledge on different drivers varies, being particularly poor for cultural and behavioural drivers. As a result of these data gaps, it can be difficult to ascertain or predict how multiple drivers will impact on ecosystems and ecosystem services. On an individual basis, the way in which drivers impact upon provisioning services is relatively well understood, followed by a reasonable understanding of the impacts on regulating services, but there remains poor knowledge of the impacts on cultural and supporting services.

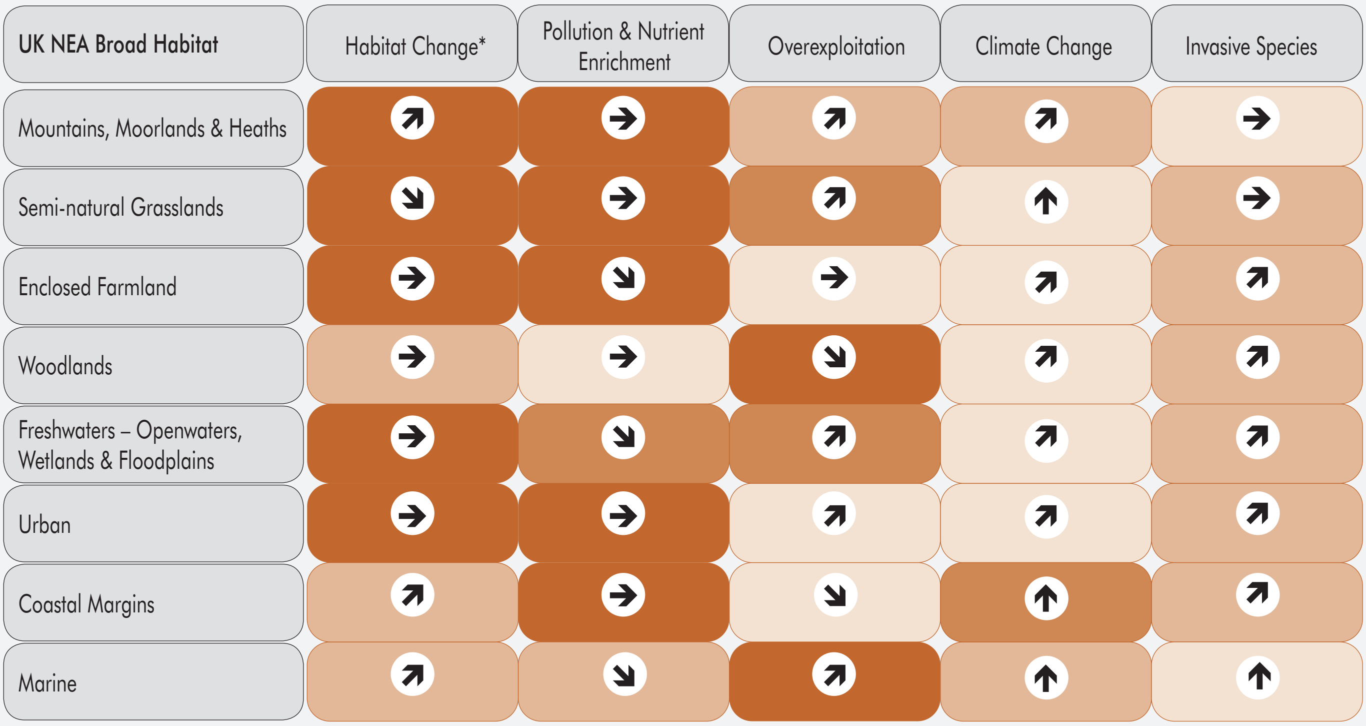
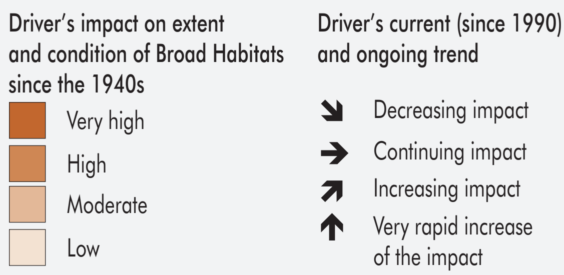


Figure 3.1 Relative importance of, and trends in, the impact of direct drivers on UK NEA Broad Habitat extent and condition. *Cell colour* indicates the impact to date of each driver on extent and condition of Broad Habitats since the 1940s. The *arrows* indicate the current (since the 1990s) and ongoing trend in the impact of the driver on extent and condition of the Broad Habitat. Change in both impacts or trends can be positive or negative. This figure is based on information synthesised from each Broad Habitat chapter of the UK NEA Technical Report (Chapters 5–12) and expert opinion. This figure presents UK-wide impacts and trends, and so may be different from those in specific sub-habitats or regions; however more details can be found in the individual Broad Habitat chapters. *Habitat change can be a result of either land use change or deterioration/improvement in the condition of the habitat.



Service Group	Final Ecosystem Service	Habitat Change*	Pollution & Nutrient Enrichment	Overexploitation	Climate Change	Invasive Species
Provisioning	Crops	Very high →	High →	Low →	Low ↗	Low →
	Livestock	Very high →	High →	Moderate →	Low ↗	Moderate ↗
	Wild fish	Very high ↗	Moderate ↘	Very high →	Moderate ↑	Moderate →
	Farmed fish (aquaculture)	High →	Moderate →	Moderate ↗	Low ↗	Low ↗
	Timber	Very high ↗	High →	Very high ↗	Low ↑	High ↑
	Water	Moderate →	Very high ↗	Very high ↗	Low ↑	Low ↗
	Peat	Very high →	Low →	High ↘	Low →	Low →
	Wild game	High ↗	Moderate →	Moderate ↘	Low ↗	High →
	Honey	Low ↗	Low →	Moderate ↗	Low ↑	Moderate ↑
	Ornamentals	Moderate ↗	Low →	High ↗	Low ↗	Low →
	Genetic resources	High →	Low →	Moderate ↗	Low ↗	Very high →
	Wild species diversity	Very high ↗	Very high ↘	Very high ↗	Moderate ↑	High ↗
Cultural	Environmental settings	Very high ↗	High →	Moderate →	Low ↗	Moderate ↗
Regulating	Climate	Very high →	High →	High ↘	Moderate ↑	Low →
	Hazard	Very high →	Low →	High ↗	Moderate ↑	Moderate ↗
	Disease and pests	Very high →	Moderate →	Moderate ↗	Moderate ↗	High ↗
	Pollination	Very high →	High →	Low →	Low ↗	Very high ↗
	Noise	Very high →	Low →	Moderate ↗	Low →	Low →
	Water quality	High →	Very high ↘	High →	Low ↗	Moderate →
	Soil quality	Very high →	Very high →	High ↘	Low ↗	Low →
	Air quality	Very high →	Very high ↘	High →	Moderate ↑	Low →
Supporting	Soil formation	Very high ↗	Very high ↘	High ↗	Low ↑	Low ↗
	Nutrient cycling	High →	Very high →	Moderate →	Low ↗	Low →
	Water cycling	Very high →	Low ↗	High ↗	Moderate ↑	Low →
	Primary production	Very high →	High →	Moderate →	Low ↑	Low →

Figure 3.2 Relative importance of, and trends in, the impact of direct drivers on UK ecosystem services. *Cell colour* indicates the impact to date of each driver on service delivery since the 1940s. The *arrows* indicate the current (since the 1990s) and ongoing trend in the impact of the driver on service delivery. Change in both impacts or trends can be positive or negative. This figure is based on information synthesised from the biodiversity and ecosystem service chapters of the UK NEA Technical Report (Chapters 4 and 13–16), as well as expert opinion. This figure presents UK-wide impacts and trends, and so may be different from those for specific final ecosystem services; however more details can be found in the biodiversity and ecosystem service chapters. *Habitat change can be a result of either land use change or deterioration/improvement in the condition of the habitat.

Driver's impact on ecosystem service delivery since the 1940s
- Very high
- High
- Moderate
- Low

Driver's current (since 1990) and ongoing trend
- ↘ Decreasing impact
- → Continuing impact
- ↗ Increasing impact
- ↑ Very rapid increase of the impact

3.3 Indirect Drivers of Change

Indirect drivers interact with other driving forces in complex ways, including at different spatial and temporal scales, to change pressures exerted on ecosystems and their associated services (MA 2005b). For example, society may exhibit a new preference for certain food types. Such change can act as an indirect driver, altering market demands and hence causing landowners to employ different farming practices like switching from arable- to pastoral-dominated farming or increasing the use of fertilisers to improve yield. This, in turn, may have associated impacts on different ecosystems. As such, indirect drivers rarely act in isolation, and identifying causal links between specific drivers and specific ecosystem changes is seldom possible. However, for the sake of clarity, we will examine each driver separately, recognising that this is a simplification and that driving forces are usually multiple and interactive (MA 2005b). We will discuss five indirect drivers that have been identified as causing change in UK ecosystems and the services they provide: demographic, economic, sociopolitical, cultural, and science and technology.

3.3.1 Demographic Drivers

Population size and consumption patterns (which may vary between age groups, living arrangements and geographic regions) are important variables which influence trends in ecosystem condition (Nelson *et al.* 2005). In turn, these are regulated by available resources, how they are allocated (economic, social and cultural drivers), and the changes in technology that enable the conversion of raw materials into goods and services used by humans (scientific and technological drivers) (Nelson *et al.* 2005). In this section, we will focus on how population growth, demographic change and migration have changed in the UK since WWII, and the consequences these changes have had on ecosystem services.

3.3.1.1 Population growth and distribution

Between 1951 and 2009, the UK population increased by 18% from 50.3 million to 61.8 million people (Jefferies 2005; ONS 2010b; **Table 3.1**). The rate of growth has been variable during this time period, ranging between 0.5–5% per decade (Jefferies 2005). Up until 1998, population growth was primarily due to natural increase (i.e. a greater number of births than deaths); however, since 1998, net migration has been the main contributor (66%) to the increase in population size (Section 3.3.1.3).

Population size and growth varies throughout the UK: with 85% of the UK's population, England has the greatest number of people, followed by Scotland (8%), Wales (5%) and Northern Ireland (3%) (Jefferies 2005; ONS 2010b). Between 1971 and 1981, the fastest growing population was in Wales (2.7% per decade compared to 0.8% for the rest of the UK); in the 1980s, however, the fastest growing population was in Northern Ireland—a trend which continued between 1991 and 2001 (5% increase compared to 3% for the UK). Meanwhile, the population in Scotland has decreased from 5.2 million to 5.1 million during the whole of this period (1971 to 2001).

England is also the most densely populated country (385 people/km^2). Wales and Northern Ireland have similar, but substantially lower, density figures (126 and 142 people/km^2, respectively), while Scotland is the least densely populated country (65 people/km^2) (Shaw & Jefferies 2005).

3.3.1.2 Population demographics

The UK's population is ageing: the current median age is 38.6 years, compared to 34.1 in 1971—an increase of 4.5 years in just three decades (Jefferies 2005; Smith *et al.* 2005; ONS 2010a). Between 1984 and 2009, the proportion of the population aged 65 years and over rose from 15% to 16%—an increase of 1.7 million people. Conversely, the proportion of the population aged 16 years or younger decreased from 21% to 19% during the same period (ONS 2010a). The fastest growing group is the 85 years and over age group, which doubled from 600,000 in 1983 to 1.4 million in 2009 (ONS 2010a). In general, Scotland and Wales tend to have an older demographic, whereas Northern Ireland has a younger one, and England sits in between (Jefferies 2005; Smith *et al.* 2005). However, Northern Ireland's population is aging the fastest of the four component countries, and will continue to do so. Differences in patterns between countries arise due to different patterns of fertility and improvements in mortality at older ages (Smith *et al.* 2005).

The main contributing factors to this change in population structure are low fertility and mortality rates (**Table 3.1**). For example, in 2009, the Total Fertility Rate (TFR) in the UK was 1.94 children per woman, which is below the level needed to

Table 3.1 Population change ('000) and its components in the UK, 1993 to 2008. Source: adapted from Jefferies (2005) and ONS (2010b).

		Components of change (mid-year to mid-year)					
Mid-year to mid-year	Population at start of period	Total change	Births	Deaths	Natural Change*	Net Migration and other changes†	Population at end of period
1993–1994	57,714	148	763	651	112	+36	57,862
1998–1999	58,475	210	711	634	77	133	58,684
2003–2004	59,522	+290	707	603	+104	+186	60,235
2008–2009	61,398	+394	787	570	+217	+177	61,792

* Natural increase refers to the excess of births over deaths in that year. Natural decrease refers to the excess of deaths over births.
† Net migration and other changes refers mainly to international migration. Other small changes include changes in the numbers of armed forces.

replace the population (2.1 children per woman). The TFR has varied through time, peaking at 2.93 in 1964; but since 1973 it has been below 2.1 (Chamberlain & Gill 2005). Life expectancy, on the other hand, has risen: between 1950 and 2008, it increased from 66 to 78 years for men, and 71 to 82 years for women (ONS 2010a).

3.3.1.3 Migration and ethnicity

The arrival of international migrants into the UK has risen substantially since the early 1990s, in particular since the expansion of the EU in 2004 which enabled a greater freedom of movement into the UK for non-UK European citizens. For example, in 2004, 582,000 people migrated to the UK compared to 314,000 in 1994 (Jefferies 2005). The net flow of migrants has been variable over the last 30 years: between 1975 and 1982, the net flow was 300,000 people; between 1983 and 1993, it was 240,000; but between 1994 and 2004 there was a substantial increase in net flow to 1.4 million people (Jefferies 2005; see **Table 3.1**).

Migrants have arrived from a variety of countries; however, the majority have originated from the EU, with numbers showing an increasing trend over time (75,000 in 1994; 123,000 in 2003). Immigrants from the Middle East have also increased (12,000 in 1994; 27,000 in 2003) and there has been a net inflow from Australia since the late 1990s (Jefferies 2005). Ninety per cent of migrants chose to live in England (primarily in London (30%) and the south-east (18%)), followed by Scotland (7%), and Wales and Northern Ireland (2% each). A primary factor driving international migration to the UK is economics: about 20% of migrants who arrived between 1994 and 2003 citied their reason for moving as 'work', although there has also been a 37% increase in the number of people arriving to study (50,000 in 1994; 135,000 in 2003).

Over the past 80 years, the trend in migration within the UK has been for people to move to southern England (Champion 2005; **Figure 3.3**), particularly to coastal villages and retirement districts in the south-west peninsula and along the south coast. There has also been significant migration, in both directions, between urban and rural areas. As an illustration of this point, areas like East Anglia, Lincolnshire and cities on the fringes of the main urban centres of the Midlands and the north of England have seen population growth, while much of western Northern Ireland, northern Scotland, south-west Scotland, Glasgow and several large English cities such as Liverpool and Birmingham, have seen population reductions (Champion 2005). The younger and/or 'skilled' workforce sections of the population tend to migrate to urban areas, while families and the older section of the population are more likely to move to rural areas (Champion 2005).

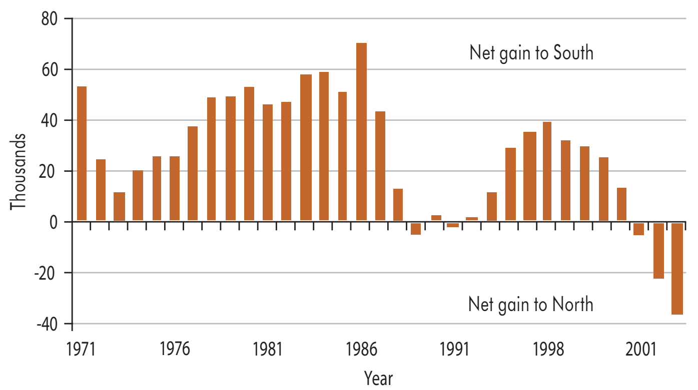


Figure 3.3 Net migration between the North* and South of the UK from 1971 to 2003[†]. *The South comprises the Government Office Regions of London, South East, South West, East and East Midlands; 'the North' is the remainder of the UK. [†]Data refer to calendar years. Source: data from National Health Service Central Register; General Register Office for Scotland; Northern Ireland Statistics and Research Agency; figure reproduced from Champion (2005).

3.3.1.4 Consequences of demographic change on UK NEA Broad Habitats and ecosystem services

Demographic changes have impacted on all UK habitat types and ecosystem services, and have led to increased urbanisation. The increasing population of the UK, combined with a rise in the number of single-person households (in Great Britain (GB) from 12% to 29% between 1961 and 2004 (Jefferies 2005)), has placed increased pressure on land conversion for housing, and has created higher demands on water and energy resources, hence having the potential to contribute to future climate change. Such pressure is particularly strong in the south-east of England where population growth and migration have been greatest. Here there is potential for the following:

i) Loss of local provisioning services when high quality farmland is used to house the growing population;
ii) Loss of supporting services, such as soil formation, through the construction of new buildings and the use of non-permeable surfaces; and/or
iii) Loss of regulating services, such as those provided by natural coastal sea defences, when an increase in building exacerbates coastal squeeze (i.e. the reduction and loss of coastal habitat that occurs when natural landward migration of a habitat is prevented by man-made defences and structures).

However, these potential losses can be counteracted, in part, by policy which favours the re-use of previously built land known as 'brownfield'. This has already been demonstrated in England where, although the density of dwellings erected has increased since 1989—from about 25 to 43 dwellings per hectare (ha)—the proportion built on previously developed land had increased from around 55% to 80%, while that on previously agricultural land has reduced from almost 30% to just 14% in 2009 (Planning Statistical Release 2010).

However, the relative impact of these demographic changes on provisioning services at least, has been low compared with other drivers of environmental change. For example, while population increase can be expected to drive provisioning services, such as crops and livestock production, the rates of such service increase in the UK have been far higher than the population increase would have required (Chapter 15). Therefore, it is clear that other drivers, such as economic (e.g. market forces) and sociopolitical (e.g. consumption choices and subsidies) factors, have been more important in impacting on service delivery.

3.3.2 Economic Drivers

Patterns in economic activity often reflect the actions which we take to improve our own well-being (Nelson *et al.* 2005). Economic activity, as described by the MA, "is influenced by the endowment of natural resources, including ecosystem services (natural capital), the number and skills of humans (human capital), the stock of built resources (manufactured capital), [the] nature of human institutions, both formal and informal (social capital)...and by available technologies, [which may] be enhanced by access to international markets" (Nelson *et al.* 2005 p82–83).The latter can change which activities take place at home and the variety of items available for consumption.

The economic drivers affecting UK ecosystems have altered over the last 60 years as the economy has grown (reflected by an increasing trend in Gross Domestic Product) and transformed from an industrial-based to post-industrial service-based economy; currently, developments are towards a low-carbon, high technology-based economy. Market forces at play within the environment have altered as wealth has increased and consumption choices have changed. Typical business and industry sizes have grown, reflecting the development of larger industry bases and the impact that the growth of multinational companies and globalisation have had on the flow of trade and market conditions for many commodities. These drivers are closely related to cultural and demographic drivers, in addition to scientific and technological developments. Economic drivers impact ecosystems by their close association with land and sea use, as well as pollution and exploitation levels as landowners and managers react to market conditions. These economic drivers operate spatially across the whole of the UK but their impact has become more uniform over time as the economic environment, both in the UK, and the world generally, has become more globalised. Hence, in this section, we will discuss economic growth and consumer choice, market forces, and industry size and globalisation.

3.3.2.1 Economic growth and consumer choice

Personal and family wealth in the UK has increased significantly since the 1940s (ONS 2009). The proportion of average family expenditure on essential items, such as food, has decreased, leaving money available to spend on luxury items, travel and leisure. It should also be noted that this improved wealth, combined with population growth and a more general drive towards consumerism (including non-luxury items), has increased the overall level of consumption in society (i.e. the material through-put). Additionally, as spending ability has increased, the origin of consumed items has become ever more global, and the type of products purchased has altered in line with technological developments. Therefore, the potential for proactive consumer choice to drive ecosystem change has been established. For instance, the increase in the demand for organic products (**Figure 3.4**) may act as an incentive for farm conversion and the change of management practices; however, evidence for the full extent of such changes on ecosystem condition and extent are limited.

3.3.2.2 Market forces

Market forces can influence the proportion of land or marine areas managed under different uses (for example, the type and variety of agricultural crops grown, the area of land used for forestry, or the scale of fishing activities), and thereby influence the provision of final goods and benefits. They also affect the way urban land is used, particularly demands for the development of housing and office space.

In recent years, specialist crops, cereals and dairy farming have seen a greater increase in net farm income in the UK than livestock-grazing or mixed farms (Clothier *et al.* 2008; Defra 2010b,c). This has influenced land use management decisions, and, in particular, resulted in greater parcels of land designated for 'set-aside' (when this practise was in place), which may facilitate increased biodiversity. Likewise, economic support and the profitability of producing organic crops and/or high welfare meat from conservation grade farms have influenced management practices. For example, there are now 7,567 organic producers in the UK, a 20% rise on numbers in 2004 (6,038) (Defra 2010d).

Imports and exports to a country reflect dominant market forces and consumer choice. Since the 1960s, the UK markets, as indicated by imports, showed an increase in demand for fruits (+260%), vegetables (+355%) and alcoholic drinks (+526%). Decreases were observed in the import of cereals (-45%), perhaps due to an already sufficient supply within the UK. Although timber exports of sawn wood in 2009 were 15 times greater than those in 1961 (1961: 14,300 cubic metres (m^3), worth USD$1.5 million, or equivalent to £900,000 in today's terms; 2009: 203,000 m^3, worth £41 million; Forestry Commission 2010b; FAOSTAT 2011a), higher levels have not been attained due to strong competing markets from abroad. The relatively low value for UK timber has reduced the amount of woodland in the UK felled for timber products, and has instead increased the number of woodlands managed for recreation and conservation purposes (Chapter 8).

Market forces in the marine environment have driven high, and often unsustainable harvest levels of economically important species. High returns have also promoted diversification into new areas such as harvesting fish for aquaculture feed and fertiliser.

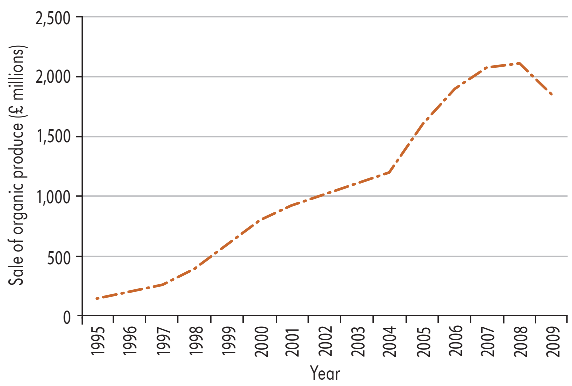


Figure 3.4 Sale of organic produce in the UK, 1995 to 2009. Source: data extracted from Cottingham & Perrett (2010).

3.3.2.3 Industry size and globalisation

Since the 1940s, the business landscape has changed. As global trade increased, the growth of large, chain business and multinational companies expanded to form the globalised economy we see today, where a relatively small number of large companies dominate certain markets and enterprises, including agriculture and food. The scale of business development has paralleled increases in transport infrastructure such that the domestic agriculture, forestry and fisheries trades are linked to European and global markets. These drivers link to consumer choices, market forces, land and sea use, pollution, and exploitation levels of natural resources. Market forces and the move to globalised and larger industries can also be argued to have caused the reduction of cultural services, especially landscapes and seascapes due to the promotion of certain aspects, such as large, uniform field patterns and simplified cropping, which are deemed to detract from the local character.

3.3.3 Sociopolitical Drivers

Sociopolitical drivers operate in connection with economic and cultural drivers. They illustrate the different values that society places on the environment, and how trade-offs between such values are managed. As such, sociopolitical drivers have been identified as some of the most fundamental factors behind the way in which humans influence the environment, although much research still needs to be conducted in order to fully understand how these drivers operate and interact (Nelson *et al.* 2005).

Over the past 60 years, the sociopolitical system within the UK has changed, leading to important consequences for ecosystem condition, extent and delivery of services, primarily in a positive direction. This has been due to the evolution and development of legislation protecting a wider range of public benefits, and the shift in agricultural and forestry support mechanisms from single-focus schemes that promoted large yields and returns, to more multi-objective land use regimes that support diversification, environmental management and amenity; such changes have often been brought about by societal pressure on government. Accordingly, changes have had strong impacts on direct drivers such as land conversion and resource consumption.

Sociopolitical drivers tend to operate across the whole of the UK. However, increasingly, the way legislation is implemented differs between each devolved administration, as well as the relevant agencies and regulatory bodies, and hence impacts may differ between each constituent country (Chapters 17–20). In this section, we will discuss legislation, regulation and support mechanisms, highlighting the consequences these drivers have had on the UK's ecosystems and their services.

3.3.3.1 Legislation, regulation and state versus private relationships

Legislation and regulation. As society has become more aware and concerned about environmental change, legislation and regulation has been developed and implemented to protect human well-being and, consequently, ecosystem health. Following the pioneering Clean Air Act of 1956, a range of legislation has been developed that limits private development rights and increasingly values the common rights of society and the environment (**Table 3.2**). Themes in this developing legislation have included: pollution control and emissions regulation; protection of amenity and natural beauty; provision of access rights; and ecosystem and species protection.

As regulation and legislation has developed there has been a concurrent increase in the scale of responsibility of actions from the individual to society, from local to global, and from reacting to short-term events to assessing the potential impacts of actions over much longer periods (decades or even centuries). There is now regulation of a wide range of human activities with the overarching objective of protecting or enhancing current and future environmental conditions. Some examples are discussed:

- *Pollution and emissions control*: Pollution control legislation at a national and international level has set standards for air and water pollution levels which, through regulation, monitoring and enforcement by country agencies, have enabled pollution emissions to be tracked and dramatically reduced (Section 3.4.2).
- *Conservation and protection of nature and ecosystems*: Legislation aimed at nature conservation has led to the designation of areas of land under national (e.g. Sites of Special Scientific Interest (SSSIs)) and international (e.g. Special Areas of Conservation (SACs); Special Protection Areas (SPAs)) designations. These designations exist to protect rare habitats and species, and can provide incentives for ecological restoration or management. Some marine habitats are also covered by such legislation, but there are still large areas that are afforded no protection at all (Chapter 12).
- *Land use*: Under current land use planning regimes, more attention is now given to the rarity and importance of habitats and land cover types than was seen in the 1940s. Town and country planning laws now regulate land use change discussions, and, through measures such as Environmental Impact Assessments (EIAs), incorporate consideration of the potential impact a change in land use may have on ecosystems. Recent extensions to these regulations now impose restrictions on how different land can be used. For example, the 'uncultivated land' EIA regulations stipulate that land which has not previously been under cultivation or agricultural improvement is now protected from such use, therefore, affecting future land use change decisions.
- *Access rights*: An evolving range of legislation has addressed access to the countryside, from the National Parks and Access to the Countryside Act of 1949 through to the Countryside and Rights of Way Act 2000 and the Marine and Coastal Access Act 2009. These legislation changes have opened up an ever increasing area of the countryside for public access and enjoyment, although the delivery of these acts has been different in the separate countries of the UK.
- *Climate variability*: In response to the threats of climate change, the UK government has committed to monitoring greenhouse gases in order to help combat future climate change. Greenhouse gas and carbon

Table 3.2 Important UK, European and global environmental legislation.

Year	UK environmental legislation	Theme
1949	National Parks and Access to the Countryside Act	Access
1956	Clean Air Act	Air pollution control
1974	Control of Pollution Act	Noise management
1981	The Wildlife and Countryside Act 1981 as amended	Ecosystem and species protection
1984	Road Traffic Act	Air pollution control
1990	The Environmental Protection Act	Air pollution, noise, waste management
1991	Water Resources Act	Waste, water management
1991	Water Industry Act	Water management
1993	Clean Air Act	Air pollution control
1993	Noise and statutory nuisance Act	Noise management
1994	Criminal Justice and Public Order Act	Noise management
1994	Waste management licensing regulations (SI1994/1056)	Waste management
1994	The Conservation (Natural Habitats, &c.) Regulations 1994 (the Habitats Regulations)	Ecosystem protection
1995	Environment Act	Air pollution, waste, water, flood management
1996	Noise Act	Noise management
1999	Pollution prevention and control Act	Air pollution control
2000	Pollution prevention and control regulations (England, Wales)	Air pollution control
2000	Countryside and Rights of Way Act 2000	Access
2000	Transport Act	Air pollution control
2000	Finance Act	Air pollution and climate change mitigation
2003	Waste and emissions trading Act	Air pollution control
2003	Water Act	Water management
2004	Environmental information regulations	Freedom of information/justice
2006	Environmental noise regulations (England)	Noise management
2007	Transfrontier shipment of waste regulations SI1711	Waste management
2007	Environmental permitting regulations (England, Wales)	Waste management
2007	Air quality standards regulations	Air pollution control
2008	Climate Change Act	Climate change mitigation
2009	Marine and Coastal Access Act	Access
2009	Environmental damage and liability regulations	Pollution liability
2010	The conservation of habitats and species regulations	Ecosystem and species protection
Year	**European environmental legislation**	**Theme**
1976	Bathing Water Directive 76/160/EEC	Pollution control
1979	Conservation of wild birds (the Birds Directive) 79/409/EEC	Species protection
1986	Single European Act	Environmental assessment
1991	EC Directive 91/689/EEC on hazardous waste	Waste management
1991	Urban Waste Water Directive 91/271/EEC	Waste management
1992	Maastricht Treaty	Sustainable development
1992	Conservation of natural habitats and of wild fauna and flora (the Habitats Directive 92/43/EEC)	Ecosystem species protection
1997	Amsterdam Treaty	Sustainable development
1999	Landfill waste	Waste management
2000	Water Framework Directive 2000/60/EC	Pollution, ecological quality, water management
2001	Integrated pollution prevention and control (IPCC)	Pollution control
2001	Deliberate Release Directive 2001/18/EC	Impact assessment
2003	EU Directive 2003/4/EC Public Access to Environmental Information	Justice/participation
2005	EU emissions trading scheme	Pollution control

Table 3.2 continued. Important UK, European and global environmental legislation.

Year	European environmental legislation, continued	Theme
2006	Waste Directive 2006/12/EC	Waste management
2006	Groundwater Directive 2006/118/EC	Water management
2007	Lisbon Treaty	Sustainable development
2007	Floods Directive	Flooding
Year	**International environmental legislation**	**Theme**
1950	International convention for the protection of birds	Species protection
1971	Convention on wetlands of international importance, especially waterfall habitat (Ramsar)	Ecosystem protection
1972	Convention on the Prevention of Marine Pollution by Dumping from Ships and Aircraft	Pollution control
1973	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	Species protection
1974	Convention for the Prevention of Marine Pollution from Land Based Sources (London Convention)	Pollution control
1979	Convention on Long Range Transboundary Air Pollution	Pollution control
1979	Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention)	Ecosystem and species protection
1979	Convention on the Conservation of Migratory Species of Wild Animals (CMS or Bonn Convention)	Species protection
1991	Convention on Environmental Impact Assessment in a Transboundary Context (Espo)	Impact assessment
1992	Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR)	Ecosystem protection
1992	Convention on Biological Diversity	Ecosystem and species protection
1992	UN Framework Convention on Climate Change	Climate change
1997	Kyoto Protocol	Climate change
1998	Aarhus Convention – Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters	Justice
2000	European Landscape Convention	Landscape/amenity protection
2003	Protocol on strategic environmental assessment	Impact assessment

dioxide emissions in the UK have decreased since 1990 (MacCarthy *et al.* 2010; Section 3.4.4.3). Recent legislation (e.g. the Renewable Transport Fuel Obligation; the Renewables Obligation for Electricity Production and the EU Emission Trading Scheme) aims to encourage the use of sustainable and renewable fuel sources which may impact on future land use management decisions. Such legislation was introduced following the Energy Act 2004, and meets requirements under both the EU Renewable Energy Directive 2009/28/EC and UK targets, which aim to ensure 20% and 15%, respectively, of energy is produced from renewable sources by 2020.

State versus private relationships. Recent trends in the development of environmental legislation and regulation have shown a shift from prosecution through criminal courts to more empowered environmental agencies; a move from reactive addressing of individual environmental threats to a consideration of the strategic and long-term implications of plans and policies; and a move to empower society and citizens to monitor environmental change, industry and environmental agency practices by freely accessing environmental information. There has also been a shift from regulation control through enforcement to a market-regulated approach where emission or waste permits can be traded, and market forces and technology can aid in the regulation of emission or pollution levels. The effect of devolution is likely to further impact on future legislation as the different countries of the UK react to their own particular mix of pressures and societal demands to formulate different policy.

Consequences of legislation and regulation changes on UK ecosystems and ecosystem services. Changing legislation and regulation has protected a number of key ecosystem services in recognition of their importance and value to ensuring human well-being. For example:

- *Provisioning services*: The range of forestry legislation in place has protected the national resource of trees and timber, preventing undesirable felling and ensuring restocking to maintain both forest cover and a timber resource (Chapter 8; Chapter 15).
- *Cultural services*: The continual evolution of 'access' legislation has led to a large increase in the area and type of landscape available for public recreation (Chapter 16).
- *Regulating services*: The wide range of pollution and emissions control legislation has been successful in reducing system inputs, such as nitrogen and phosphorous, to a number of ecosystems (Section 3.4.2) (Chapter 14).
- *Biodiversity*: There has been a growing list of legislation directed at protecting the diversity of wild species in the UK. While there have been some successes (Section 3.3.3.2), biodiversity continues to be lost which impacts on many ecosystem services (Chapter 4).

Some legislation has resulted in the protection of services that were not the prime focus of the original legislation. For instance, there is a range of European legislation that now protects much of the Mountains, Moorlands and Heaths habitat from being developed for housing or converted to farmland (Chapter 5). As a result, this legislation also affords protection to standing vegetation and peat which are final ecosystem services that are important for carbon storage and climate regulation (Chapter 14). Although it should be noted that there does remain a legacy of sites where permission for peat extraction pre-dates such concerns (Section 3.4.1.4).

Legislative changes are expected to continue to be major drivers of change in the future; the Water Framework Directive, for example, will address the ecological status of ecosystems potentially affected by pollution, and should lead to an improvement in the condition of freshwater and wetlands and the services they provide (such as water, improved biodiversity and flood regulation).

3.3.3.2 Support mechanisms: subsidies and grants

With changing cultural preferences and social and economic conditions, society and governments have encouraged different forms of activity by supplying subsidies and grants in order to affect personal and business behaviour. Ultimately, these influence direct drivers such as land use change, harvest rates and pollution levels.

Agricultural subsidies. There has been a strong post-war tradition of support for productive agriculture and forestry which has influenced land management practices and land conversion. The Agriculture Acts of 1947 and 1967 began a system of price support for agricultural production that was supported by market-aiding organisations such as the Meat and Livestock Commission. These were followed in 1973 and 1991 by EU subsidies under the CAP (Chapter 7; Chapter 15). Over time, these payments greatly supported activities, such as land drainage and land conversion to increase food production from farmland, and also allowed for specialisation, investment and improvement in machinery, livestock breeds, crop growth and drainage systems across the UK. When production levels became too high, financial subsidies were also been offered to farmers to reduce output: for example the 'set-aside' policy that was introduced in 1988, although note this has recently been abolished (**Box 3.1**).

More recently, agricultural support schemes have reduced their focus on production and now include support and rewards for positive management enhancement and 'environmental stewardship' works. Under current initiatives, including agri-environment schemes such as the Defra Environmental Stewardship Schemes (Entry Level, Organic Entry Level, Upland Entry Level and Higher Level Stewarship), support is available for organic farm conversion, energy crop cultivation and farm diversification, and there is also a range of payments that are linked to a system of cross compliance activities that promote traditional and environmentally beneficial management options, such as maintenance of hedges, crop rotations and woodland coppicing.

Forestry subsidies. Financial support for forestry has evolved from the support of traditional timber production to the promotion of multiple uses of forests and forest products, including the consideration of landscape and amenity factors. Initial grant aid encouraged large areas of afforestation, particularly in the uplands and upland fringes of the UK. This caused widespread ecosystem change and damage to peatland and moorland habitats (Chapter 5; Chapter 14).

Although there has long been tension between the promotion of modern productive forestry and its impact on the wider landscape, recent target grants and initiatives, such as Community Forests and the Challenge Schemes for native woodland in National Parks, now provide strong financial support for community- or conservation-based woodland creation programmes which, in turn, influence land cover patterns. Afforestation of sensitive habitats is no longer encouraged by current grants; instead, funding is now often available to allow restoration to other habitat types such as peatland (Patterson & Anderson 2000).

Grants. Since the 1990s, an increasing number of specialist grant schemes have become available to land managers to support conservation activities. Initially, these were focused within designated areas, such as Environmentally Sensitive Areas (ESAs) and targeted upland areas and National Parks, in particular, both of which are difficult to farm and had natural beauty. Ongoing reform to schemes such as the CAP Higher Level Stewardship schemes has led to a shift from site- or protected landscape-based protection to a focus on proactive management within the wider countryside (Natural England 2011). In the UK, the land area supported by such mechanisms has increased by 1,000% between 1992 and the mid-2000s (**Figure 3.5**). Therefore, there is currently less of a distinction between support payments targeted at conservation and those targeted at agriculture as they now mostly fall under the single heading of 'environmental stewardship'.

Government conservation initiatives. The financial support given to biodiversity and conservation initiatives by the UK government has increased by 124% from around £250 million in 2001 to £547 million in 2009 (Defra 2010a). This demonstrates the government's commitment to meeting both national and international obligations—for example, targets set by the Convention on Biological Diversity (www.cbd.int/), which are largely executed through the UK Biodiversity Action Plans (UK BAPs). Elements of this funding are available as grants to support UK BAP work at local levels, such as within local nature reserves, or to support conservation land management. In recent years, significant sums of money have also been provided by the Lottery Fund to support environmental initiatives.

Private support mechanisms. In contrast to state-provided economic support to encourage forestry or agricultural production, there has also been a history of private support for land management and ownership for wildlife and landscape conservation purposes. In this sense, the membership payments to organisations such as The Royal Society for the Protection of Birds (RSPB; www.rspb.org.uk/) and The Wildlife Trusts (www.wildlifetrusts.org) are support mechanisms for conservation management. With the sizeable and growing membership base of the various conservation charities there has been a significant increase in expenditure and action for nature conservation purposes over recent decades. Conservation charities, such as the RSPB, The Wildlife Trusts, the Wildfowl & Wetlands Trust (www.wwt.org.uk/) and the Woodland Trust (www.woodlandtrust.org.uk), are able to buy or lease large areas of land that they manage for conservation purposes but that also bring benefits to human well-being. This can impact on direct drivers, such as land use change and pollution, as seen by the RSPB Fens 'Futurescape' (www.rspb.org.uk/news/276106-rspb-launches-new-landscape-scale-conservation-project) which has acquired farmland areas and is now flooding them to create new wetlands in their place. This project, along with the joint Natural England project, 'Fenland Bird Recovery Project' (www.rspb.org.uk/ourwork/projects/details/218989-fenland-farmland-

Box 3.1 How socio-political economic and cultural/behavioural drivers have driven the implementation, abolishment and reform of set-aside policy.

A traditional land management practice used across Europe throughout its agricultural history is the fallowing of land in arable rotation, that is taking parcels of land out of production for various lengths of time. This practice aids in a number of agronomic benefits including: weed control, disease production and improved fertility (IEEP 2008). However, technological improvements during the second half of the 20th Century that gave farmers the capability to have continuous arable crops, including during winter, resulted in a dramatic decrease in the proportion of agricultural land left fallow.

In turn, this contributed to a European-wide surplus of foodstuffs. In response, 'set-aside' was introduced into the Common Agricultural Policy (CAP) (Chapter 7; Chapter 15) as a production control measure, and adopted by EU countries, including the UK, in 1988. At first voluntary, set-aside policy called for land managers (particularly farmers) to take areas of arable land out of production. In 1992, the MacSharry CAP reforms made set-aside obligatory and farmers were required to set-aside 15% of their cropped land for at least five years in return for annual payment from the government, compensating for loss of production revenue (Curry 2008b; IEEP 2008). Since 1992, the percentage of set-aside required has varied from between 5% and 15%, with decisions governed by market fluctuations (Curry 2008b); but, in England, it has typically stood at approximately 500,000 hectares per year, making it England's' third largest category of land use.

Although introduced as a production control measure, set-aside did (in some cases), or could result in three major environmental benefits (Curry 2008b; IEEP 2008):

1. *Increased biodiversity*. Set-aside or fallow land can provid winter food sources (e.g. seed) and spring/summer nesting and brood-rearing habitat for birds. It improves conditions for scarce arable plants (especially in rotational set-aside) or for stands of mixed grass and wild flowers (particularly in non-rotational sea-aside); and it supports higher densities of invertebrates and small mammals (e.g. hares prefer set-aside to other arable fields, and bats can forage on the increased number of invertebrates).
2. *Resources protection*. Fertiliser and pesticide use and soil disturbance is reduced when less land is managed for production, consequently reducing diffuse pollution. Well-placed set-aside land can act as a buffer between cropped land and more sensitive sites, including water courses, and can afford protection to areas typically exposed to the forces of wind and water erosion, such as sloped sites.
3. *Ecological connectivity*. 'Corridors' enabling the movement of species between patches of fragmented habitat can be created by set-aside land, and can also increase the range of habitats available.

Increases in soil carbon sequestration through the conversion of conventional agricultural land to that with high carbon inputs and low-levels of disturbance (e.g. natural regeneration or permanent set-aside) may have also resulted in set-aside contributing to climate change mitigation (IEEP 2008). In July 2007, in response to increased market demands for arable crops, particularly cereals, the European Commission (EC) announced that it would reduce set-aside requirement to 0%; and in November 2008, it agreed to abolish it completely through the CAP Health Check. Although farmers would not necessarily lose future payments received for keeping land as set-aside, it was predicted that between 50% and 70% of set-aside in England in 2007 would be brought back into production by 2009.

The abolishment of set-aside has caused concern, particularly among UK environmental agencies and non-governmental organisations (NGOs), that the environmental benefits of set-aside will be lost. This could impact on the UK's ability to meet both national and international commitments, such as: meeting farming and land management targets (e.g. Defra's Departmental Strategic Objectives and Public Service Agreement targets); halting or reducing the loss of biodiversity (e.g. Convention on Biological Diversity targets); improving or maintaining water and soil quality (e.g. as required under the Water Framework Directive, Soil Thematic Strategy and Soil Framework Directive); and mitigating climate change (e.g. meeting commitments to greenhouse gas emissions) (Curry 2008b; IEEP 2008).

The Department for Environment, Food and Rural Affairs (Defra) and farming bodies, such as the National Farmers' Union (NFU), have recognised the environmental benefits that set-aside has delivered. In 2008, Defra commissioned a body of work (undertaken by NFU, Country Land and Business Association, the Royal Society for the Protection of Birds, Environment Agency and Natural England) to assess the impacts of 0% set-aside, to further improve understanding of the environmental benefits set-aside provides, and to formulate mitigation responses for any losses (Curry 2008a).
This review concluded that the implementation of any new policies to counter the loss of environmental benefits brought about the abolition of set-aside could not, realistically, be brought in until the 2009–2010 cropping year. In the interim, farmers were encouraged to retain uncropped land and manage it in such a way that environmental benefits were optimised (Curry 2008a). In July 2009, Defra announced its 'Campaign for the Farmed Environment' initiative—an industry-led, voluntary approach to recapture the environmental benefits of set-aside.

The Campaign, which is supported by a wide variety of organisations across the agricultural sector[1] , will bring together the work farmers and land managers already do to benefit wildlife, maintain soil and water resources, and support farmland birds. It will also promote existing stewardship schemes and encourage voluntary management that will benefit the environment, while ensuring efficient and profitable food production. The Campaign has until 2012 to make the voluntary approach work, otherwise regulation will be reinstated (NFU 2011).

1 National Farmers' Union (NFU), Country Land and Business Association (CLA), Farming and Wildlife Advisory Group (FWAG), Linking Environment and Farming (LEAF), the Game and Wildlife Conservation Trust (GWCT), the Agricultural Industries Confederation (AIC), the Association of Independent Crop Consultants (AICC) and the Central Association of Agricultural Valuers (CAAV). The Royal Society for the Protection of Birds (RSPB), Natural England and the Environment Agency have also given the Campaign their full backing.

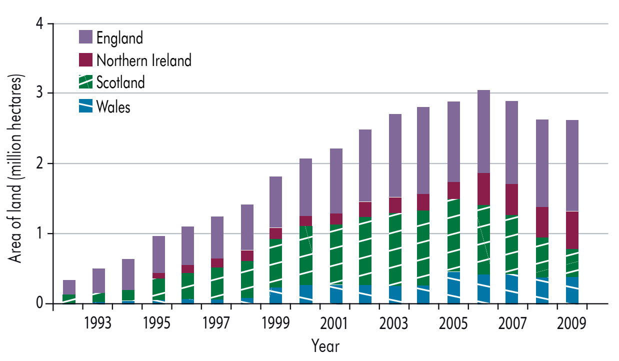


Figure 3.5 Area of land covered by Higher Level Stewardship or targeted agri-environment schemes*† in the UK, 1992 to 2009‡. *The following schemes have been included here as higher level or targeted agri-environment schemes: England – Environmentally Sensitive Areas (ESA), Countryside Stewardship (CS), and new Higher Level Stewardship (HLS); Scotland – ESA, Countryside Premium, and Rural Stewardship; Wales – ESA, Tir Cymen, and Tir Gofal; Northern Ireland – ESA, Countryside Management. †Higher level or targeted agri-environment schemes have stricter criteria for qualification than other agri-environment schemes. ‡Data for 2009 are provisional. Source: data from Welsh Assembly Government, Countryside Council for Wales, Scottish Government, Natural England, Defra; figure reproduced from Defra (2010a). © Crown copyright 2010.

bird-recovery-project#work), is also working with farmers, assisting them to access financial support from government agri-environment schemes to put nature-friendly farm management strategies into practise.

Consequence of change to support mechanisms on UK ecosystems and ecosystem services. Over the past 60 years, subsidies and support mechanisms have greatly enhanced the provisioning services, especially the final service of crops, livestock and fish. Historical support and CAP payments to the agricultural sector have greatly increased crop yields, by both the expansion of agricultural area and by providing stabilised prices that allowed farmers to invest in inputs, mechanisation and improved farming methods (Chapter 7). Support to the forestry sector has encouraged the continued increase in woodland area (Section 3.4.1.2). The recent expansion of these support mechanisms for broader environmental management has benefited the services of climate regulation and landscape amenity, in addition to enhancing the provisioning services (Chapter 14; Chapter 15).

There is evidence of the recent success of agri-environment schemes in bringing areas of Semi-natural Grassland back into 'favourable condition' (Critchley *et al.* 2004; Hewins *et al.* 2005; Chapter 6). Agri-environment schemes have also been successful in increasing the biodiversity ecosystem service within targeted areas. For example, cirl buntings (*Emberiza cirlus*) and corncrake (*Crex crex*) are both identified as being of the highest priority for conservation action in the UK BAP. Targeted conservation action, such as the provision of year-round habitat requirements through agri-environment schemes and the modification of mowing and grazing schemes, are believed to be one driver behind the numbers of both species showing considerable recovery over the past 17 years: breeding pairs of cirl bunting have risen by 145% from 352 in 1993 to 862 in 2009; while the number of calling male corncrake (an indicator of breeding population size) has increased by 140% from 430 in 1993 to 1,156 in 2009 (Eaton *et al.* 2010).

3.3.4 Cultural and Behavioural Drivers

The value, beliefs and norms shared by a group of people can influence decision-making related to the environment. These values and beliefs are often shaped by cultural influences which mould how an individual perceives the world, what they consider is important and what course of action to take (Nelson *et al.* 2005).

Cultural drivers, which are those aspects of society ranging from knowledge to attitudes and consumption choices, can impact on ecosystems through their links to other drivers such as market forces and legislation. These drivers have changed across the UK over time as the economics and demographics of the country have altered and impacted on a number of habitats and services. Consumption choices by society can, for example, affect market forces, thus impacting on land and sea use, pollution and exploitation levels. Such choices may, therefore, favour the delivery of certain provisioning services over others. When such choices are based upon price alone they would be expected to favour services such as farming and fishing systems that are weighted to maximise production and minimise costs. However, in combination with other cultural drivers, such as societal knowledge and environmental attitudes, there is the potential for consumption choices to cause ecosystem change by favouring alternative farming or fishing practises, such as support for organic farming or sustainable fishing, which can have a positive impact on both ecosystem condition and human well-being. In this section, we will discuss knowledge, and the link between environmental attitudes and the media, as cultural drivers of change.

3.3.4.1 Knowledge

Knowledge is a key driver of ecosystem change as it allows the impact of man's activities on the environment to be seen, understood and acted upon. Knowledge informs legislation, subsidies, science and technology; it was the increased understanding of the detrimental effects that air pollution had on human health, for instance, that led to the development and implementation of the Clean Air Act in 1956—the first piece of legislation directed at reducing pollutants. Likewise, knowledge on the dangers and impacts of acid rain and climate change has stimulated further development and implementation of legislation to reduce levels of sulphur dioxide and greenhouse gas emissions (Section 3.4.2) (Chapter 14).

3.3.4.2 Environmental attitudes and the media

Our attitudes towards the environment can influence ecosystem change through consumer and consumption choice and through public pressure forcing change in legislation. Changes in environmental attitudes can raise public awareness of environmental topics and bring political pressure on particular issues.

The media is one of the biggest influences on environmental attitudes, which, in turn, can influence it. From the first printing presses to today's international internet, the media has had a huge impact on our knowledge and awareness of particular topics. For example, Rachel Carson's book, *Silent Spring* (1962), raised awareness across a wide audience of the threat of agricultural pesticides to wildlife (particularly birds), and eventually resulted in reform, including a ban on the use of the pesticide DDT across the USA in 1972.

More recent issues brought to the attention of the public through the media have included the impact of peat compost on wetlands, and the potential benefits to wildlife and human well-being of organic farming.

The environmental attitudes of UK citizens can be tracked through a variety of means, for example: conducting surveys on public attitudes and behaviours towards the environment and energy issues, such as those undertaken by the Massachusetts Institute of Technology and University of Cambridge in 2005 (Curry *et al.* 2005), and by Defra in 2009 (Thornton 2009); appraising membership figures of environmental campaign groups and political parties; and judging the reaction of the public to specific campaigns. Peoples' concern for the environment and willingness to take action to mitigate their own impact on the environment has shown a continually positive trend over past decades—one indication of this is the 51% increase, between 2001 and 2009, in the time that people spent volunteering in eight UK conservation organisations[1]. In 2009, this equated to approximately 1 million working days (Defra 2010a). However, it should be noted that concern for other issues, such as national security, health care and education, have recently taken precedence for many people (Curry *et al.* 2005).

3.3.5 Scientific and Technological Drivers

Advances in science and technology result in a greater understanding of how the world functions, and in the development of new products, chemicals, electronics, industries and species. These advances can interact with other indirect drivers to influence the rise and fall of economic markets, affect the cultural and religious values of society, or lead to changes in demographics. These drivers have also strongly influenced direct drivers such as land and sea use, pollution levels and climate change. We will discuss innovation and technological change, biotechnology, energy production and transport.

3.3.5.1 Innovation and technological change

Innovative ideas and/or the development of new technologies typically influence other drivers that impact on ecosystem extent or condition. Key technological developments either in, or adopted by, the UK have included the increased mechanisation of farming and fishing practices and the choice of the type of crops sown and livestock reared. Although fishing and farming activities have constantly evolved, changes over the past 60 years, largely resulting from the development of new technology, have had profound effects on ecosystems and the services they provide.

Mechanisation: farming. Improvements to farm machinery and techniques developed since WWII have allowed more frequent and deeper ploughing of agricultural land. Consequently, this has led to changes in farming practices such as a shift to select crops that can be sown in autumn and a reduction in the extent and timing of fallow land (the latter declining to less than a quarter of the area it occupied in 1940).

The introduction of mechanical harvesting began a long-term decline in the traditional management of grasslands for hay, and resulted in a shift to silage production. Although silage is still permanent grassland, the new cutting regime has caused significant, detrimental changes in species composition of these communities. Recently, in recognition of the biodiversity and cultural importance of hay meadow landscapes, many projects have been initiated to restore and retain traditional harvest techniques, particularly in upland areas such as the Yorkshire Dales, Lake and Peak District National Parks, and North Pennines Area of Outstanding Natural Beauty.

Other advancements in mechanical technology have been associated with significant ecosystem change. For instance, the increased use of machinery for peat extraction in the 1970s meant that larger areas and depths of peat could be extracted than had previously been possible by hand. In addition, technological advancements since the 1940s, such as the use of motor pumps, have led to the development of highly effective drainage systems and the consequent introduction of schemes to reclaim land, particularly in the lowlands of England and Northern Ireland. This has led to an increase in productive agricultural land, but a reduction in the area of wetland habitats, seasonally flooded grassland and lowland mires (Chapter 9). The impact of such activities can be considered over time by comparing the modelled historical (last ten millennia) extent of wetlands, against the current extent of wetland habitats (**Figure 3.6**).

Until the 1990s, drainage channels were also installed in the upland moorlands, often with the support of grant aid to help enhance production in poor soils or to boost heather growth in grouse moor areas. Capital grants were also provided in England and Wales for farm improvements which led to an increase in drainage activity. Field drainage was eligible for grant aid of up to 60% of capital expenditure, for example, and by 1972 approximately 100,000 ha per year were being drained (Marshall *et al.* 1978). Because of the devastating impact on ecosystems that such modifications of water flow caused, much of this activity has now ceased and new technology is being used to maintain or increase water levels. As a consequence, the re-wetting of many conservation landscapes in the lowlands has already been achieved, and 'grip blocking' in upland mires has used machinery to maintain water within the landscape, benefiting biodiversity and carbon sequestration.

Mechanisation: fishing. Technological changes during the 1950s led to the development of industrial fisheries.

1 Bat Conservation Trust, British Trust for Conservation Volunteers, British Trust for Ornithology, Butterfly Conservation, Plantlife, Royal Society for the Protection of Birds, The Wildlife Trusts, Woodland Trust, and a public body: Natural England.

Enhanced netting equipment and sonar technology enabled fish to be located and captured more efficiently, therefore increasing harvest levels. Increased returns also facilitated a rise in the number of vessels. However, the ability to capture different components of the population, for example juvenile fish in nets with finer mesh sizes, and the destruction of marine habitat through the development of techniques such as bottom trawling, have led to ecosystem-wide changes (Thurstan & Roberts 2010). Advances in fishing technology have also led to overexploitation of fisheries resources, the trends and impacts of which are discussed in Section 3.4.3.1 and in Chapters 12 and 15.

Development and use of chemicals. The development of novel chemicals during the last century has supported the modern agricultural revolution, resulting in an increase in food production and harvest rates. Significant developments have included the discovery of the Haber-Bosch process for ammonia production in the early 1900s resulting in industrial fertilisers, and the development of pesticides, such as the organochlorine DDT, chlordane and endrin, in the 1940s and 1950s. The use of these chemicals removed the constraint of nutrient limitation for crop growth, as well as competitive pests and weeds, resulting in increased yields.

The development of farming chemicals (such as fertilisers, herbicides and pesticides) made it possible for agricultural activity to extend to areas of land that would otherwise have been unsuitable for agricultural use, and has, therefore, influenced land cover patterns. Chemicals have also been used in the forestry sector to aid in the conversion of large areas of broadleaved woodland to conifer plantation in places where mechanical felling and removal of trees would not have been economically viable.

Environmental monitoring. Improvements to information technology and monitoring techniques are enhancing our ability to (rapidly) collect data and build on knowledge that can be used to inform land management decisions and provide input to policy development. For example, increased efforts in monitoring the levels of pollution have provided better information on emission levels (Section 3.4.2). Detailed mapping and modelling of soil fertility status has also led to 'precision farming' where specifically tailored programs of fertiliser application are developed in order to target certain areas of fields, thereby helping to minimise the use of chemicals.

Furthermore, information technology that can be applied to environmental monitoring is increasing our ability to detect ecosystem change, and has facilitated feedback to policy development aimed at the drivers of such change. For instance, remote sensing has aided the Land Cover Map projects undertaken by the Centre of Ecology and Hydrology, and mapping of oceanic environmental variables (e.g. chlorophyll *a* or sea-surface temperature), resulting in improved land-use and land-use change models and ocean processes models, respectively.

3.3.5.2 Biotechnology

Innovation in biotechnology, such as crop selection to produce improved strains and recent advances in genetically

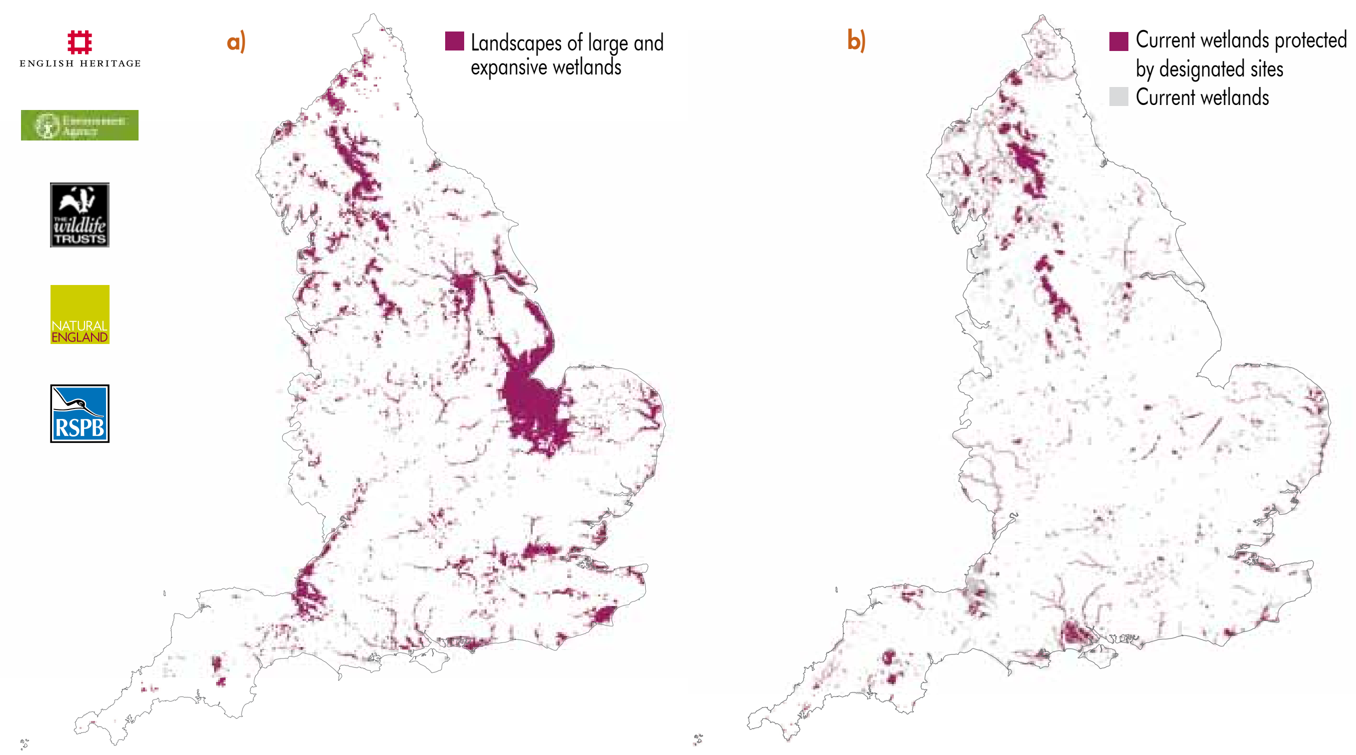


Figure 3.6 Extent of wetlands in England: a) Historical* maximum extent; b) Current extent of modelled wetland habitats. *Last ten millennia. Source: maps from Hume *et al.* (2008). © Wetland Vision, a partnership between Environment Agency, English Heritage, Natural England, RSPB, and The Wildlife Trusts. Derived from data supplied by Natural England © Natural England 2008. This map is based upon Ordnance Survey material with the permisson of Ordnance Survey on behalf of the Controller of Her Majesty's Stationary Office © Crown copyright. Unauthorised reproduction infringes Crown copyright and may lead to prosecution or civil proceedings. Natural England 100046223 2008.

modified organisms (GMOs), can act as a driver of change by influencing other drivers. For example, while there is a long history of improvement through traditional crop selection techniques, recent changes in GMOs hold scope for increased advances in crop yield. However, it should be noted that considerable concerns exist in some arenas about the potential environmental effects of such technology.

3.3.5.3 Energy production technology

The development of technology used for energy production in the UK is strongly linked to changes in land use and land cover, waste disposal and pollution emissions. During the past 60 years, advances in technology have seen the traditional sources of energy used in the UK, such as coal, peat and wood fuel, supplemented by oil and gas (extracted from undersea reserves), nuclear power and renewable solar, wind and wave power. The uptake of different energy production methods often depends on the mix of market forces, subsides and legislation—this mix can create or amend markets in which these industries develop.

A variety of new technologies are being developed to use biomass for the production of heat, electricity and transport fuels, ranging from direct energy production through to more novel techniques of bio-digestion and fermentation. The production of energy from these sources, and other renewables (wind, wave, solar) have shown a strong increase over recent years (Defra 2010e) and is likely to drive future changes in land use if it proves effective and popular. There is evidence that such changes are already occurring: in England, there has been an increase of land managed for short-rotation coppice (a biomass crop) grown specifically for biofuel (**Figure 3.7**) (Chapter 7; Chapter 15). However, there are concerns that such crops can cause environmental 'sterility'; for example, *Miscanthus* x *giganteus* which is often planted in large fields, can almost completely suppress invertebrates in the crop. Consequently, this may have negative impacts on levels of biodiversity and the delivery of ecosystem services.

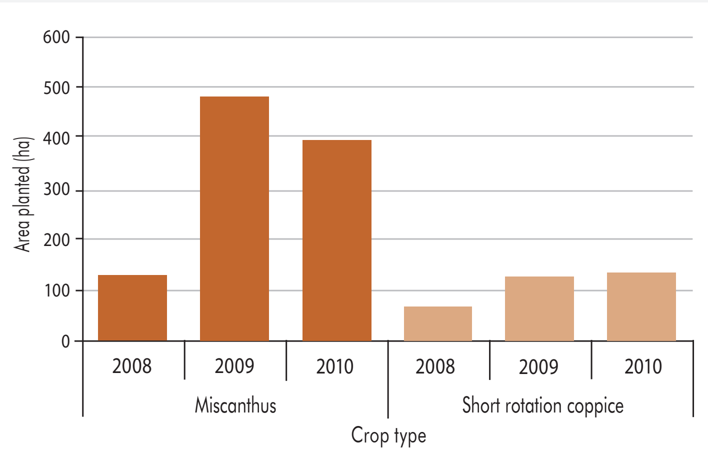


Figure 3.7: Area of energy crops (*Miscanthus* and Short-rotation coppice) planted in England between 2008 and 2010 under the Energy Crops Scheme 2. Source: data provided from Natural England. © Natural England 2010.

3.3.5.4 Transport

Transport technology has altered greatly over the past 60 years, and, as such, has influenced the impact that a number of direct drivers have had on ecosystem change. An illustration of this is the rise in alien and invasive species introductions as a consequence of increased international trade, facilitated through improvements to air and sea transport systems; for instance, the spread of non-native species into UK marine waters has been linked to the increase in movement of ballast water from transport ships. Changing transport technology is also associated with the rise in emission levels and impacts on land use in terms of land being converted to transport infrastructure, such as air and sea ports, rail terminals and road networks.

The use and uptake in these technologies can be linked to legislation and policy, such as the relative promotion of rail versus roads links and the different environmental impacts these have had. A further sociopolitical and cultural driver behind such change has been the promotion of long-distance mobility rather than a focus on facilitating local access and proximity, and reducing the need to travel as the fundamental objective of transport policy. Recently, there has been signs of political interest in 'localism', both as a social value for promoting community well-being and for the benefit of environmental sustainability; although there is yet to be any serious, practical implementation of such action.

3.4 Direct Drivers of Change

As outlined in the introduction to this chapter, direct drivers have an explicit effect on ecosystem processes (Nelson *et al.* 2005), and usually cause physical change that can be identified and monitored (Ash *et al.* 2008). The most important direct drivers identified as causing change in UK ecosystems and to biodiversity are: land use and use of the marine environment, leading to habitat change; pollution and nutrient enrichment (system inputs); overexploitation of terrestrial, marine and freshwater resources (harvest and resource consumption); climate variability and change; and biological drivers, such as invasive alien species.

3.4.1 Habitat Change

Human-induced change in the use and cover of the UK's habitats has been a key driver in altering ecosystem extent, as well as the condition of all habitat types and the ecosystem services that they provide (see **Figure 3.1; 3.2**). The underlying components behind such change include the utilisation and conversion of habitats for agriculture, forestry, fisheries, mineral extraction, and urban and infrastructure development, and the intensity of those uses. Rates of habitat change throughout the UK have varied both in space and time (although they are believed to be slower now than during the period between the end of WWII and the 1970s (Bibby 2009), and are mediated by, or reflect trends in, market forces, demographics and technological developments.

3.4.1.1 Conversion of land for agriculture

The most recent assessments of UK land cover—the Countryside Survey 2007[2] (CS2007; Carey *et al.* 2008a) and the Land Cover Map 2000[3] (LCM2000; Fuller *et al.* 2002)—report that agricultural land[4] dominates habitat, and, by inference, land use in the UK, covering approximately half of the UK land surface (47% LCM2000, 39% CS2007) (**Table 3.3; Figure 3.8**). However, this varies between the four countries with enclosed farmland covering 62% of England, 57% of Northern Ireland, 42% of Wales, but only 23% of Scotland.

Although figures have changed significantly since WWII, the majority of change occurred in the period between the 1940s and 1980s. Historically, the extent of agricultural land was primarily determined by topography and climate, as well as the availability of naturally productive workable soils which influenced what, and where, crops or stock could be managed. However, with the development of chemical fertilisers and mechanised farming practices, steeper and more remote slopes could be utilised and previously infertile soils were rendered productive. These advancements, driven, in part, by the desire for the UK to become more productive and self-sufficient after WWII, plus support from

Table 3.3 Land cover estimates (hectares; ha) of UK NEA Broad Habitat types derived from the Land Cover Map 2000 project (LCM2000; Fuller *et al.* 2002), the Countryside Survey 2007 (CS2007; Carey *et al.* 2008a) and spatial analysis by the UNEP World Conservation Monitoring Programme (UNEP-WCMC) using LCM2000 data*. The Marine area is that encompassed within the 12 nautical mile zone, and was only estimated by UNEP-WCMC.

UK NEA Broad Habitat	LCM2000 ('000s ha)	CS2007 ('000s ha)	UNEP-WCMC ('000s ha)
Mountains, Moorlands & Heaths	4,080	4,603	4,103
Semi-natural Grasslands	3,969	4,065	3,941
Enclosed Farmland	11,670	10,220	11,530
Woodlands	2,914	2,867	2,918
Freshwaters – Openwaters, Wetlands & Floodplains	277	328	272
Urban	1,664	1,398	1,675
Coastal Margins	94	71	336
Marine	-	-	16,477

* The LCM2000 and CS2007 apply different methods to estimate habitat extent (see Section 3.4.1.1). Therefore differences in figures for similar habitat can be expected and likely represent differences in the classification of component habitats and/or the ability to measure extent of a particular habitat type. Likewise, differences observed in estimates between LCM2000 and UNEP-WCMC estimates are due to differences in the way component habitats were aggregated into the UK NEA Broad Habitats (Chapter 1).

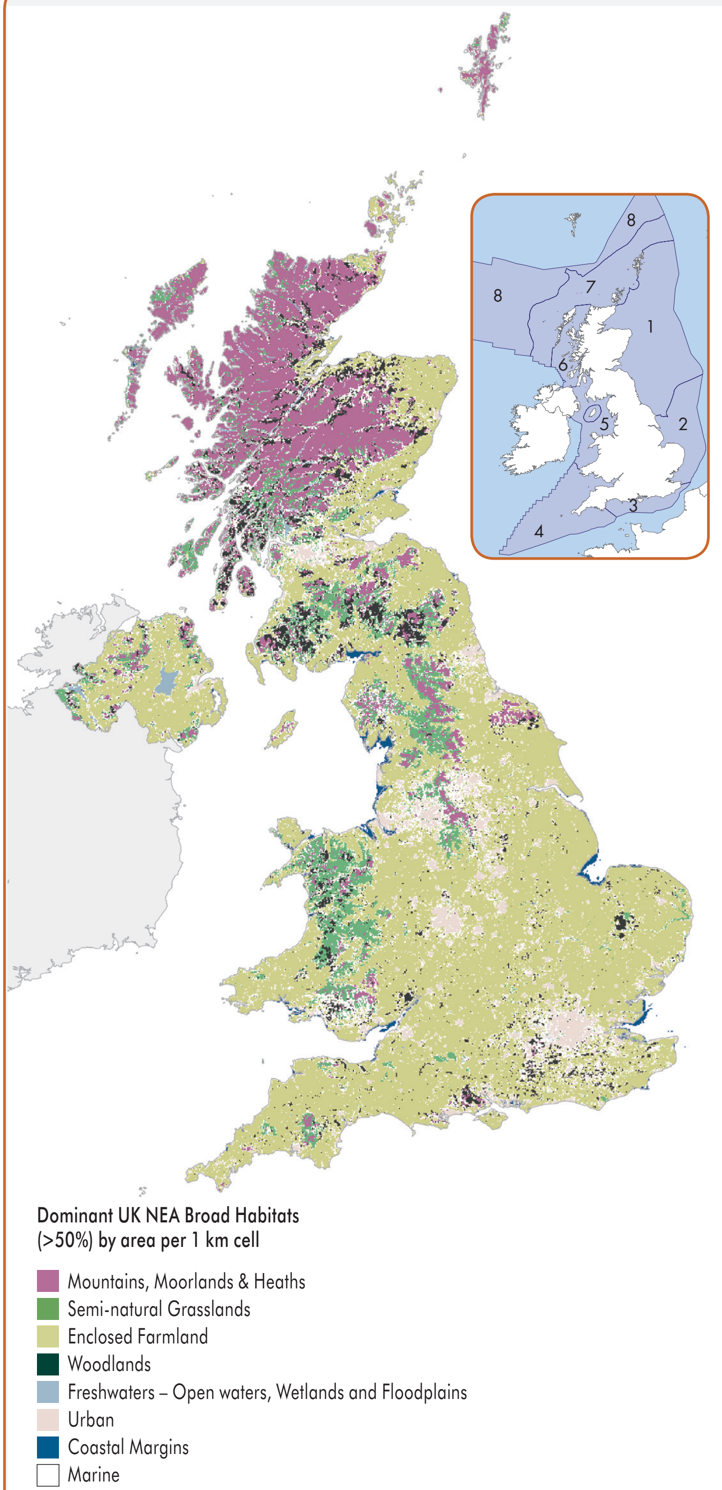


Figure 3.8 Distribution (%) of the UK NEA Broad Habitat types by area at 1x1 km resolution. Inset: Charting Progress 2, UK Regional Sea boundaries: 1) Northern North Sea; 2) Southern North Sea; 3) Eastern Channel; 4) Western Channel and Celtic Sea; 5) Irish Sea; 6) Minches and Western Scotland; 7) Scottish Continental Shelf; 8) Atlantic North-West Approaches, Rockall Trough and Faeroe/Shetland Channel. Source: Broad Habitat distribution – Land Cover Map 2000 (Fuller *et al.* 2002); Regional seas – based on UKMMAS (2010). Coastline: World Vector Shoreline@National – Geospatial Intelligence Agency. Source: NOASS, NGDC.

2 Estimates of land cover compiled by the Countryside Survey are assessed through ground surveys of 1 km^2 parcels of land (Carey *et al.* 2008).
3 The Land Cover Map is a digital map of different types of land and vegetation cover compiled from satellite imagery (Fuller *et al.* 2002).
4 Designated as Enclosed Farmland by the UK NEA, and incorporating Arable and Horticultural land plus Improved Grassland habitats.

government subsidies (Section 3.3.3.2) (Chapter 7), not only shifted the balance between arable and pastoral land use, but also resulted in semi-natural habitats being converted to farmland.

It is believed that the rate of change in the conversion of land for agricultural purposes has decreased, yet change is still being observed. Between 1998 and 2007, there was a significant decrease in arable and horticultural land (-9.1%), while some Semi-natural Grassland habitat types increased (Neutral grassland: +6.0%; Acid grassland: +5.5%; **Table 3.4**) (Chapter 6), possibly indicating the de-intensification of farming. However, there has been a concurrent increase in Improved Grassland (which is used for agriculture) by +5% (Carey *et al.* 2008a; **Table 3.4**) (Chapter 7).

Variables such as land use records, field sizes and the presence of field boundaries (e.g. hedgerows and dry stone walls) indicate that the management and use of agricultural land has undergone significant change and simplification since WWII. Records of farm holding sizes kept by the Department for Environment, Food and Rural Affairs (Defra) Observatory Programme indicate that farm size has increased, larger individual fields are maintained (indicated by significant reduction in boundary features), and livestock and cropping patterns have become more simplified and specialised (Foresight 2010). In regards to the latter, while the area of land managed for cereal crops remained relatively stable between 1961 and 2009, there have been significant reductions in the amount of land managed for harvested fruit (-50%), root crops (-49%) and vegetables and melons (-30%); however, the area of harvested pulses increased by 300% during this time (FAOSTAT 2011b; also Chapter 7 and Chapter 15).

3.4.1.2 Conversion of land for forestry

Historically, UK woodlands (incorporating Mixed, Broadleaved and Yew woodland, plus Coniferous woodland) were primarily used for the production of forestry products, such as timber and fuel wood. However, in more recent times, they have also come to be valued for their role in conservation (e.g. of biodiversity) and recreational and cultural pursuits (such as hiking, camping and aesthetics). The decision of land managers to convert land to woodlands (afforestation) or to expand/replace already established stands (reforestation) has been influenced over time by different indirect drivers such as market forces, support mechanisms and cultural attitudes (Chapter 8).

The total amount of woodland cover in the UK has increased by 5.9% since 1947, and currently stands at 11.7% (Forestry Commission 2010a; see **Figure 3.8**). From the 1940s, annual rates of new plantings rose steadily, reaching, in 1976, approximately 27,400 and 900 ha for a coniferous and broadleaved species, respectively; 28,300 ha in total. Since then, however, planting rates have followed a general decline, falling to just 5,400 ha in 2010, with new plantings

Table 3.4 The change in area ('000s hectares (ha) and percentage) of Countryside Survey broad habitats in Great Britain between 1990 and 2007, and in the UK between 1998 and 2007. Arrows denote significant change ($p<0.05$) in the direction shown. Source: reproduced from Carey *et al.* (2008a). Countryside Survey data owned by NERC – Centre for Ecology & Hydrology.

	Great Britain							UK		
	1990–1998		1990–2007		1998–2007		Direction of significant changes 1998–2007	1998–2007		Direction of significant changes 1998–2007
Countryside Survey Broad Habitats	Change ('000s ha)	% Change	Change ('000s ha)	% Change	Change ('000s ha)	% Change		Change ('000s ha)	% Change	
Broadleaved, Mixed and Yew Woodland	-15	-1.1	63	4.7	78	5.9	↓↑	96	6.9	↑
Coniferous Woodland	147	11.9	80	6.5	-67	-4.8		-69	-4.7	
Linear Features	-70	-12.0	-85	-14.6	-15	-2.9		-13	-2.5	
Arable and Horticulture	43	0.9	-416	-8.3	-459	-9.1	↓	-467	-9.1	↓
Improved Grassland	-368	-8.0	-125	-2.7	243	5.7	↑	261	5.4	↑
Neutral Grassland	338	20.3	507	30.4	169	8.4	↑	136	6.0	↑
Calcareous Grassland	-17	-21.8	-21	-27.2	-4	-7.3		-4	-6.3	
Acid Grassland	-318	-17.5	-232	-12.7	86	5.7	↑	83	5.5	↑
Bracken	43	15.8	-12	-4.4	-55	-17.5	↓	-55	-17.4	↑
Dwarf Shrub Heath	-137	-9.5	-93	-6.5	44	3.4		47	3.6	
Fen, Marsh, Swamp	-1	-0.2	-35	-8.2	-34	-8.0		-40	-8.3	
Bog	172	8.4	182	8.9	10	0.5		7	0.3	
Standing Open Waters	17	8.4	23	11.8	5	2.6	↑	5	1.9	
Rivers and Streams	-3	-3.9	-2	-2.7	0	-0.2		0	0.0	
Montane	na	na	na	na	1	2.4		1	2.4	
Inland Rock	35	46.1	25	32.3	-10	-9.4		-13	-10.9	
Built-up Areas and Gardens	13	1.0	57	4.5	44	3.4		61	4.6	
Other land								6	5.4	↑

of broadleaved species (4,800 ha) greatly outstripping those of coniferous species (500 ha), a pattern which emerged in the mid-1990s (Forestry Commission 2011). Consequently, although there has been a general decline in planting rates across the UK, broadleaved woodland cover has increased significantly from 1.4 million ha in 1998 to 1.5 million ha 2007: a 6% rise in nine years (Carey *et al.* 2008b). The greatest change was recorded in Northern Ireland (+1.3%), followed by England (+0.4%) and Scotland (+0.2%). There was no significant change recorded in Wales during this time period (Carey *et al.* 2008b). These changes in forest management and planting rates reflect changes in forestry management objectives and policy, including afforestation projects and incentives (Chapter 8).

3.4.1.3 Coastal and Marine habitats

The UK has both used, or relied heavily upon, coastal and marine habitats for a variety of purposes, such as food provisioning, infrastructure development (both industrial and domestic) and energy production. Historically, such utilisation has caused widespread habitat change, and, given current rates and projected use, is likely to continue, although at potentially reduced levels due to the implementation of conservation initiatives and policy.

The patterns of change vary spatially, temporally and in the type of habitat found around the UK (Frost 2010). In the Coastal Margins, habitats like Sand Dunes, Saltmarshes and Shingle have been lost to agricultural land-claim and extensive development for housing, tourism and industry (Doody 2001)—it is estimated that these three habitats have suffered a 20% loss in extent since WWII. Sea-level rise is an increasingly important factor in habitat loss of soft coast habitats (French 1997). In the Marine environment, areas in southern UK waters are subject to a greater range of drivers causing habitat change compared to northern regions, and sediment habitats are more extensively degraded than rocky habitats; although these, too, have suffered physical damage due to towed fishing gear (UKMMAS 2010). In the sub-tidal zone, including sediment and reef habitat down to depths of 200 m or more, mobile fishing gear, such as trawls and dredges, have caused substantial damage and loss of habitat, effecting levels of biodiversity and ecosystem function. Although fishing activity has been reduced in some regions, and some fish species are showing signs of recovery, many habitats have suffered so much damage, that this, plus ongoing impacts from other pressures (including climate change and the development of offshore infrastructure such as windfarms), may affect their potential to recover (UKMMAS 2010).

3.4.1.4 Mineral, aggregate and peat extraction

The UK draws on various minerals, fossil fuels (coal) and aggregates to provide, amongst other things, construction materials and fuel for the production of energy. The extraction of mineral and coal deposits has caused widespread ecosystem change including habitat conversion, degradation and fragmentation through both the extraction process and the deposition of waste products. The latter has had major effects on marine and coastal habitats, particularly in the north-east of the UK.

Immediately after WWII, peat extraction for both fuel and horticulture was high and led directly to significant ecosystem changes (e.g. loss of biodiversity) in many areas of accessible mire, especially in England and Northern Ireland (Chapter 5). More recent figures show a reduction in both the amount of land used for peat extraction (14,980 ha in 1994; 10,690 ha in 2009) and in the level of extraction (in GB, 1.6 million m^3 sold in 1999; 760,000 m^3 in 2009) (Chapter 15). These reductions are primarily due to current legislation that protects mire habitat and largely prevents new applications for the extraction of peat, as well as a drop in demand for peat. However, it should be noted that at existing extraction sites peat removal may continue until the resource has been removed or permissions are rescinded. Removal of permissions may require the government to pay compensation to owners of peat extraction rights.

3.4.1.5 Urbanisation

In the UK, urban habitat (built-up areas and gardens), calculated using the LCM2000 (Fuller *et al.* 2002) directly affects only 6.7% of land area, but approximately 75–80% of the population reside here (Pointer 2005; Chapter 10). Although changes in, and impacts of, UK urbanisation have not been properly quantified since WWII, trends in population growth, domestic migration and the extent of built-up area can be used as indicators. The growth of UK urban populations, in particular, has acted as a direct driver of change of ecosystem condition when habitat (usually highly productive land) has been converted into urban land cover such as residential buildings, infrastructure and amenities (Section 3.3.1) (Chapter 10). Increased urbanisation has also had a major influence on consumption pressure (i.e. demands for food, fuel, water and other natural resources), exerting increased pressure on ecosystems or regions outside urban areas both national and international (Nelson *et al.* 2005; Hannah 2010).

One other way in which the changing pattern of urban cover and infrastructure development can be assessed is by modelling the effects of urban 'intrusion', defined as increasing noise from urban and transport infrastructure. Such studies conducted in England show that the proportion of the country considered disturbed by urban influence or infrastructure noise rose from 26% in the 1960s, to 41% by the 1990s, and to 50% by 2007 (CPRE 2007; **Figure 3.9**).

The direct impact of urban areas could be reduced in the future by evoking various activities including water harvesting, growing local food, promoting local 'green-modes' of accessibility rather than motorised mobility, planting gardens that will increase biodiversity, and developing Sustainable Urban Drainage Systems (SUDS). However, such changes will be dependent on changing cultural views of how people see their relationship with the natural environment.

3.4.1.6 Infrastructure

There have been significant infrastructure development programmes carried out in the UK to ensure water supply for both human consumption and irrigation purposes (e.g. the creation of reservoirs and the canalisation of rivers), to provide public transport systems (road, rail, air and canal networks), deliver protection from flooding (river and coastal flood defences), and supply energy (power stations, hydroelectric schemes and windfarms).

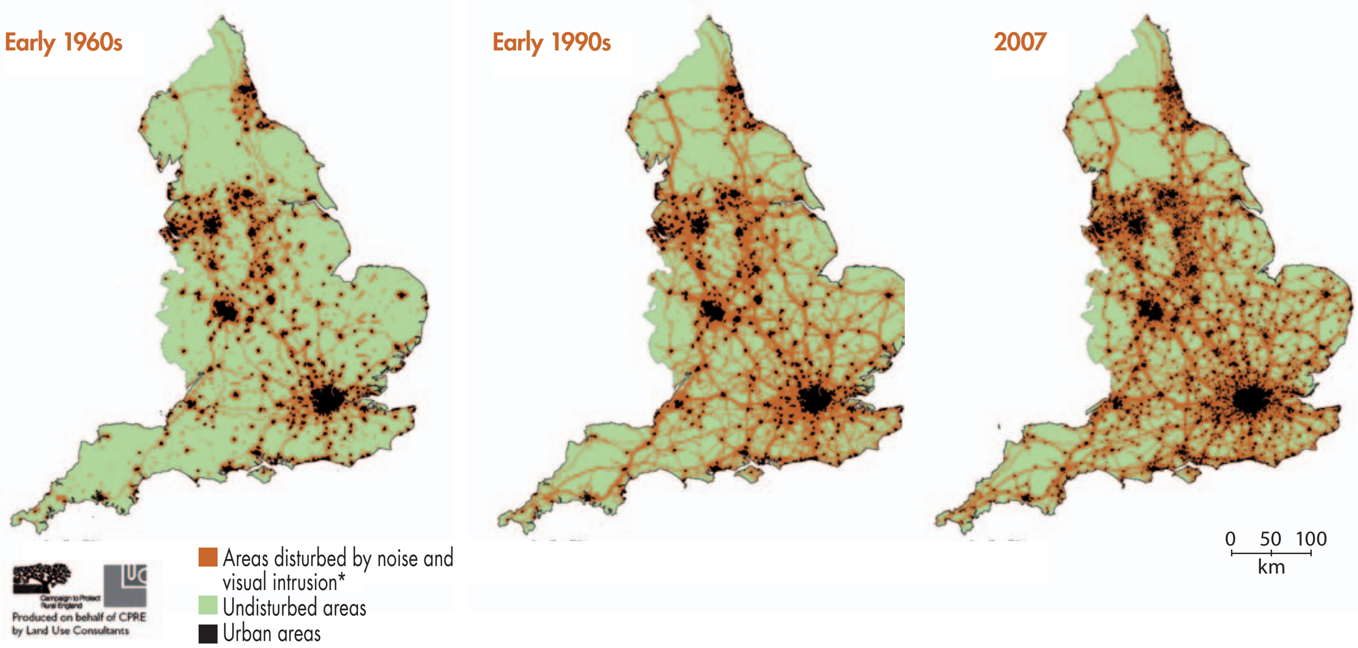


Figure 3.9 Areas of urban intrusion in the 1960s, 1990s and 2007. *Areas disturbed by urban development, major infrastructure projects and other noise and visual intrusion. Source: maps reproduced with permission from the Campaign for the Protection of Rural England (CPRE 2007). Crown copyright 2007. Produced by Land Use Consultants 2007. Licence No. 100019265.

This driver can alter ecosystems when land is directly converted to such infrastructure use, but also, as is the case for water supply, flood defences and renewable energy schemes, where ecosystem processes are affected. For example, river modification can alter levels and flow regimes, which, in turn, can impact on the movement of sediment along the coast (Chapter 11; Chapter 12).

The construction of much of the infrastructure outlined above pre-dates the time frame of this assessment. However, it is constructive to note the long history of public debate over the relative environmental costs and public benefits of large schemes, especially when those receiving the benefits of such schemes are distant from the area of impact. For example, the controversial construction of Haweswater Reservoir in the valley of Mardale in England's Cumbria Lake District. Here, in 1929, Parliament gave permission to Manchester Corporation to build a reservoir to supply water to the conurbations of north-west England. Although not heeded, public outcry was strong, particularly from the farming villages of Measand and Mardale Green which were to be flooded and lost, and the population moved, as result of the construction. Many also considered the valley one of the most picturesque in Westmorland, and voiced opposition against altering its natural aesthetic beauty (Visit Cumbria 2011).

Historically, urbanisation was the major factor behind early water supply infrastructure, while more recently, dominance of motorised transport has driven the expansion of public roads. With the probable future emphasis on renewable energy sources, the development of infrastructure, such as upland, coastal and marine windfarms, is also likely to continue.

3.4.2 Pollution and Nutrient Enrichment

Chemicals and nutrients, particularly nitrogen, phosphorous and sulphur (or their derivatives), entering ecosystems from point source, diffuse pollution and direct agricultural inputs can cause significant habitat change and impact on ecosystem services (see **Figure 3.1; Figure 3.2**). Their impact may be observed both at the point of input as well as at more distant sites due to some chemicals or nutrients moving beyond the area to which they were applied or emitted. For example, nutrient enrichment and runoff can drive shifts in the species composition and structure of both terrestrial and aquatic communities (freshwater, estuarine and marine), while atmospheric pollutants can be transported many thousands of miles.

The relative input of chemicals and nutrients into the environment, and the types used, has varied significantly in the UK since WWII. Consequential pollution and nutrient enrichment have impacted on provisioning, regulating and supporting services (**Figure 3.2**), and affected all eight UK NEA Broad Habitats (**Figure 3.1**). For example, nitrogen pollution from the atmosphere exceeds 'critical pollution loads' for the ground flora and epiphytic lichens of Atlantic Oakwoods, impacting on biodiversity levels and service provision, and increased ozone concentrations which can reduce forest growth (RoTAP 2010). Likewise, high atmospheric nitrogen deposition is linked to a decline in species diversity in Semi-natural Grassland (Stevens *et al.* 2004; Maskell *et al.* 2009; Chapter 6) and in Coastal Margin habitats (Jones *et al.* 2004). It should be noted, however, that often the greatest effect of nitrogen is at low levels (Bobbink *et al.* 2010), and for much of the UK it is likely that the major effects of nitrogen deposition have already taken place.

Due to the potential health risks many pollutants present, levels from both UK sources and transboundary depositions, are now heavily monitored and regulated by a variety of bodies including national and local government authorities, and environment agencies. Long-term research programmes, such as the Environmental Change Network (ECN; www.ecn.ac.uk/), also aim to detect environmental effects over time.

In this section we briefly outline the trends in a variety of nutrients and pollutants that have driven changes in UK habitats. More details can be found in the relevant sections of each of the habitat and service chapters.

3.4.2.1 Air pollution

Impacts on human health. Air quality levels are the result of the interaction of pollution emissions and local weather events (Defra 2010h). Air pollutants are known to impact on human health, contributing to the risk of developing cardiovascular diseases, lung cancer, breathing problems and triggering asthma symptoms (Defra 2010g). Over time, the sources of air pollutants impacting on human health have changed from being dominated by emissions from processes of energy production (sulphur dioxide) to those arising from road transport (i.e. particulates made up of a mixture of carbon, organic chemicals, sulphate, nitrates, ammonium, sodium chloride, mineral dust, water and metals) (Defra 2010g). National monitoring of these emissions began in the 1960s, with a wide range of other pollutants being added to monitoring schemes in the 1970s following the development of automatic recording devices. Road transport emissions, monitored by the UK Sustainable Development Indicators, show that while roadside and urban background particulate emission levels have fallen by 41% and 48%, respectively, since the 1990s, background urban ozone levels have continued to rise, averaging 55 micro-grams per cubic metre (μg/m^3) in 2009 compared with 44 μg/m^3 in 1992 (Defra 2010h). The cost of air pollution, and specifically particulates, to the UK in health terms is estimated to be in the order of £15 million annually (Defra 2010g).

Impacts on the environment: Sulphur. Historically, sulphur deposition has been the major cause of acidification in Europe. However, deposition peaked in the 1970s, and there has been a major decline of around 90% since that peak (RoTAP 2010). Nitrogen compounds are now a greater contributor to acidification than sulphur. The effect of acid deposition on habitats can be measured by assessing whether 'critical loads' (i.e. damage thresholds) have been exceeded (RoTAP 2010) (**Figure 3.10**). Exceedance of critical loads for acidity has reduced from 71% to 51%, with some limited recovery in freshwater pH and biological parameters (Monteith *et al.* 2005). Nevertheless, recovery is slow and is not likely to recover to pre-industrial levels (RoTAP 2010).

Impacts on the environment: Nitrogen. Atmospheric nitrogen comes primarily from oxidised nitrogen from combustion sources. Whereas, reduced nitrogen compounds, including ammonia, come primarily from agricultural sources (RoTAP 2010). Since 1990, emissions of nitrogen oxides have declined by 60% (108 million tonnes compared to 288 million tonnes), and ammonia emissions by 22% (288,000 tonnes compared to 368,000 tonnes).

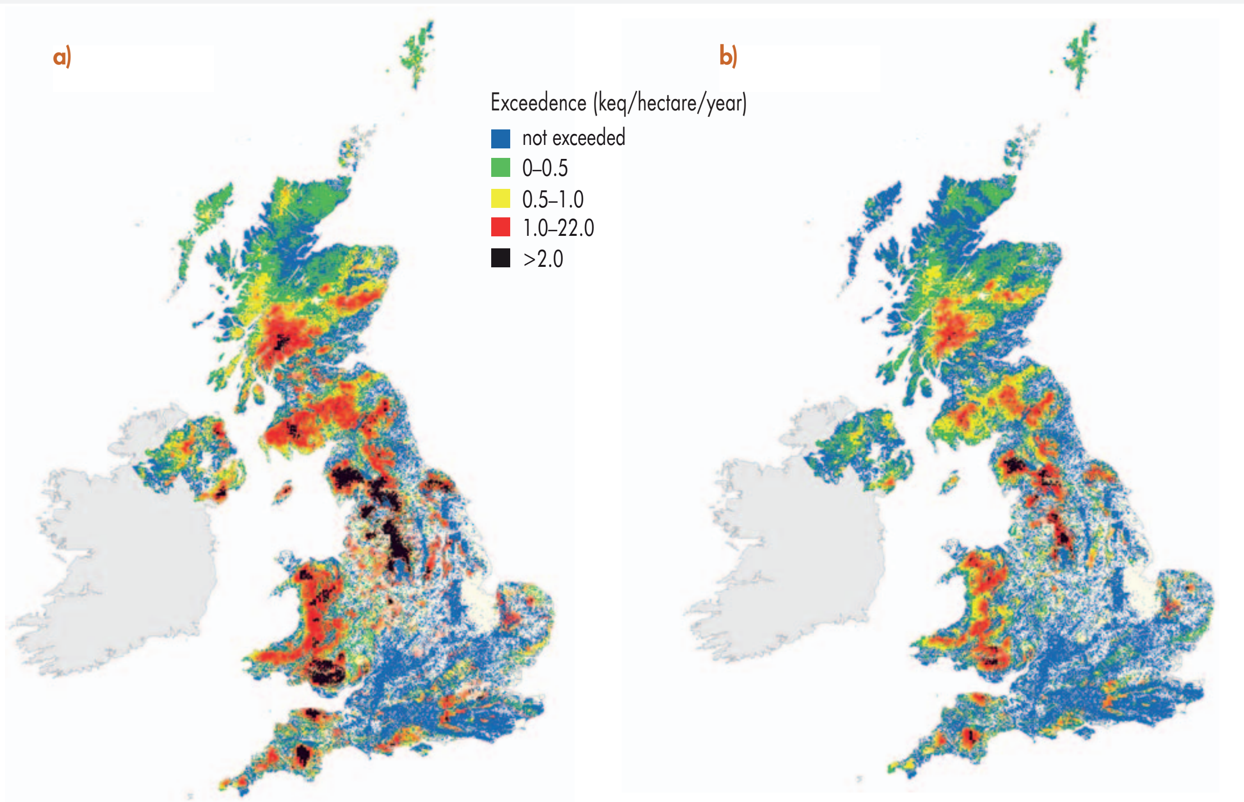


Figure 3.10 Exceedance of 5th percentile critical loads of acidity by acid deposition at 1x1 km resolution for a) 1996 to 1998 and b) 2004 to 2006. Source: data and maps from RoTAP (2010).

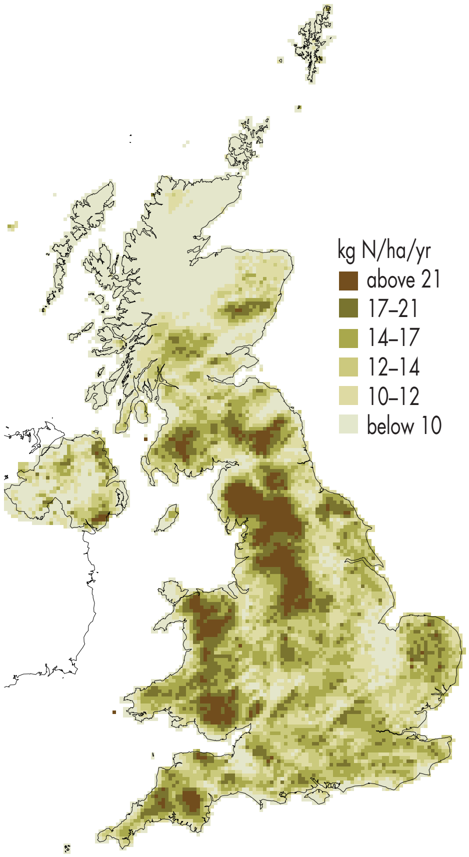


Figure 3.11 Total (oxidised + reduced) deposition of fixed nitrogen over the UK in 2008 (kilograms of nitrogen per hectare per year; kg N/ha/yr). Source: data and map from RoTAP (2010).

Reductions of the former are largely attributable to the introduction of catalytic convertors and stricter regulations on road transport and power stations; reductions in the latter are largely due to a decrease in cattle herds and more efficient fertiliser use (Defra 2010f). However, these declines in emissions have primarily affected transboundary export, and deposition in the UK has changed little (RoTAP 2010). Therefore, nitrogen deposition continues to impact on terrestrial and aquatic ecosystems (Chapter 13). High nitrogen deposition levels tend to be concentrated in the uplands and western areas of the UK (**Figure 3.11**), largely due to greater rainfall in these locations. Exceedance of Critical Loads for nutrient nitrogen varies across the UK and between habitat types (**Figure 3.12**); while there has been some decline in Critical Load exceedance over the past 20 years, this has not been significant.

Impacts of nitrogen deposition include soil and freshwater acidification, eutrophication of ecosystems, losses in plant species diversity (Jones *et al.* 2004; Stevens *et al.* 2004; Maskell *et al.* 2009), increases in emissions of greenhouse gases, and the modification of the transport and deposition patterns of sulphur dioxide (APIS 2010). As ammonia tends to be deposited rapidly, close to its source, it can cause ecosystem change in areas of sensitive habitat close to agricultural systems. On the other hand, nitrogen dioxides are transported longer distances and cause eutrophication far from their source.

3.4.2.2 Point source and diffuse agricultural pollution

Nitrogen, phosphorous and potassium are essential to plant growth (Nelson *et al.* 2005). The development of nitrogen,

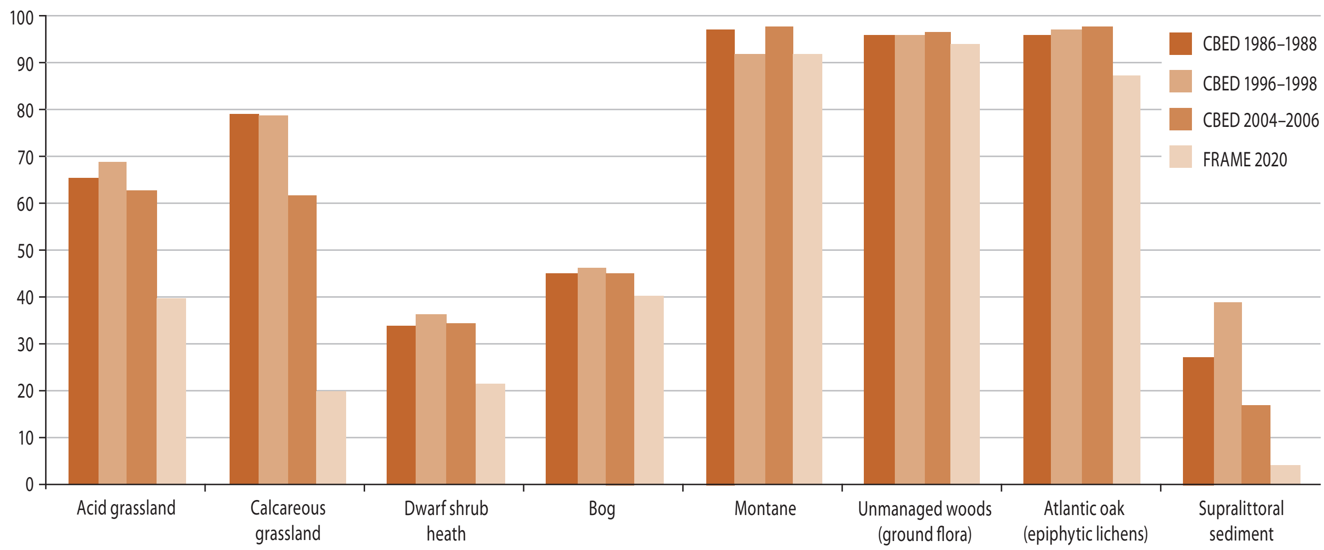


Figure 3.12 Exceedance of critical loads for effects of nitrogen deposition for sensitive semi-natural habitats. This shows the estimated percentage area of each major habitat with exceedance of the relevant critical loads in the mid-1980s, the mid-1990s and the mid-2000s, as well as projected exceedance for 2020. The critical loads used for this estimate were: 7 kilograms nitrogen per hectare per year (kg N/ha/yr) for montane (moss- and lichen-dominated summits); 10 kg N/ha/yr for bogs and for epiphytic lichens (in Atlantic oak woods); 12 kg N/ha/yr for woodland ground flora and dry dwarf shrub heath; 15 kg N/ha/yr for wet dwarf shrub heath, acid grassland and supralittoral sediments (coastal dune grasslands); and 20 kg N/ha/yr for calcareous grassland. Source: data from RoTAP (2010).

phosphorous and potassium based fertilisers and pesticides in the 1940s revolutionised farming and increased crop yields by supplementing natural sources of these nutrients in soils. Following WWII, the application of fertilisers and pesticides in the UK increased rapidly in response to demands for greater food production which were driven by the government's desire to increase security and self-sufficiency, as well as population growth. By 1986, nitrogen application rates had increased to 144 kg/ha, nearly twice that used in 1971, while levels of phosphorous and potassium had increased by almost one-third, to an average of 40 kg/ha and 48 kg/ha, respectively (Thomas 2010; **Figure 3.13**). Since then, fertiliser application rates have declined, particularly in grasslands compared with tilled land. For example, nitrogen application rates on tilled land in GB fell from 139 kg/ha in 1987 to 113 kg/ha in 2009, while application rates on grassland dropped from 132 kg/ha in 1986 to 57 kg/ha in 2009, the second lowest level since 1983 (Thomas 2010).

The primary source of excess nitrogen in ecosystems is derived from runoff from agricultural land, with between 40–60% of the amount of fertiliser applied typically being lost (Nelson *et al.* 2005). On the other hand, the primary source of phosphorous in the waters of GB is household sources (73–78%); this is distantly followed by agriculture (13–20%) and industry (3–4%) (White & Hammond 2009). While levels of nitrogen deposition appear to have changed little over the last 20-years, levels of phosphorous are believed to have declined across all UK habitats between 1998 and 2007 (Emmett *et al.* 2010; Chapter 13).

Pesticides used in the 1960s and early 1970s that were made of novel chemicals, such as DDT, are known to have caused community changes in wildlife such as declines in bird species (Carson 1962; Newton & Wyllie 1992). The types of pesticides used have changed continuously over time, and application rates have also been variable on national and local levels, generally increasing between 1970 and 2000, but decreasing over the last two decades (Ewald & Aebischer 2000; Fera 2011). For example, 20.2 kg of pesticides was used to treat 71 million ha of land in 2009, compared with 34.5 million kg used in 1990 to treat 45 million ha (Fera 2011). However, due to the changing nature of the chemicals applied, their toxicity and longevity, application levels cannot be taken as an indicator of the potential environmental impact of these system inputs. It should also be noted that, in an attempt to reduce the impact of pesticides on wildlife, 85% of the sprayed area in England and Wales is now being treated with tested machines under the National Sprayer Testing Scheme (NSTS) which are operated by members of the National Register of Sprayer Operators (NRoSO). Additionally, more than 2 million ha are now covered by a Voluntary Initiative Crop Protection Management Plan (www.voluntaryinitiative.org.uk).

Pollutants in rivers and streams. Pollution levels within rivers, and the impacts that they may have, can be assessed using measures of chemical and biological quality. In the UK, these metrics are monitored under the UK Sustainable Development Indicators which are reported separately for each country (Defra 2010e). Between 1990 and 2007, water quality was higher in Scotland and Wales than it was in England and Northern Ireland. In terms of national trends, the biological quality of rivers in Northern Ireland has decreased over the past decade, but chemical quality has increased; rivers in Scotland and Wales have remained stable in terms of both indicators, while both chemical and biological quality of English rivers have been improving (Defra 2010e), demonstrated by a decrease in the percentage of rivers tested showing exceedance levels for phosphorous and nitrate (Defra 2009b). The Countryside Survey Freshwater Stream Report has also shown that headwater streams in GB have continued to improve over the past 17 years (Dunbar *et al.* 2010).

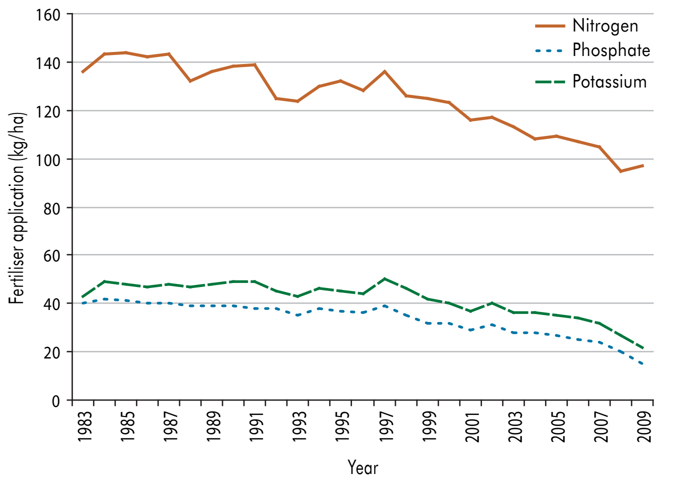


Figure 3.13 Overall nitrogen, phosphate and potassium application rates (kg/ha) on tillage crops and grassland in Great Britain from 1983 to 2009. Source: data extracted from Thomas (2010).

Pollutants in the marine environment. Marine pollution levels can be monitored by testing both the quality of coastal water and bathing water. Such testing has shown that, since 1995, the percentage of sites around the UK that comply with quality standards set by the UK Bathing Water Directive (which are more stringent than standards set by the European Bathing Water Directive) have increased from 41% (189 sites out of 464) to 70% (412 sites out of 587) in 2009 (Defra 2009a). Monitoring has also shown that, between 1995 and 2009, the number of sites complying with standards improved in England (41–71%), Scotland (17–56%) and Wales (38–89%), but declined in Northern Ireland (75–46%; Defra 2009a). Such improvements (i.e. reductions in pollution emissions to marine environments) have largely been attributed to improvements in sewage treatment and new pollution control legislation.

3.4.3 Overexploitation of Resources

Rates of consumption and/or exploitation of biotic resources can have major impacts on biodiversity and ecosystems. In the UK, the overexploitation of commercial fish stocks, the amount and type of timber harvested, the number of livestock, and the levels of abstracted water have all been responsible for directly driving changes in ecosystems and levels of biodiversity (see **Figure 3.1; Figure 3.2**).

3.4.3.1 Fisheries

The UK fishing fleet primarily targets fishing grounds in the north-east Atlantic which are some of the most productive and intensively exploited in the world (Thurstan *et al.* 2010). Excluding declines observed during both World Wars, total landings of demersal fish (i.e. bottom-living fish such as cod, haddock and plaice) in the UK rose rapidly from the late 19th Century to the middle of the 20th Century, corresponding to growth of the fleet, technological advancement and expansion into new grounds. Although fishing power (i.e. a measure of how fishermen increase their catching power over time, for example, through improvements to gear and ability to detect fish) associated with motor trawlers continued to increase up until the late 1970s, commercial landings of demersal fish have undergone a steady, long-term decline since the 1960s (**Figure 3.14**); they are now 5.4 times lower than the historical peak in 1938, dropping from approximately 800,000 tonnes to 150,000 tonnes in 2007 (Thurstan *et al.* 2010). Likewise, landings of pelagic fish have also decreased, but those of shellfish have grown from 34,090 tonnes in 1966 to 144,986 tonnes in 2008 (MMO 2010), largely as a result of the fishing industry switching to shellfish due to both a reduction in, and imposed quotas on, demersal and pelagic stocks.

Since the 1880s, it is thought that the catch rates of individual commercial species in the UK have declined by at least 83% or more, and, in some cases, by more than 99% (e.g. haddock and halibut) (Thurstan *et al.* 2010). Spawning stock biomass of species exploited by UK fleets is also estimated to have fallen by 42.6% since 1982. The decline in fish stocks is primarily thought to be a result of unsustainable catch rates and habitat destruction (e.g. from towed bottom-trawling equipment). This has not only led to reduced levels of productivity in both commercial and non-commercial species, but has also caused the complete collapse or reorganisation of whole marine ecosystems, such as that seen in the Firth of the Clyde in Scotland (Saunders 2010; Thurstan *et al.* 2010; Thurstan & Roberts 2010).

Despite these warnings, which are mirrored in the seas worldwide, the majority of global scientifically assessed stocks continue to be fished at levels above the Maximum Sustainable Yield (MSY), particularly under the current environmental conditions affecting stock productivity (Armstrong & Holmes 2010; Saunders 2010). Yet it should be noted that the diversity and overall abundance of soft-bottom demersal fish in the UK have made significant improvements over the last five to ten years (UKMMAS 2010). For example, it is believed that, of the 18 fish stocks assessed around the UK, the proportion of stocks being fished sustainably and which are at full reproductive capacity has risen from between 5–10% in the 1990s to 50% in 2008; those that are just harvested sustainably from 10% to 61%; and those just at full reproductive capacity from 35% to 61% (Armstrong & Holmes 2010; **Figure 3.15**). This is likely to be a result of enforced reductions in the size of the UK fleet and revised Total Allowable Catches set by the UK government and devolved administrations in line with the EU Common Fisheries Policy (Saunders 2010).

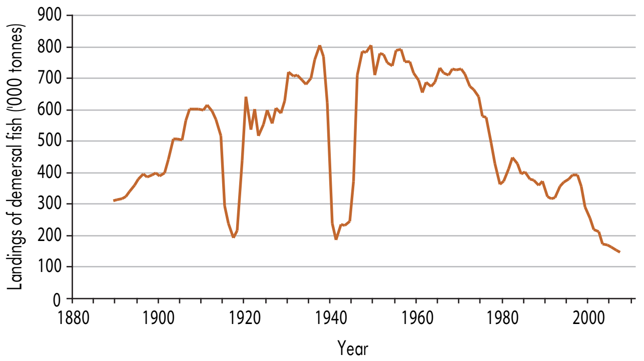


Figure 3.14 Change in total landings of demersal (bottom-living) fish into the UK by British vessels between 1889 and 2007. The two abrupt declines can be attributed to the First and Second World Wars when it was too dangerous to fish and vessels were put to other uses. The general decline since the 1940s can be attributed to overexploitation of fish resources (see text). Source: adapted from Thurstan *et al.* (2010).

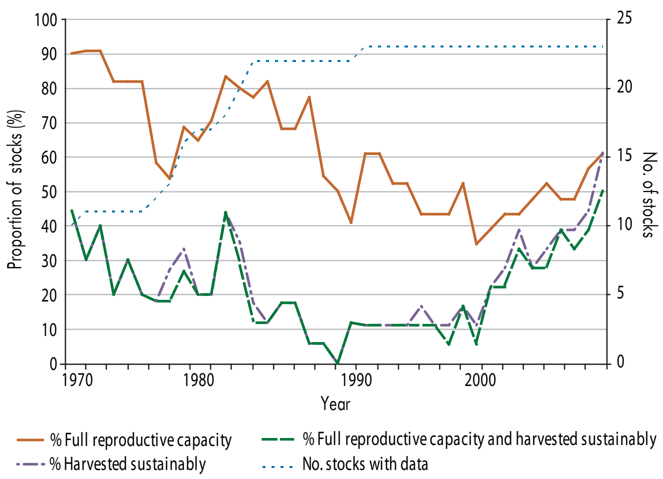


Figure 3.15 Percentage of finfish stocks around the UK which are at full reproductive capacity, harvested sustainably, and both at full reproductive capacity and harvested sustainably, 1970 to 2008. Source: Armstrong & Holmes (2010), CEFAS.

3.4.3.2 Timber harvest

Data collected by the Forestry Commission indicates a trend of continuing decline in the production of hardwoods and a steady increase in the production of softwoods since 1976. These harvest trends reflect the earlier increase in planting of coniferous woodlands with their relatively short harvest times from planting to felling. These figures indicate that management activities remain an active force in UK woodlands and that conifer woodlands can be expected to be more intensively managed than broadleaved woodlands.

3.4.3.3 Livestock stocking rates

Since WWII, the number of livestock in the UK has increased (Chapter 7; Chapter 15). In 2009, there were approximately 10.0 million cattle, 32.0 million sheep and 4.7 million pigs, compared with 8.4, 25.5 and 3.4 million in 1940, respectively. However, these figures mask the range of changes within this period. For example, sheep numbers peaked in 1990 at 44.5

million, which is 44% greater than those in 1950 (19.7 million), but have since declined by 28% to 32.1 million. Until recent times, the increase in stock numbers was associated with increased levels of agricultural improvement. Consequently, grazing pressure increased, leading to ecological change such as the conversion of moorland and mire habitat to grassland communities. Changes in stock numbers have also been driven, at various times, by the incidence of disease (such as Foot and Mouth Disease) and agricultural subsidies.

3.4.3.4 Water abstraction

Water is an essential resource for all life on earth and is heavily utilised by humans for both personal consumption and agricultural production. Water extraction can cause ecosystem change when the levels of rivers or the water table are excessively reduced. The amount of water available for abstraction is largely dependent on rainfall and water use patterns, while the observed increases in the amount abstracted has been linked to economic growth (Defra 2010e). As these factors are not distributed evenly across the UK, some regions, particularly the densely populated and dry south-east of England, suffer greater water stress, resulting in over-abstracted water catchments and rivers (Foresight 2010). In an attempt to avoid detrimental extraction levels, various licensing strategies, such as Catchment Abstraction Management Areas (CAMS) managed by the Environment Agency for England and Wales, have been introduced.

3.4.4 Climate Variability and Change

Change and variability in global climatic variables, such as temperature, precipitation and sea level, can affect biodiversity and ecosystems (Nelson *et al.* 2005). Impacts that have already been observed include changes to species distribution, population sizes, timing of reproduction and migration events, and increased frequency in outbreaks of pests and disease (MA 2005a).

Although climate change has not been identified as a major driver of change in most UK habitats to date, it is expected to play a significant role in future change (see **Figure 3.1)** (Chapter 26), and, in particular, impact on regulating, supporting and provisioning services (see **Figure 3.2)** (Chapters 13–15). For instance, coupled with other drivers and pressures, such as land use intensity, loss of habitat and the introduction of invasive species, increased temperature could result in continued pole-ward movement of species or movement to higher elevations. Higher temperatures and greater prevalence of hot days could increase stress in plants and animals and reduce productivity, but extend the range and activity of pest and disease vectors. And more intense precipitation events could result in increased soil erosion and flood runoff (Nelson *et al.* 2005). In this section, we outline some of the observed trends for key climatic parameters in the UK, including temperature and precipitation, sea levels, greenhouse gas emissions, carbon dioxide and its impact on ocean acidification, as well as patterns in extreme weather events.

3.4.4.1 Trends in temperature and precipitation

Global surface air temperatures have risen by 0.75°C since the late 19th Century, and have been steadily warming by an average of 0.13°C per decade since the 1950s, with the years between 1995 and 2006 being the warmest on record (IPCC 2007). This is mirrored in the UK where the mean annual Central England Temperature (the longest continuous record of surface air temperature in the world) and temperatures in Wales, Scotland and Northern Ireland have risen by approximately 1°C since the beginning of the 20th Century (Jenkins *et al.* 2009; Huthnance 2010; **Figure 3.16**). The greatest regions of warming have occurred in the Midlands, South East England and East Anglia (Perry 2006). Concurrent with rising air temperatures, sea-surface temperatures of UK waters have increased by 0.5–1.0°C during the period between 1870 and 2007 (Huthnance 2010; **Figure 3.17**). Rising sea-surface temperatures are likely to impact on the ability of the ocean to take up carbon dioxide, may affect species distributions, and contribute to sea-level rise (Huthnance 2010).

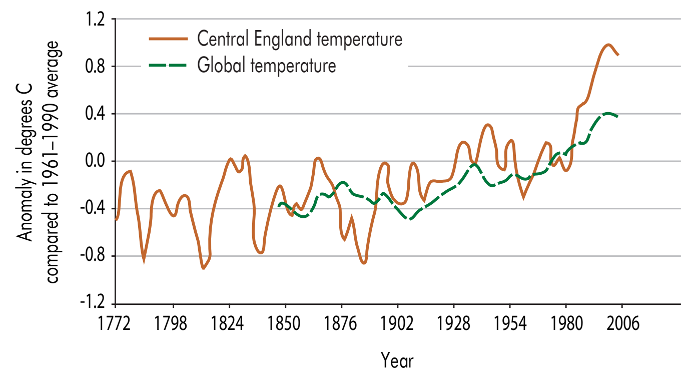


Figure 3.16 Central England surface air temperature (°C) from 1772 to 2008. Source: data from the Hadley Centre; figure reproduced from Defra (2009c). © Crown copyright 2009.

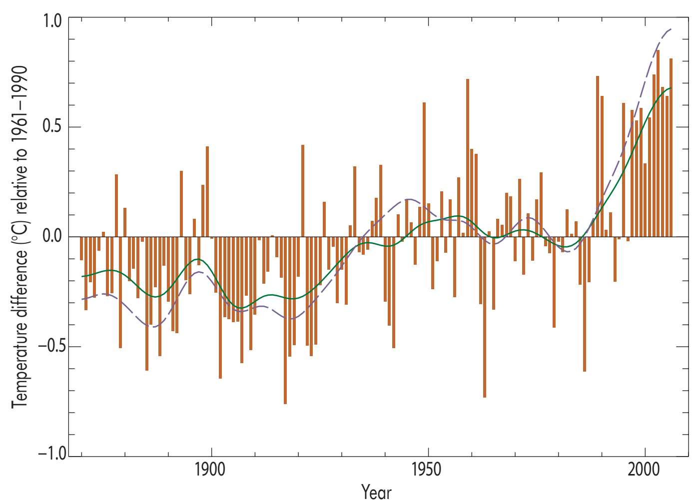


Figure 3.17 Annual mean sea-surface temperature (°C) averaged around the UK coastline, 1870 to 2006 (the orange bars extending from 1961 to 1990 average of 11.3 °C); the smoothed green line emphasises decadal variations. The purple curve (dashed line) shows night marine air temperature over roughly the same area, with the same smoothing. Source: reproduced from Jenkins *et al.* (2009).

Between 1914 and 2004, precipitation patterns (as monitored by the UK Met Office) showed that all districts in the UK experienced a decrease in summer precipitation, although these changes were significant in only three out of ten districts[5]: East Scotland, North West England and Wales, and Northern Ireland (Perry 2006). Despite this, there has been a tendency towards wetter winters in the north and west of Scotland (Huthnance 2010). During the winters of 1961–1962 and 2004–2005, there was a decrease in the number of days with snow across all ten UK districts, of which, four—East and North East England, North West England and Wales, South West England and South Wales, and Central, South and South East England—were strongly significant. The strongest trend is in Central, South and South East England where there are approximately 75% less days with snow compared to 1961 (Perry 2006).

3.4.4.2 Sea-level change

Global sea-level rose by 1.7 mm per year during the 20th Century; while in the UK, and correcting for land movement, the rate of rise was approximately 1 mm per year during the same time period (Jenkins *et al.* 2009; Huthnance 2010). However, this rate of rise was variable, with a much more rapid rise during the 1990s of 3–4 mm per year. Allowing for land movement, net sea-level rise is greater in England and Wales, but lower in Scotland (**Figure 3.18**). As populations and urbanisation expand into the coastal zones, an increasing number of people will become vulnerable to extreme rises in sea-level, particularly in the south-east of the UK. Change in sea-level will also impact on intertidal habitats and groundwater storage, and may lead to more severe flooding and coastal erosion by waves (Huthnance 2010).

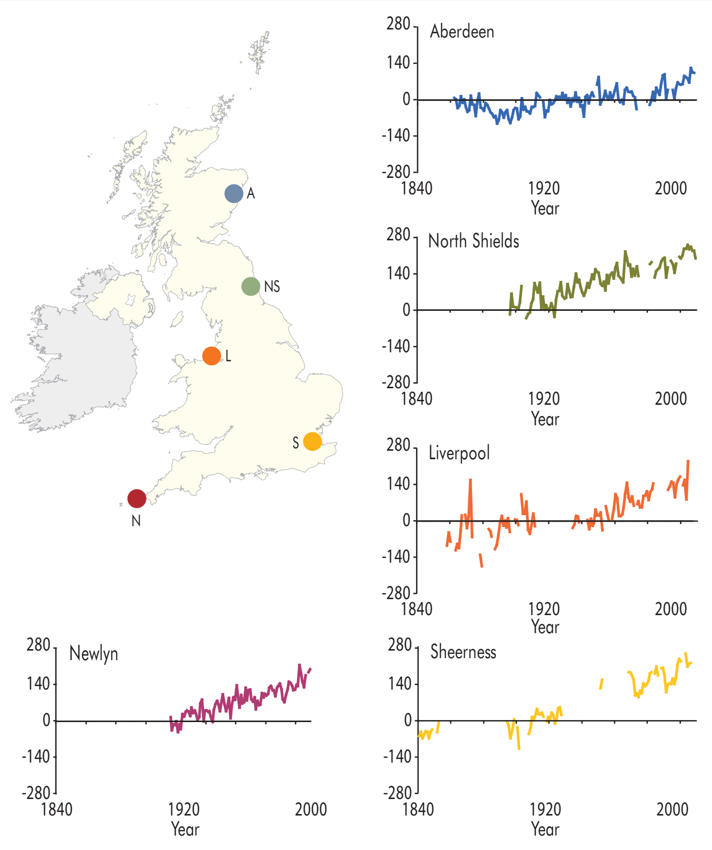


Figure 3.18 Annual mean sea-level anomalies at various sites around the UK compared to the 1920 baseline. Source: data from the Permanent Service for Mean Sea-level (PSMSL; 2011) and Woodworth *et al.* (2009); adapted from Defra (2009c).

3.4.4.3 Greenhouse gas emissions

There is now strong evidence that the changes to the earth's climate that have occurred during the 20th Century are linked to greenhouse gases emitted as a result of human activities (MacCarthy *et al.* 2010). The 'greenhouse effect' is a natural process that regulates the temperature of the earth; however, the release of excess greenhouse gases by human activities contributes to this process, trapping heat in the atmosphere and resulting in increased temperatures, which can have adverse impacts on ecosystems (MacCarthy *et al.* 2010).

Emissions of the six direct greenhouse gases—carbon dioxide, methane, nitrous oxide, hydrofluorocarbons and perfluorocarbons—have decreased in the UK since 1990 (MacCarthy *et al.* 2010; **Figure 3.19**). Decreases are a result of policy implementation, reduced greenhouse gas-emitting activities (e.g. coal mining) and sources (e.g. livestock numbers and fertiliser application), and changes to processes (e.g. improved methane recovery systems and fluorinated gas abatement equipment) (MacCarthy *et al.* 2010).

3.4.4.4 Carbon dioxide and ocean acidification

Oceans absorb more carbon dioxide than they release, and hence play an important role in mitigating climate change by reducing the amount of carbon dioxide in the atmosphere. However, this also makes oceans more acidic, which not only reduces their capacity to take up carbon dioxide, but alters their carbonate chemistry. Ocean acidification is a direct

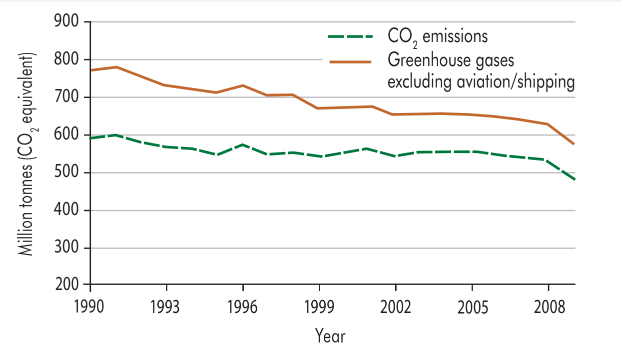


Figure 3.19 Trends in greenhouse gas and carbon dioxide (CO_2) emissions for the UK, 1990 to 2009*. Source: Department for Environment, Food and Rural Affairs, Department of Energy and Climate Change, AEA Energy and Environment; figure reproduced from Defra (2010e). © Crown copyright 2010. *2009 figures are provisional.

5 The ten climate districts used by Perry (2006) to assess the patterns of differentiation and change in UK climate between 1914 and 2004 are: 1. Scotland N; 2. Scotland E; 3. Scotland W; 4. England E and NE; 5. England NW and Wales; 6. Midlands; 7. East Anglia; 8. England SW and Wales S; 9. England SE, Central, S; 10. Northern Ireland.

consequence of anthropogenic carbon dioxide emissions and, if these continue at the same rate, may impact on marine organisms, food webs, ecosystems and ocean biogeochemistry within decades (**Box 3.2**). Currently, there is a lack of knowledge about how ocean acidification impacts on UK waters due to a dearth of baseline measurements and a limited understanding of the processes controlling an ocean's ability to absorb carbon dioxide (Huthnance 2010). Nonetheless, it is projected to be a major contributing factor to future changes in the marine environment.

3.4.4.5 Extreme weather events

Since 1961, there has been a decrease in the length of winter cold spells, and an increase in the length of summer heat waves (Perry 2006), although there appears to be no clear trend in drought frequency in England and Wales (Marsh 2007). Across the UK, heavy precipitation events have made a higher contribution to total winter rainfall levels over the last 45 years (Jenkins *et al.* 2009). In contrast, in summer, all regions except North East England and North Scotland have shown a reduced number of heavy rainfall events in the last 45 years (Jenkins *et al.* 2009). The incidence of extreme stormy weather events has increased over the past 50 years, but these are not above levels recorded in the 1920s (Jenkins *et al.* 2009; Huthnance 2010).

Box 3.2 Carbon dioxide and ocean acidification.

Oceans and seas are becoming more acidic as they absorb increasing amounts of atmospheric carbon dioxide (Zeebe & Wolf-Gladrow 2001; Caldeira & Wickett 2003; Orr *et al.* 2005). Models and measurements suggest about a 30% decrease in surface pH and about a 16% decrease in carbonate ion concentration (used by organisms to make shells, skeletons and liths) since pre-industrial days (Caldeira & Wickett 2003; Feely *et al.* 2004; Sabine *et al.* 2004; Orr *et al.* 2005). By the year 2100, ocean acidity is projected to rise by up to 150% if carbon dioxide emissions continue at their current rate (Caldeira & Wickett 2003; Feely *et al.* 2004; Orr *et al.* 2005). The rate of change in acidity is faster than anything experienced in the last 65 million years (Ridgwell & Schmidt 2010), and it will take tens of thousands of years for these changes in ocean chemistry to be buffered through neutralisation by calcium carbonate sediments (Archer & Brovkin 2008). While evidence of current impacts of these changes to the carbonate system is lacking, there is rising concern for future marine ecosystems and the goods and services they provide as acidification tracks carbon dioxide emissions to the atmosphere (for reviews see Royal Society 2005; Kleypas *et al.* 2006; Fabry *et al.* 2008; Doney *et al.* 2009; Turley & Findlay 2009; Turley & Boot 2010 and references therein).

Ocean acidification may impact some ecosystems directly (e.g. coral ecosystems) or indirectly by reducing the fitness of a keystone species (e.g. echinoderms, pteropods) (Kleypas *et al.* 2006; Fabry *et al.* 2008; Hall-Spencer *et al.* 2008; Turley & Findlay 2009). These future increases in ocean acidity may have major negative impacts on some shell- and skeleton-forming organisms, such as cold water corals (Guinotte *et al.* 2006; Maier *et al.* 2009) and tropical coral reefs (Kleypas *et al.* 2006; Feely *et al.* 2008; Hoegh-Guldberg *et al.* 2008), within this century. While it is a global issue, polar and sub-polar waters (Orr *et al.* 2005; Steinacher *et al.* 2009), deep waters (Orr *et al.* 2005) and some upwelling regions (Feely *et al.* 2008) already naturally rich in carbon dioxide may be the first to experience the impacts of ocean acidification. Projections indicate that European shelf seas will also be vulnerable to changing acidity (Blackford & Gilbert 2007).

3.4.5 Invasive Species

The introduction of invasive and non-native (or 'alien') invasive species, and/or the introduction and naturalisation of domestic forest, crop or livestock species, can drive ecosystem change that affects human well-being through their impacts on economic activities (such as losses in crops or fisheries) or public health (Nelson *et al.* 2005). In the UK, biological drivers are considered to have had important impacts on all UK NEA Broad Habitat types, but especially Semi-natural Grasslands, Enclosed Farmland, Woodlands, Freshwaters and the Urban habitat (see **Figure 3.1**).

3.4.5.1 Invasive non-native species

An invasive species can be taken to mean a species that "spreads in space, either occupying new habitats or increasing its cover in areas previously occupied" (Nelson *et al.* 2005, p209). Typically, invasive species are primarily non-native, but the above definition can also apply to native species that 'invade' after habitat or climate change (Nelson *et al.* 2005).

Invasive species are generally thought to have detrimental impacts on ecosystems and their services, often acting as vectors for disease, changing biodiversity, altering service provision, disrupting cultural landscapes, and reducing the value of land and water for human activities (DAISIE 2011). They can also have significant socioeconomic consequences, especially when they cause damage to livestock, crops and timber plantations. In GB, non-native invasive species are estimated to cost more than £1.7 billion annually in control, mitigation, structural damage to infrastructure or loss of production (Williams *et al.* 2010; **Table 3.5**). The spread of these costs across different sectors are shown in **Table 3.5** for three non-native invasive species in GB (Williams *et al.* 2010):

- Japanese knotweed (*Fallopia japonica*)—originally introduced as an ornamental garden plant in the mid-19th Century, but is now widespread in a range of habitats where it displaces native flora and causes structural damage.
- American signal crayfish (*Pacifastacus leniusculus*)—originally introduced in the late 1970s primarily to farm for food; it soon escaped or was deliberately released and spread rapidly across England and Wales, although its distribution is now limited to Scotland. It out-competes native crayfish, carries a crayfish plague that kills native species, burrows into riverbanks, increasing erosion, and predates on the eggs of wild fish stocks.
- Floating Pennywort (*Hydrocotyle ranunculoides*)—originally introduced from North America in the 1980s through the aquatic plant trade, it now infests at least 150 sites in England and Wales. It forms dense vegetative mats that out-compete most native aquatic plants, can contribute to localised flooding through blocking drainage systems, and may have a negative impact on fish by restricting their access to feeding and resting spots.

Conversely, the effects of introduced non-native species may be benign or even valued. The public may welcome views of rhododendron within upland woodland, for example, or

Table 3.5 Total cost (£ '000s) of three non-native invasive species (Japanese knotweed, signal crayfish and floating Pennywort) to the British economy. Note, Floating Pennywort is not present in Scotland. Source: data extracted from Williams *et al.* (2010).

Sector	England	Scotland	Wales	GB
Japanese knotweed				
Local authorities	270	96	66	432
Research	319	32	19	370
Railways	1,726	174	100	2,000
Roadsides	3,901	757	438	5,096
Riparian	3,444	1,724	469	5,637
House devaluation	963	97	56	1,116
Development	141,358	1,508	7,644	150,510
Householders	383	42	23	448
Total	**152,364**	**4,430**	**8,815**	**165,609**
Signal crayfish				
Management	776	163	363	1,302
River bank restoration	100	50	50	200
Angling	550	325	125	1,000
Research	112	38	37	187
Total	**1,538**	**576**	**575**	**2,689**
Floating Pennywort				
Management	1,815	-	115	1,930
Recreation	23,468	-	69	23,537
Total	**25,283**	**-**	**184**	**25,467**

enjoy sightings of parakeets in the south of England; while grey squirrels (*Sciurus carolinensis*) offer a chance to get close to wildlife for many visitors to urban parks. For these reasons, the control of non-native species by conservation agencies may be controversial.

In GB, 3,473 non-native species have been recorded (Hill *et al.* 2009), with at least 49 being categorised as 'high threat' (**Table 3.6**). Some have been successfully eradicated, while others continue to spread. The number of records of non-native species rose by 23% between 1990 and 2007 (Hill *et al.* 2009). The area in which they occur and are considered invasive has also risen, by 40%, during the same time period (Hill *et al.* 2009), with England being the most affected (2,721 non-native species, of which, 100 are considered to have a negative impact on the environment; Hill *et al.* 2005), followed by Wales and then Scotland (988 non-native terrestrial and freshwater species were identified in 2001, with 76 tagged as potential problem species; Welch *et al.* 2001; SPICe 2010). In England, most non-native flora was introduced in the 18th and 19th Centuries, while most faunal introductions occurred in the second half of the 20th Century and are more prominent in the south of the country (Hill *et al.* 2005). In Scotland, over 100 non-native plants increased their range between the 1950s and 1980s (Welch *et al.* 2001). The rise of global trade and tourism, which facilitates the transfer of species between locations, has been largely responsible for the recent increases in incidence and spread of non-native invasive species (SPICe 2010).

The extent to which current non-native species may become problematic and cause detrimental ecosystem

Table 3.6 Invasive species categorised as 'High Threat' in Great Britain. Common names are provided in parentheses. Source: data extracted from Hill *et al.* (2009).

a) Marine plants	c) Freshwater plants	e) Terrestrial plants
Sargassum muticum (Japweed, Wire Weed)	*Crassula helmsii* (New Zealand Pigmyweed)	*Carpobrotus edulis* (Hottentot Fig)
Undaria pinnatifida (Japanese Kelp, Wakame)	*Hydrocotyle ranunculoides* (Floating Pennywort)	*Disphyma crassifolium* (Purple Dewplant)
Codium fragile ssp. *tomentosoides* (Green Sea Fingers)	*Ludwigia grandiflora* (Uruguayan Hampshire-purslane)	*Fallopia japonica* (Japanese Knotweed)
b) Marine animals	*Myriophyllum aquaticum* (Parrot's-feather)	*Heracleum mantegazzianum* (Giant Hogweed)
Tricellaria inopinata (bryozoan)	**d) Freshwater animals**	*Impatiens glandulifera* (Himalayan Balsam)
Watersipora subtorquata (bryozoan)	*Pacifastacus leniusculus* (Signal Crayfish)	*Quercus ilex* (Evergreen Oak)
Corophium sextonae (amphipod)	*Procambarus clarkii* (Red Swamp Crayfish)	*Rhododendron ponticum* (Rhododendron)
Gammarus tigrinus (amphipod)	*Corbicula fluminea* (Asian Clam)	*Rosa rugosa* (Japanese Rose)
Elminius modestus (acorn barnacle)	*Dreissena polymorpha* (Zebra Mussel)	**f) Terrestrial animals**
Solidobalanus fallax (barnacle)	*Pseudorasbora parva* (Topmouth Gudgeon)	*Arthurdendyus triangulata* (New Zealand Flatworm)
Eriocheir sinensis (Chinese Mitten Crab)	*Sander lucioperca* (Pikeperch, Zander)	*Harmonia axyridis* (Harlequin Ladybird)
Rhithropanopeus harrisii (Dwarf Crab)	*Lithobates catesbeianus* (American Bullfrog)	*Branta canadensis* (Canada Goose)
Crassostrea gigas (Pacific Oyster)	*Trachemys scripta* (Common Slider Turtle)	*Oxyura jamaicensis* (Ruddy Duck)
Crepidula fornicata (Slipper Limpet)		*Cervus nippon* (Sika Deer)
Rapana venosa (Rapa Whelk)		*Muntiacus reevesi* (Reeves' Muntjac)
Anguillicola crassus (Swim-bladder Nematode)		*Mustela vison* (American Mink)
Botrylloides violaceus (tunicate)		*Myocastor coypus* (Coypu)
Corella eumyota (tunicate)		*Rattus norvegicus* (Brown Rat)
Didemnum vexillum (tunicate)		*Sciurus carolinensis* (Grey Squirrel)
Styela clava (Leathery Sea Squirt)		

change is often unknown due to the lag time between species first invading and subsequently increasing in occurrence within the country. However, to improve records and develop more timely management strategies, a British non-native species secretariat was formed in 2008 (www.nonnativespecies.org). The secretariat manages a risk register and a central depository for data on invasive species. An Invasive Non-Native Species Framework Strategy for GB has also been recently published (Defra 2008).

3.4.5.2 Introduction of domestic species

The majority of the UK's food and timber supply has relied on the introduction of alien domestic species. In many cases, these have now become naturalised (Williamson & Fitter 1996), but introductions have caused significant changes in a variety of UK habitats. For instance, deliberate selection of enhanced forestry species (typically of introduced conifers) led to widespread changes through UK woodlands, resulting in many broadleaved ecosystems becoming shaded, plantation woodlands. In turn, this has led to significant changes in biodiversity levels, particularly ground flora communities.

Breeding and selection of livestock species has also contributed directly to ecosystem change where species have specific grazing requirements and characteristics. The changes in stock type (e.g. sheep versus cattle) and the different breeds selected have contributed to ecosystem changes, especially in the uplands, where this is also interrelated to agricultural improvements and changes in harvest and livestock levels.

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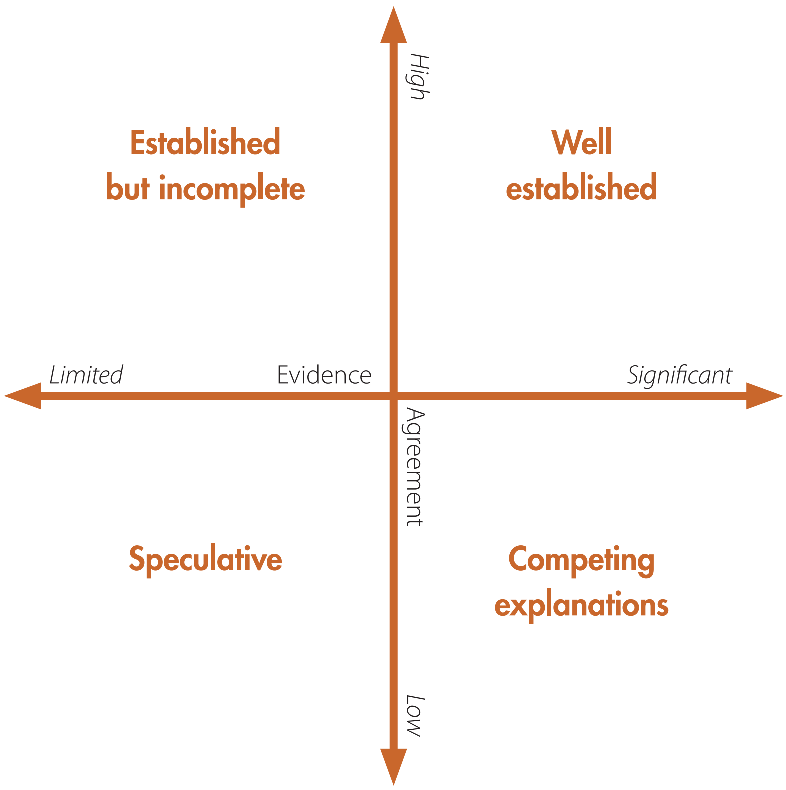
Appendix 3.1 Approach Used to Assign Certainty Terms to Chapter Key Findings

This chapter began with a set of Key Findings. Adopting the approach and terminology used by the Intergovernmental Panel on Climate Change (IPCC) and the Millennium Assessment (MA), these Key Findings also include an indication of the level of scientific certainty. The 'uncertainty approach' of the UK NEA consists of a set of qualitative uncertainty terms derived from a 4-box model and complemented, where possible, with a likelihood scale (see below). Estimates of certainty are derived from the collective judgement of authors, observational evidence, modelling results and/or theory examined for this assessment.

Throughout the Key Findings presented at the start of this chapter, superscript numbers and letters indicate the estimated level of certainty for a particular key finding:

1. *Well established:* high agreement based on significant evidence
2. *Established but incomplete evidence:* high agreement based on limited evidence
3. *Competing explanations:* low agreement, albeit with significant evidence
4. *Speculative:* low agreement based on limited evidence



a. *Virtually certain:* >99% probability of occurrence
b. *Very likely:* >90% probability
c. *Likely:* >66% probability
d. *About as likely as not:* >33–66% probability
e. *Unlikely:* <33% probability
f. *Very unlikely:* <10% probability
g. *Exceptionally unlikely:* <1% probability

Certainty terms 1 to 4 constitute the 4-box model, while *a* to *g* constitute the likelihood scale.