

Chapter 17:

Status and Changes in the UK Ecosystems and their Services to Society: England

Coordinating Lead Authors: Pam Berry and John Hopkins

Contributing Authors: Todd Sajwaj, Melanie C. Austen, Laurence Jones and Emma Burnett

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Key Findings*

About 70% of England is farmed. England has a population of over 52 million people, making it one of the world's most densely populated countries, with over 80% of the population living in towns and cities¹. These urban areas are virtually certain to make the highest demands on, and be the greatest recipients of, ecosystem services².

¹ well established

² established but incomplete evidence

There have been significant changes to England's biodiversity, with declines in many well-recorded species over the last 50 years¹. Recently (2003–2006) the overall trends in selected indicator species were positive¹, although 26% of England's species are still depleted or on the UK Biodiversity Action Plan (BAP) list². Sites of Special Scientific Interest cover 8% of England and while many are not in favourable conservation status, it is likely that their condition is improving².

¹ well established

² established but incomplete evidence

England contains the majority of the UK's Enclosed Farmland¹. The condition of the Broad Habitat has been declining over the last 50 years, very likely because of land use change and management, but with some recovery in the last 10 years².

¹ well established

² established but incomplete evidence

The area covered by Mountains, Moorlands and Heaths has significantly decreased over the last 60 years, very likely due to afforestation and conversion to rough and improved grassland in the uplands¹. Loss of lowland heathland is likely to have been due to the development of towns and roads, afforestation and agricultural improvement¹. There were some increases between 1998 and 2007, due to restoration and re-creation¹.

¹ well established

Most Semi-natural Grasslands have been lost, very likely due to conversion to arable or intensification, but many are now protected, with 68% lying within Sites of Special Scientific Interest (SSSIs) and 40% designated as Special Areas of Conservation (SACs)¹. It is likely that Calcareous and Acid Grassland have experienced the greatest average loss of plant species of all Semi-natural Grasslands over the last 40 years².

¹ well established

² established but incomplete evidence

Arable Enclosed Farmland increased after the Second World War (WWII), but between 1998 and 2007 it decreased by 8.8%, while Improved Grassland increased by 5.2%¹. This is very likely to be due to alterations in economic and technological drivers and policy (e.g. Common Agricultural Policy (CAP) reform)¹. Some arable flowering plants have decreased dramatically in the last 50 years and are now likely to be amongst the most threatened elements of the flora¹. Since 1982, about 90% of all yield increases in wheat and barley can probably attributed to new crop varieties².

¹ well established

² established but incomplete evidence

England is comparatively poorly wooded (9%), despite cover increasing by 45% since WWII¹. Initially, mostly conifers were planted, but since the 1980s more broadleaves have been used¹. Many woodland species have declined in numbers due to lack of management, deer grazing, fragmentation and, increasingly, climate change². Woodland delivers the greatest number of identified ecosystem services².

¹ well established

² established but incomplete evidence

Wetlands only cover about 4% of England, but they have a disproportionately high biodiversity, including a significant number of internationally important species². Consequently, 47% of England's wetlands are under SSSI protection¹. England also has the greatest extent of chalk rivers in Europe¹. Forty-four per cent of SSSI open waters and 21% of wetland are classified as favourable and 11% and 48% as recovering, respectively. Eutrophication is likely to be the main cause of unfavourable condition in open waters, and overgrazing, burning, pollution and drainage in wetlands².

¹ well established

² established but incomplete evidence

* 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 indicate the uncertainty term assigned to each finding. Full details of each term and how they were assigned are presented in Appendix 17.1.

England is more urbanised than the rest of the UK and Urban areas cover about 10% of the country¹. Urban areas require more ecosystem services than they can provide; estimates suggest that London alone requires 293 times more land than its geographical area to support itself¹. Urban habitats provide greenspace, which is of importance to Urban residents¹. ^{1 well established}

England holds 73% of the UK's Saltmarsh and 86% of its Shingle¹. Saltmarsh, Shingle and Sand Dunes have suffered losses due to reclamation, development and erosion¹. Coastal Margin habitats support a wide range of highly specialised species, and it is very likely that many of these are of international importance for conservation². ^{1 well established}
^{2 established but incomplete evidence}

England's Marine habitats support a high diversity of species². Coastal erosion particularly affects England's coast, with 30% subject to erosion and 46% protected by engineering structures². It is very likely that harvesting has adversely affected marine species². Energy provision by the physical component of Marine habitats, and through biomass harvesting, is likely in the near future⁴. ^{2 established but incomplete evidence}
^{4 speculative}

Supporting services in England function at rates similar to those of other countries in the UK, but are faced with significant pressures from human activities². Nutrient cycling in England is influenced by anthropogenic nitrogen and phosphorus deposition from domestic, agricultural and industrial sources¹. Tillage practices in arable regions are very likely to have a significant negative influence on soil erosion rates². Annual losses of carbon due to peatland management are likely to exceed the rate of carbon sequestration by English peatlands that are in good condition². It is likely that primary production is increasing in agricultural and Woodland habitats². ^{1 well established}
^{2 established but incomplete evidence}

The quality of many regulating services is improving; however, various forms of pollution continue to impact deleteriously on England's ecosystems². England is a net source of greenhouse gases, but this trend is diminishing¹. England's pollinating insects are declining, with significant consequences for agricultural production and several habitats¹. Significant improvements in England's air quality have occurred over recent decades, but current concentrations and deposition rates often exceed recommended environmental thresholds¹. Although the number of English rivers of good chemical quality is increasing, concentrations of phosphates and nitrates remain problematic². ^{1 well established}
^{2 established but incomplete evidence}

England's provisioning services contribute strongly to local and national economies and while environmental management is improving, significant impacts on interdependent regulatory, cultural and supporting services must be addressed¹. It is likely that England's farmlands will continue to show steadily increasing agricultural yields with declining environmental impacts¹. Landscape management, particularly agricultural management, plays a critical role for the continued delivery of other ecosystem services². Landings of marine fish have declined since 1970². Throughout the 20th and 21st Centuries, demand for water in England has steadily increased due to population growth and will continue to grow². ^{1 well established}
^{2 established but incomplete evidence}

England's landscape provides highly important cultural ecosystem services to local populations, individual residents and external visitors, the value of which is often difficult to quantify². Urban and rural greenspaces provide important opportunities for recreation, aesthetic inspiration, community interaction and psychological well-being¹. The habitats and landscapes of England provide important sources of tourist revenues that support rural communities². ^{2 established but incomplete evidence}

The main direct drivers of change primarily affect agriculture, woodland and urban land uses, while indirect ones concern economic forces and increasing population². Agricultural expansion and intensification to meet the food demands of a growing urban population have led to habitat loss and degradation¹. It is very likely that changes in woodland management have altered woodland species composition, as have pressures, such as deer grazing². ^{1 well established}
^{2 established but incomplete evidence}

The consequences of the change in Broad Habitats and their service delivery are only broadly understood². Enclosed Farmland, Semi-natural Grasslands and Woodlands are of high importance for provisioning services, but the increase of Enclosed Farmland and Woodlands has led to the loss of other habitats¹. Enclosed Farmland management to increase the provision of food has affected biodiversity and decreased provision of some regulating and cultural services². All habitats contribute to regulating services; the condition of many of these is recovering as a result of policy intervention². All Broad Habitats are important for cultural services².

¹ well established

² established but incomplete evidence

Sustainable management of habitats and their services is critical to their long-term future and to providing an appropriate balance of services¹. It is likely that a holistic ecosystems approach would help achieve this². Further funding streams, as through Payments for Ecosystem Services schemes, are needed to support sustainable management².

¹ well established

² established but incomplete evidence

Synergies and trade-offs that occur between and within ecosystems and their services need to be managed sustainably². Research and case studies are useful to demonstrate how synergies and trade-offs can be handled to achieve sustainable management².

² established but incomplete evidence

Our knowledge of the relationship between Broad Habitats and ecosystem services is lacking, especially in the case of multifunctional delivery. This is especially important for the dominant form of land use: agriculture². There is also a lack of knowledge about the integrated impacts of the drivers of change. This significant knowledge gap will need to be filled so that future service delivery can be planned effectively².

² established but incomplete evidence

17.1 Introduction

England's distinctive landscape is characterised by a high percentage of farmland and large urban areas. This chapter concentrates particularly on England's Broad Habitats, their condition, status and trends (in space and time) and the ecosystem services that they deliver. It also provides a synopsis of the direct and indirect drivers of changes in status and trends of ecosystems and their services, before exploring possible future changes. Where possible, a valuation of ecosystem services is given, but as the different sources have used various methodologies, figures given do not represent a comprehensive and systematic picture. Valuation is difficult in the case of some cultural services, and often country-specific information is lacking. The chapter complements the UK National Ecosystem Assessment (NEA) Economics Chapter (Chapter 22), which undertook a rigorous analysis for each of the UK NEA Broad Habitats and for selected services, but is not always disaggregated to England.

Now and in the future there are possible synergies and trade-offs in many ecosystem services, especially between some agricultural activities, such as vital food supply, carbon sequestration and regulation of air and water quality. These are explored, along with sustainable management options, in order to see how ecosystem service provision can be sustained or enhanced. There is still much that is unknown about the relationship of biodiversity to ecosystem service provision, both in general and in particular. These knowledge gaps need be addressed, so as to improve future environmental management.

17.2 England—Key Environmental Features

With a land surface of 130,395 ha, England is the largest country of the United Kingdom (53.5% of the UK land area of 243,610 ha). It is also home to more than 52 million people, making it one of the world's most densely populated countries (Foresight 2010). The majority of England is lowland and underlain by recent rocks, such as the Cretaceous chalk that is extensive in parts of south and east England. The uplands cover approximately 17% of the country and occur mainly in the north and west, in areas with older, harder rocks resistant to erosion, such as the granite uplands of Devon and Cornwall and the more geologically varied Lake District. In large areas of the lowlands, the solid geology is overlain by alluvium, glacial and other drift, and peat. Additional soil diversity has been introduced by glaciation whose influence is most pronounced in the north and west of England. The resulting variation of soil attributes is one of the drivers behind the complexity of land use patterns in England.

The climate of England is typically warmer and drier than that of the other countries in the UK, with mean minimum and maximum temperatures of 5.6°C and 13.1°C

respectively (all climate figures are for 1971–2000 from: Met Office 2010). Within England there is considerable variation in temperature due to increasing latitude, local elevational gradients and maritime influence. Between 1960 and 2006, most of England experienced a 1.0–1.4°C rise in mean annual temperature, although in parts of northern England it was less than 1.0°C (Jenkins *et al.* 2009; **Figure 17.1**).

The majority of England experiences higher amounts of total sunshine (1461.8 hours) than the rest of the UK and generally has a lower annual rainfall (838.7 mm). However, the South West and North West regions receive greater mean amounts of rainfall than the rest of England (**Figure 17.2**). Between 1960 and 2006, changes in mean annual precipitation varied across England from +/- 10% to increases of 10–25% (Jenkins *et al.* 2009). This masks seasonal variations, with some areas experiencing decreases of 10–25% in spring and 25–50% in summer, with increases in the other two seasons. The decreases in spring are almost entirely confined to England, whilst the increases in winter are much higher in North West England and in much of Scotland.

A few large river catchments, such as the Thames, Severn and Trent, drain most of England, although the many smaller rivers which drain the landscape beyond these major catchments form an important part of the hydrology of the country. The few large, natural lakes and waters in England are predominantly relics of glaciation and are found in the Lake District, with most other large open waters (i.e. larger ponds, reservoirs and the wetlands of the Broads in eastern England) constructed or restored by human activities.

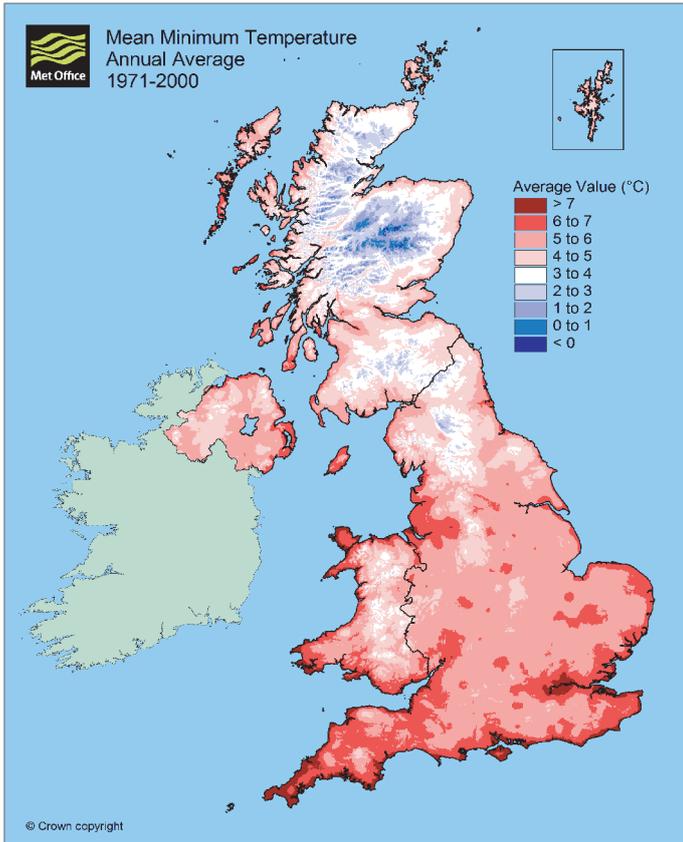
Despite its population density, most of the land area of England remains rural. With approximately 70% of the land being farmed, the majority of England falls into the Arable and Horticultural and Improved Grassland habitat classes (**Table 17.1**). Arable farming predominates in South East England, as well as other regions where soil quality is high. The north and west of England and their associated uplands are characterised by poorer quality soils and consequently, livestock farming predominates.

The regional variation in land use stemming from the variations in soil and climatic conditions has considerable impacts on the distribution and condition of England's habitats, which are important in underpinning the various ecosystem services (Section 17.5).

Whilst the proportion of woodland in England is one of the lowest in the world (just over 9%), the extent of English woodlands has been steadily increasing throughout the 20th Century (barring the two World Wars), due in part to the planting of coniferous woodland in the uplands and other marginal lands. In England (unlike Scotland), there is a majority of broadleaved woodland habitat.

The 8,000 km of coast is ecologically and scenically diverse. The low-lying coasts of the East and North West are predominantly composed of mudflats, beaches and shingle, which contrast sharply with sea cliffs and rocky foreshores occurring along the English Channel and the South West region. Many areas of the English coastline have seen significant domestic, commercial and industrial development. Also, areas of coastal and intertidal habitats have been reclaimed and converted to agricultural land uses, particularly in the south and east.

a)



b)

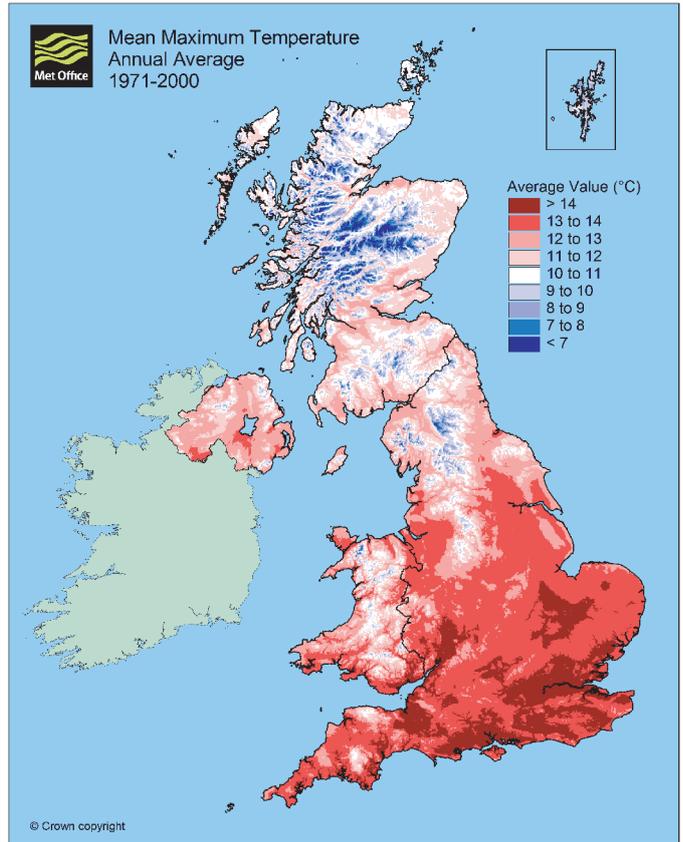
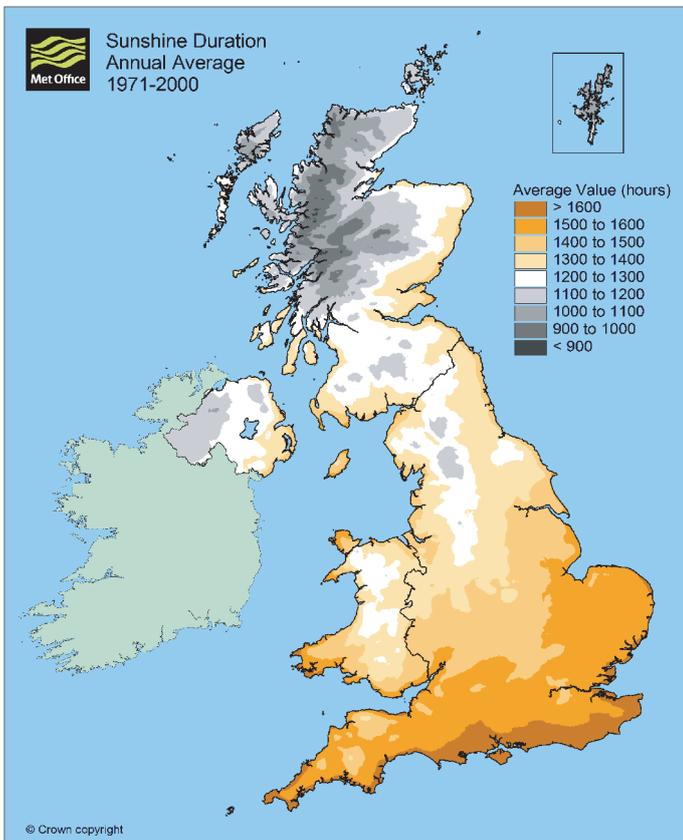


Figure 17.1 Mean annual minimum (a) and maximum (b) temperatures. Source: © Crown Copyright 2000, the Met Office.

a)



b)

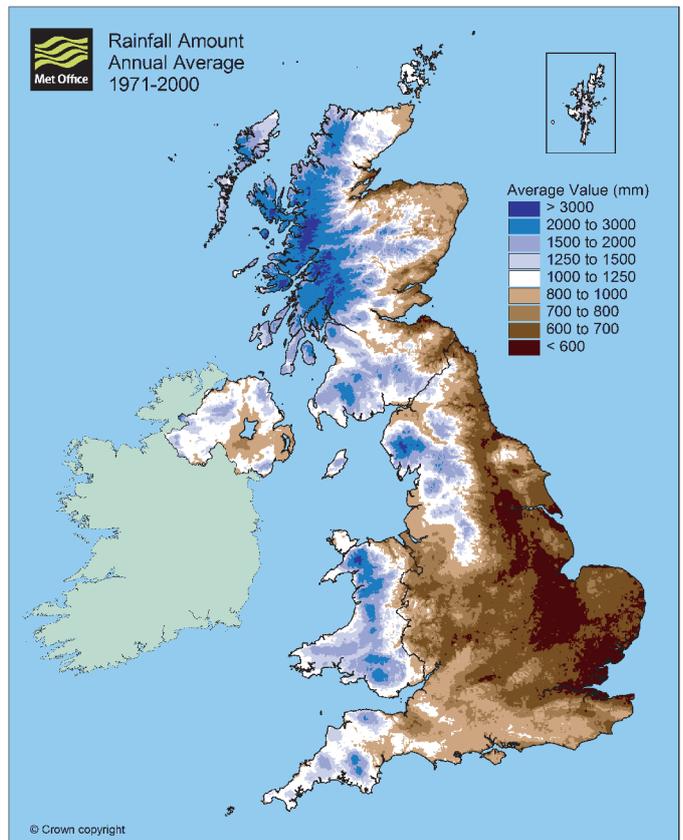


Figure 17.2 Mean annual hours of sunshine (a) and rainfall (b) in the UK. Source: © Crown Copyright 2000, the Met Office.

Table 17.1 Amounts and percentages of broad habitat classes in England from 1990 to 2007. Source: Countryside Survey (2009). Countryside Survey data owned by NERC – Centre for Ecology & Hydrology.

Broad habitats	1990		1998		2007	
	('000 ha)	% area of England	('000 ha)	% area of England	('000 ha)	% area of England
Broadleaved, Mixed and Yew Woodland	887	6.7	927	7.0	981	7.4
Coniferous Woodland	241	1.8	260	2.0	257	1.9
Boundary and Linear Features	380	2.9	354	2.7	353	2.7
Arable and Horticulture	4,380	33.2	4,389	33.3	4,002	30.4
Improved Grassland	3,075	23.3	2,714	20.6	2,856	21.7
Neutral Grassland	994	7.5	1,290	9.8	1,453	11.0
Calcareous Grassland	42	0.3	33	0.2	30	0.2
Acid Grassland	475	3.6	400	3.0	396	3.0
Bracken	93	0.7	109	0.8	91	0.7
Dwarf Shrub Heath	309	2.3	288	2.2	331	2.5
Fen, Marsh and Swamp	78	0.6	124	0.9	117	0.9
Bog	98	0.7	138	1.0	140	1.1
Standing Open Water and Canals*	105	0.8	88	0.7	97	0.7
Rivers and Streams*	33	0.2	32	0.2	29	0.2
Built-up Areas and Gardens	999	7.6	1,009	7.7	1,038	7.9
Other Land†	564	4.3	596	4.5	580	4.4
Unsurveyed Urban Land	428	3.5	428	3.5	428	3.5
Total	13,180	100	13,180	100	13,180	100

* Standing Open Water and Canals and Rivers and Streams broad habitat estimates were calculated using a different statistical model to the other broad habitats. It is not appropriate to use the consistent statistical model for these two habitats because of the distribution of the data. Change in these broad habitats is calculated independently from the differences between stock estimates.

† Other land is made up of the remaining small broad habitats and the difference between the sum of the broad habitat areas and area of England used to calculate percentage areas.

Urban areas cover between 10 and 14% of England (LCM 2000; GLUD 2005), and there has been continued growth, with 152,400 ha of new development between 1991 and 2006. Of this, an estimated 75% of new dwellings were built on brownfield (up from 57% in 1996; DCLG 2008), with only 0.4% of new dwellings built on undeveloped green belt land (Natural England 2010a). Approximately 80% of the English populace live in towns and cities, which puts increased strain on the surrounding ecosystems to deliver services, as cities are limited in the services they can produce (Gill *et al.* 2007). Urban ecosystems and the services they demand exhibit a disproportionately large importance relative to their areal extent.

17.3 Biodiversity

Biodiversity refers to the diversity of life on Earth (Chapter 4). It is, therefore, a complex concept including not only the diversity of species, but also the diversity of ecosystems and habitats. Due to its high climatic, geological and land use diversity, as well as the marked variations in depth, exposure and substrates of its seas, England's habitats exhibit wide variation by comparison with many other parts of the world of similar size. This variation of habitats and the way it has recently changed is summarised in terms of the eight UK

NEA Broad Habitats in Section 17.4; along with summaries of the ecosystem services each delivers.

Whilst the species diversity of England is not high in comparison with some areas of the world, nevertheless it has approximately 55,500 species of animals, plants and fungi. This includes five groups of species considered to be of outstanding significance in an international context: Atlantic ferns, mosses and lichens; breeding seabirds; wintering and passage waterbirds and gulls; grassland and woodland fungi; and heathland invertebrates (Natural England 2010b). England also has at least 40 endemic species and 54 species designated as internationally threatened. In addition, 492 species are known to have been lost from England, mostly since 1800. The better-known groups show losses of 22% of amphibians, 15% of dolphins and whales, 14% of stoneworts, 12% of terrestrial mammals and 12% of stoneflies (Natural England 2010b). Butterfly species are also well recorded, and in England between 1976 and 2009 there has been a moderate (19%) decline in 50 indicator butterfly species, with specialist species decreasing by 45% and generalists by 12% respectively (Brereton *et al.* 2010). Between 1990 and 2009, there have been significant declines in the abundance of farmland and woodland butterflies (42% and 65% respectively), although some improvements on land entered into agri-environment schemes are evident. An assessment of loss from 23 English counties since 1900 concluded that the highest rates of loss have generally been in southern and eastern counties, and this is partly mirrored by the figures for invertebrates (**Figure 17.3**). Local and regional losses have

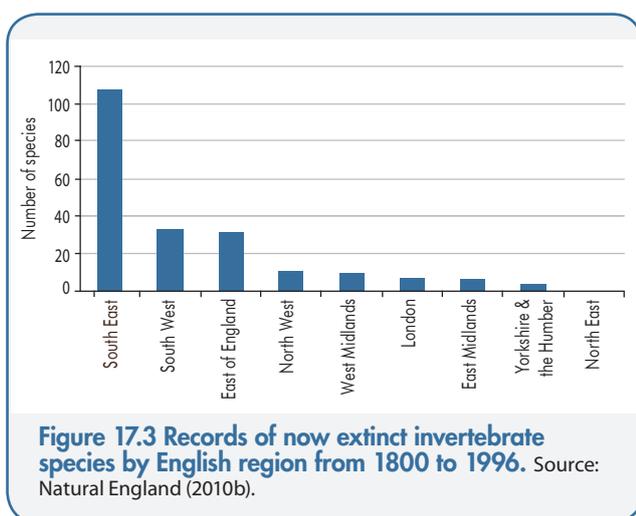


Figure 17.3 Records of now extinct invertebrate species by English region from 1800 to 1996. Source: Natural England (2010b).

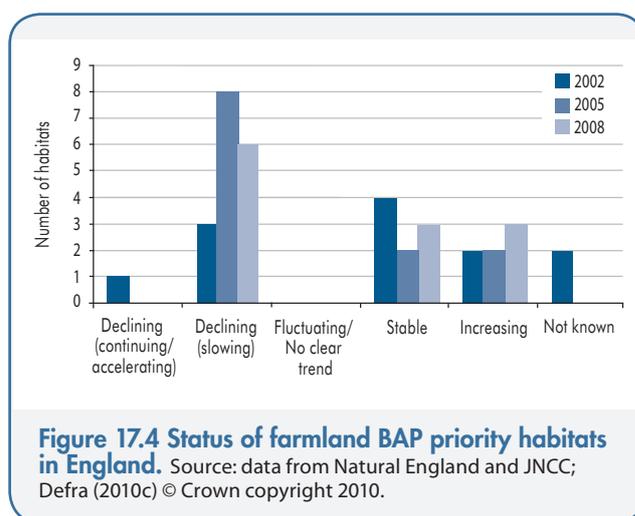


Figure 17.4 Status of farmland BAP priority habitats in England. Source: data from Natural England and JNCC; Defra (2010c) © Crown copyright 2010.

also been important, for example, the high brown fritillary butterfly (*Argynnis adippe*) has become extinct in the East Midlands, East Anglia, and South East regions in the last 50 years.

In 1993 the UK Biodiversity Action Plan (BAP) was published in response to the Convention on Biological Diversity, and between 1995 and 1999 Natural England published Action Plans for 391 priority species and 45 priority habitats. In 2002, the England Biodiversity Strategy (EBS) was published, setting out the strategy for achieving the 2010 target to halt biodiversity loss and its contribution to delivering the UK's BAP (Defra 2002). The EBS aimed to ensure a halt and, if possible, a reverse in declines of priority species and habitats. It recognised wild species and habitats as being part of healthy functioning ecosystems, and stressed that biodiversity's essential role in enhancing the quality of life should be generally accepted and that conservation should be considered in all decisions and policy making. A series of indicators were developed to help monitor the implementation of the EBS and to provide a measure of its progress. The review of EBS implementation 2003–2006 showed that, albeit over a short time span, the overall trends were positive (Table 17.2 and Figure

17.4). Trends for farmland birds are discussed in Chapter 4 (Section A.4.1.9). An assessment of better-studied groups (Natural England 2010b), however, showed that there are still groups and species of conservation concern, as shown in their BAP status (Table 17.3). In 2008, 943 species were identified as being of conservation concern under the EBS and UK BAP, with only a few of the previous 391 being removed from the list. On average, 26% of England's species are depleted or on the BAP list. The figures for the better-known groups are shown in Table 17.3.

In England, the principal agents of species loss and decline have been habitat loss and fragmentation, management practices that adversely affect habitat quality, environmental pollution and, in the past, the persecution of wildlife (EBG 2008; Natural England 2010b). Other pressures include invasive non-native species and, increasingly, climate change, which also interacts with many of the above (EBG 2008).

Protected areas have been the focus of much of England's conservation strategy, including National Parks, National Nature Reserves (NNRs) and Sites of Special Scientific Interest (SSSIs). Like species, a number of these are not in favourable conservation status, but their condition is

Table 17.2 Progress of headline indicators from 2000 to 2009. Source: Defra (2008d). © Crown copyright 2011.

Indicator	Type	Year	Assessment	
			Long term	Since 2000
Headline				
H1(a)	State	2009	✗	✗
H1(b)	State	2009	✗	≈
H2	State	2009	⋯	✓
H3	State	2009	⋯	✓
H4	Response	2009	✓	✓
H5	State	2009	✓	≈
H6	Pressure	2009	✓	✓
H7	Response	2008	⋯	✓
H8	Response	2008	⋯	✓

✓ Improving
≈ Little or no change
✗ Deteriorating
⋯ Insufficient or no comparable data/ no assessment made

Table 17.3 The degree of loss, depletion and decline in better-studied groups. Source: reproduced from Natural England (2010b).

Species group	Number of native species lost	Number of extant native species	Number of extant species on the UK BAP list	Number not on UK BAP list but with historically depleted populations	Proportion (%) of extant species with historically depleted populations or appearing on UK BAP list
Reptiles	0	7	7	0	100
Mammals—regularly occurring whales and dolphins	2	11	11	0	100
Amphibians	2	7	4	0	57
Freshwater fish	2	35	13	2	43
Mammals—terrestrial and seals	6	43	15	1	37
Bumblebees	4	20	5	2	35
Butterflies	18	57	23	2	33
Breeding birds	10	175	40	8	27
Vascular plants	20	1,297	121	194	24

improving. Agriculture-related causes of decline are shown in **Figure 17.5**. Other causes of decline include atmospheric and water pollution and lack of management. A gap analysis of England’s terrestrial protected areas (based on 2001 data) showed that there were 206 NNRs and 4,091 SSSIs covering 8% of the country, with most being found in northern or coastal areas (Oldfield *et al.* 2004). Also, only 3.5% of English lowlands (less than 200 m above sea level) had protected area status, whereas 65.8% of land above 600 m above sea level was protected. Some of the protected areas are now Special Areas of Conservation (SACs) or Special Protection Areas designated under the EC Habitats Directive. In England, there are now 249 SACs, Sites of Community Importance or candidate SACs. These cover marine and terrestrial areas and management is aimed at conserving their important or threatened habitats and species.

The focus on integrating habitat and species conservation was increased in 2008 as a key aim of England’s Biodiversity Framework which seeks (amongst other objectives), “to encourage the adoption of an ecosystem approach and embed climate change adaptation principles in conservation action, achieve biodiversity enhancements across whole landscapes and seascapes ...” (EBG 2008, p5), and whilst it does explicitly address ecosystem services, it recognises that they are underpinned by biodiversity. The relationship of different groups to ecosystem services is assessed in Table 4.2, Section 4.4, and whilst these relationships are likely to remain the same in England, as many of them are based on processes and the functioning of ecosystems and species, their relative importance may change in other parts of the UK, as do the drivers and pressures (Chapter 3, Table 3.3).

17.4 UK NEA Broad Habitat Types

Eight Broad Habitats form the basis of the UK NEA: Mountains, Moorlands and Heaths, Semi-natural Grasslands, Enclosed Farmland, Woodlands, Freshwaters—

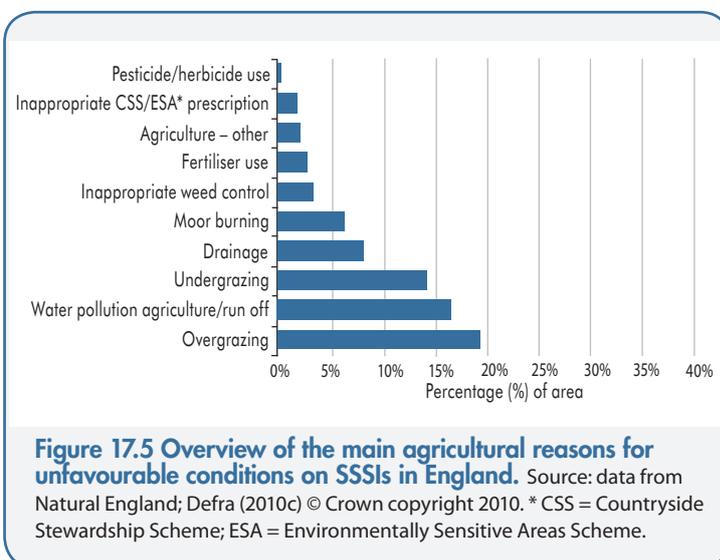
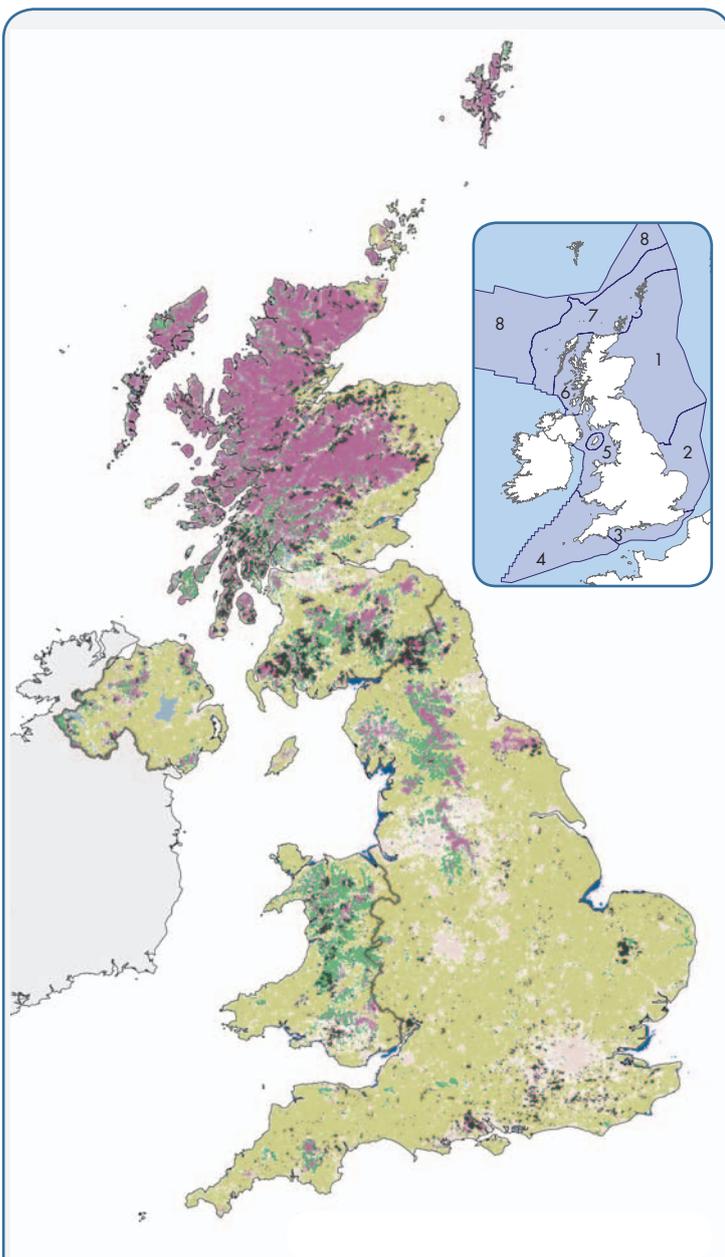


Figure 17.5 Overview of the main agricultural reasons for unfavourable conditions on SSSIs in England. Source: data from Natural England; Defra (2010c) © Crown copyright 2010. * CSS = Countryside Stewardship Scheme; ESA = Environmentally Sensitive Areas Scheme.

Openwaters, Wetlands and Floodplains, Urban, Coastal Margins and Marine. The Countryside Survey provides the most complete record of changes in land cover, although the types of habitat overlap with, but are different from, the UK NEA Broad Habitat types. This survey showed that arable and horticultural, improved grassland and neutral grassland (part of semi-natural grasslands) broad habitats covered 63.1% of the land area of England in 2007, woodlands (9.4%), with built-up areas and gardens (7.9%) being the next most important by area (Countryside Survey 2009); statistics which emphasise the largely agricultural character of England. Due to differences in physical setting, history and land use, the UK NEA

Broad Habitats are not evenly distributed across the UK (**Figure 17.6**), with England containing the majority of Enclosed Farmland and less Mountains, Moorlands and upland heaths, but more lowland heaths than other parts of the UK. Nevertheless, the more local Broad Habitats are important in giving character to landscapes in different areas. For example, lowland heaths in parts of Cornwall, Dorset, Hampshire and Surrey, wetlands in The Broads, East Anglia, and meres and mosses in the West Midlands are still



Dominant UK NEA Broad Habitats (>50%) by area per 1 km cell

- Mountains, Moorlands & Heaths
- Semi-natural Grasslands
- Enclosed Farmland
- Woodlands
- Freshwaters – Open waters, Wetlands and Floodplains
- Urban
- Coastal Margins
- Marine

Figure 17.6 Distribution (%) of the UK NEA Broad Habitats 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.

significant features, while moorland characterises much of the uplands, with blanket bogs in the wetter parts (Natural England 2009a).

The Coastal Margins and Marine habitats vary primarily as a function of geology, with low-lying coasts, such as those in East Anglia and Lancashire, containing intertidal flats and saltmarshes, which provide habitats for England’s internationally important wintering waders and wildfowl. More resistant geology, e.g. chalk in South East England and igneous rocks in the South West, has led to the development of cliffs. Offshore there is also a variety of substrata and habitats, such as mobile sandbanks off East Anglia, granite reefs off Cornwall and more underwater chalk reefs than anywhere in Europe. The area and condition of Coastal Margins and Marine habitats has been changing as a consequence of pressures, such as land and sea use change, management, pollution and invasive and alien species. These trends are reflected in **Figure 17.7**, which are very similar to those for the UK. The status, condition, trends and ecosystem services of each of the UK NEA Broad Habitats are discussed in the following sections.

17.4.1 Mountains, Moorlands and Heaths

17.4.1.1 Status, trends and condition

Mountains, Moorlands and Heaths include six component habitats: Bracken; Dwarf Shrub Heath; Bog; Upland Fen, Marsh and Swamp; Montane; and Inland Rock (Table 5.1, Section 5.1.1). Prior to human activity (about 5,000–6,000 years ago) woodland covered much of what is now Mountains, Moorlands and Heaths, except for the most exposed locations. Then, due to a combination of woodland clearance, managed burning, livestock grazing, the removal of turf and vegetation and climate, the extent of moorland and heath increased and regeneration was curtailed by browsing (Averis *et al.* 2004). Currently, Mountains, Moorlands and Heaths cover 679,000 ha, representing about 5% of England’s area, which is very small compared with 43% of Scotland and 12% of both Wales and Northern Ireland. Montane habitats are the dominant cover only in the higher areas of the Lake District, Pennines, North York Moors and

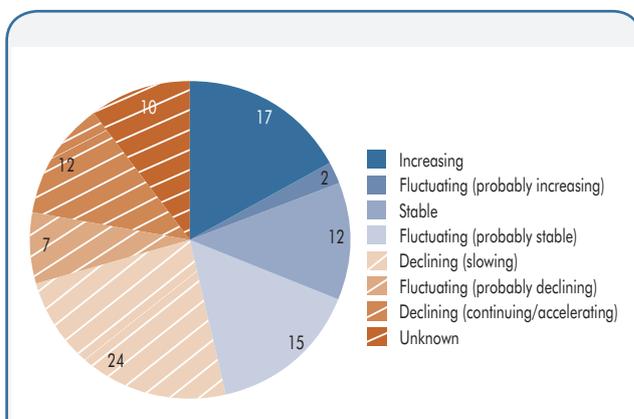


Figure 17.7 Trends for priority UK BAP habitats in England. Numbers indicate the number of priority habitats. Source: data from Biodiversity Action Reporting System (BARS 2011).

Dartmoor, whilst Inland Rock is not dominant in any grid cell. It does, however, cover about 1% of England, based on the Land Cover Map (LCM 2000), and England has about 80% of the UK's limestone pavements (Natural England 2008). These Inland Rock habitats form important refuges from grazing for several plant species.

There has been a significant decrease in Mountains, Moorlands and Heaths habitat over the last 60 years. In the uplands this has been primarily due to afforestation and conversion to rough grassland by drainage, liming, burning and grazing. A study of increased sheep numbers and loss of heather moor in the northern Peak District found that the former had trebled between 1930 and 1976, leading to a 36% decrease in moorland (Anderson & Yalden 1981), with an unknown effect on wildlife, although red grouse (*Lagopus lagopus scoticus*) declined by about two-thirds over a similar period. Monitoring following a reduction of grazing pressure on the Kinder Estate in the Peak District showed recolonisation by moorland vegetation (Anderson & Radford 1994). Airborne pollution, particularly nitrogen and sulphur, has also had a detrimental effect on the condition of Mountains, Moorlands and Heaths (Chapter 5.6.2.2). It has had the greatest impact on upland areas, in particular in the South Pennines (Lee 1998), but it was also a possible factor in the decline of Dorset heathland between 1987 and 1996 (Rose *et al.* 2000).

Inland Rock has been affected by mineral extraction and quarry landfill, but 57% is in unfavourable condition due to overgrazing, whilst lack of management, recreational pressure and air pollution have also contributed (BRIG 2006; Natural England 2008). For limestone pavements, the mechanised removal of stone meant that by 1975, only 75% of the area was intact and 3% remained undamaged (Braithwaite *et al.* 2006).

Lowland heathland has mostly been lost due to development of towns and roads, afforestation and agricultural improvement, as well as succession leading to woodland encroachment following abandonment. This loss has been particularly well documented for the Dorset heathlands and those in East Anglia (Webb & Haskins 1980; Webb 1990; Table 5.2, Section 5.2.1.1).

The most noticeable changes in areas of Mountains, Moorlands and Heath habitats in England between 1998 and 2007 is a strong increase (15%) in dwarf shrub heath (Countryside Survey 2009). This has been attributed to efforts to restore and recreate lowland and upland heathland (to meet BAP targets) through programmes such as Tomorrow's Heathland Heritage, Countryside Stewardship, and more recently the Higher Level Scheme in Environmental Stewardship. In the uplands, it has probably been helped by grazing pressure controls, possibly aided by livestock reductions, for example in Cumbria, following the 2001 outbreak of Foot and Mouth Disease. In the lowlands, the schemes have led to reductions in the extent of scrub and secondary woodland, the creation of new heathland sites (e.g. over 4,000 ha recreated or restored in the china clay area of Cornwall), the control of bracken and the reintroduction of grazing.

There are four main drivers of the contemporary changes in Mountains, Moorlands and Heaths habitats and their

ecosystem services: land use changes, airborne pollution, climate change and recreational pressures. These in turn depend on a number of underlying factors, including agricultural prices, Common Agricultural Policy (CAP) and agri-environmental schemes. These direct and underlying factors are moderated by a number of policy mechanisms (e.g. EC Birds, Habitats, Water Framework and National Emissions Ceilings Directives) and cultural pressures, such as those which led to the setting up of seven National Parks in the uplands and, more recently, the New Forest, which has important areas of lowland heath.

The status and condition of the Mountains, Moorlands and Heaths habitat have declined over the last 60 years and this is reflected in the Mountains, Moorlands and Heaths-related BAP habitats (UKBAP 2007). Their status and condition varies and, based on this, they have different conservation targets. Lowland heath is the only one that is increasing in area, as a consequence of restoration and recreation objectives; all the habitats have regionally differentiated targets aimed at increasing status and improving its condition (Table 17.4).

Many of these habitats are important for species of conservation importance. There are 133 BAP species associated with lowland heath, of which 53% require bare ground and early successional stages (Webb *et al.* 2009), and so are highly dependent upon management. Grazing, when combined with other management options, is important in providing such conditions (Lake *et al.* 2001), so livestock are now being reintroduced to many lowland heaths, often supported by agri-environment scheme funding. Important birds include Dartford warbler (*Sylvia undata*), which is in the northern part of its range in southern England. It is found almost exclusively on dry lowland heath, feeding on invertebrates, and its main threat is habitat loss (Cantos & Isenmann 1994; van den Berg *et al.* 2001). Given the increase in heathland, along with possible shifts in habitat and more

Table 17.4 Regional targets (ha) for upland heathland, blanket bog, upland calcareous grassland and limestone pavement.

Source: data from Measures (2008). *Area of existing BAP habitat to be in favourable or unfavourable recovering condition. †To ensure there is no further deterioration in the geodiversity/biodiversity interest.

Regions	Regional targets (ha)			
	Achieve condition* within SSSIs by 2015			Achieve condition† by 2015
	Upland heathland	Blanket bog	Upland calcareous grassland	Limestone pavement
North East	31,632	50,645	257	-
North West	31,805	48,866	2,619	1,276
Yorkshire & Humber	78,531	46,956	5,602	1,359
East Midlands	9,571	12,319	-	-
West Midlands	4,934	1,613	30	-
East of England	-	-	-	-
South East	-	-	-	-
London	-	-	-	-
South West	23,455	15,743	-	-
England Total	179,928	176,142	8,507	2,635

sympathetic management of plantation forests and farmland, this and several other birds have increased in population numbers—the Dartford warbler by 70% since 1994, nightjar (*Caprimulgus europaeus*) by 35% since the 1990s and woodlark (*Lullula arborea*) by 89% since 1997, whilst black grouse (*Tetrao tetrix*) numbers have stabilised (Baines 2005; RSPB 2005, 2006, 2007; Warren & Baines 2008).

17.4.1.2 Ecosystem services

In many cases the total service provision from Mountains, Moorlands and Heaths is low because they are concentrated in particular areas, although the provision per unit area may be high, e.g. water purification and provisioning functions. There is higher service provision from moorland, not because of profound ecological differences compared with other habitats, but because of its extent.

Regulating services. Peatlands are an important terrestrial carbon store and a potential sink, thus they contribute significantly to climate regulation. The largest stocks in England are in the north and it has been estimated that in their current state, English peatlands store 584 million tonnes of carbon, but are responsible for about 3 million tonnes of carbon dioxide equivalent (CO₂e) emissions per year (Natural England 2010c). Changes in topsoil carbon stocks in England (1998–2007) were estimated as -9.3 teragrams carbon (Tg C) from bracken, -2.5 Tg C from fens, marsh and swamp, 11.6 Tg C from shrub heath and 10.4 Tg C from bogs (Chamberlain *et al.* 2010). Careful management and restoration of these habitats, and in particular peat, can ensure that they continue to deliver this service, as well as contributing to conservation objectives, thus achieving a synergy in services (Worrall *et al.* 2009). Restoration of key types of degraded peatlands could deliver emissions reductions of up to 2.4 million tonnes of CO₂e each year, with 1.1 million tonnes of this reduction delivered by rewetting cultivated deep peatlands (Natural England 2010c). Restoration of degraded habitats may also contribute to small-scale flood risk mitigation. For example, grip blocking may be an effective measure, and in Upper Wharfedale has been shown to decrease flow velocities and discharge from drains (Holden 2005; Holden *et al.* 2008).

Blanket bogs and dwarf dry heaths are not good at sustaining flow in dry periods (Holden & Burt 2003b) and this, together with rapid runoff, means that reservoirs are needed for water regulation for human supply, although some lowland bogs and marshes trap water and prevent flooding (Natural England 2009a). The uplands receive disproportionate amounts of airborne pollutants including pesticide residues, nitrogen and sulphur compounds (Caporn & Emmett 2009), but they retain a proportion of these pollutants, including anthropogenic sulphur and nitrogen and heavy metals, that otherwise would contaminate drainage waters. This water quality service also helps to reduce downstream treatment costs. The provision of (relatively) clean water is a consequence of limited human impacts, relatively low weathering rates, extensive peat cover and widespread overland flow. The continued provision of the service is dependent on maintaining the stability of the peatlands (and other habitats) to avoid the release of these contaminants (Rothwell *et al.* 2007, 2008).

Maintaining intact ecosystems is also important for avoiding erosion with associated landscape degradation, contaminant activation, sediment affecting water quality and reservoir capacity. The extent of areas affected by erosion within upland England and Wales has been estimated at 24,566 ha, which represents 2.46% of the total upland area surveyed in 1999, with sheep being a major driver (McHugh *et al.* 2002). A reduction of sheep grazing pressure in a catchment in the Peak District showed that recolonisation of vegetation can be a relatively rapid process (5–10 years), but it may take decades on high slopes (Evans 2005).

Provisioning services. Livestock grazing on Mountains, Moorlands and Heaths has long contributed to a variety of ecosystem services, including landscape appearance, habitat management (especially of undesirable vegetation) and rural economies (in the production of grazing beef and lamb/mutton). There has been a fall in grazing livestock numbers since 2004 in Less Favoured Areas (LFAs) in England (more so than on lowland agricultural habitats), with the number of breeding ewes falling by 12%, beef cows by 13%, dairy cows and the number of other cattle and calves by 11% (Defra 2010a). This relates to LFAs in general, not Mountains, Moorlands and Heaths habitats specifically, although the impacts have been most felt in areas such as the North York Moors, the South West's moors and parts of the South Pennines. Many rare breeds are grazed on Mountains, Moorlands and Heaths and thus they provide a service in maintaining genetic diversity (Tisdell 2003). Wool fibre from sheep used to be an important commodity, from medieval times through to the 19th Century. Wool as a commodity is also covered under Enclosed Farmland (Section 17.4.3).

Historically, peat has been used as a fuel due to its calorific value of around 20 megajoules per kg, which is similar to wood and lignite and, more recently, for horticulture, with gardeners now responsible for 69% of total peat usage. Extraction for these uses is still significant, but more localised and declining (ADAS & Enviros 2008). The decline is partly a consequence of the UK government's target for 2010 that 90% of total market requirements for soil improvers and growing media should be supplied by non-peat materials. Coal is also extracted from sites with Mountains, Moorlands and Heaths, including extensive open cast mines, but no figures were found for England. Both these activities could be considered antagonistic to service delivery in that they result in habitat destruction, although in both cases some restoration is often undertaken (Natural England 2010c).

The uplands are important for water supply, due to their higher rainfall (Malby *et al.* 2007) and rapid runoff (Holden and Burt 2003a). Contributions to water regulation are addressed in the previous section. A number of minor products are gathered from heaths and moorland (Sanderson & Prendergast 2002), including:

- heather for animal bedding, thatch, use in air and water filters, fencing and screening;
- bracken for soap making, animal bedding, as a soil improver, and recently bracken has been trialled as a horticultural medium, suitable for ericaceous/calicifuge plants;
- whinberries (*Vaccinium myrtillus*), which are gathered in Shropshire; and

- honey: heath and moorland are important to beekeepers as heather honey commands a price premium.

Shooting is a major driver of land management in parts of the Pennines, North York Moors and Cheviots, where upland heath may be managed by rotational burning to promote new grass or heather growth for red grouse. Shooting makes only a minor contribution to food supply, being primarily for sport, and thus is also a cultural service. In England, grouse shooting has risen from 1,560 potential shooting days per year, with 196 game keepers employed in 2000, to 1,898 potential shooting days per year, with 253 game keepers employed in 2009 (Natural England 2009a).

Cultural services. The majority of National Parks contain Mountains, Moorlands and Heaths. Areas of moorland and lowland heathland are valued for their perceived wildness, openness and ‘bleakness’, although they are not universally thought to be beautiful places (Natural England 2009a). Moorland, like many other Broad Habitats, is often important for those living within it (e.g. Exmoor) by contributing to a sense of local identity. Bogs and marshes are seen as not delivering many cultural services, other than for birdwatchers (Natural England 2009a), but may also be important as biological and historical archives.

Mountains, Moorlands and Heaths are also important for tourism and recreation, although moorland is less accessible than some other landscape types due to its location away from population centres. Focus group research showed that areas of lowland heathland (e.g. in and around the New Forest) were seen as more accessible than other habitat types (Natural England 2009a). However, in England, National Parks, the great majority of which are in the uplands, have 69.4 million visitor days per year, with the Lake District and Peak District being the most visited (Natural England 2005b). Mountains, Moorlands and Heaths can also be of spiritual and religious value through experience of the wild and beautiful terrain (Natural England 2009a). There are also many monuments related to religious practices, such as ancient burial mounds and stone circles, on Mountains, Moorlands and Heaths, whilst some pilgrimages involve passing through these habitats (e.g. St. Cuthbert’s Way in Northumbria, a 100 km trail from Melrose to Lindisfarne). Mountains, Moorlands and Heaths have inspired writers like Thomas Hardy and William Wordsworth and artists such as Turner.

17.4.1.3 Valuation

There is no complete valuation of Mountains, Moorlands and Heaths services across England, although six case studies which were undertaken as part of an economic valuation of uplands ecosystem services provide illustrative figures (Natural England 2009b). Case studies relating to particular services include Thirgood and Redpath (1997), who estimated the cost of losing the hunting service for a commercial shoot in the UK to be about £100,000 per year. A choice experiment to assess non-market landscape benefits of Mountains, Moorlands and Heaths (Hanley *et al.* 2007; Hanley & Colombo 2009) is reported in Chapter 5, Box 5.9.

Given the importance of peat as a carbon store, the restoration of cultivated or agriculturally improved deep

peat has been calculated to produce net economic benefits of up to £19,000/ha after 40 years, even at the lowest shadow carbon value, whilst the restoration and management costs associated with blocking moorland drainage ditches can be repaid by the value of emissions reductions over this period (Natural England 2010c). If the mid-range shadow carbon values are used, all the peatland restoration techniques considered deliver net economic benefits after 40 years, which makes most peatland restoration options a cost-effective means of reducing greenhouse gas emissions.

17.4.2 Semi-natural Grasslands

17.4.2.1 Status, trends and condition

There are an estimated 4.8 million ha of grassland (all types) in England, based on Land Cover Map (LCM 2000) data. This is primarily agriculturally improved grassland, with Semi-natural Grasslands making up only about 3% (Natural England 2008), although semi-improved grasslands can be important for biodiversity, especially where the Semi-natural Grasslands resource is low (e.g. parts of Lincolnshire and Cambridgeshire). There are various types of Semi-natural Grasslands, including Acid, Neutral and Calcareous Grassland habitats, along with purple moor-grass and rush pastures, which are part of the Fen, Marsh and Swamp habitat. Within these, a number of specific Semi-natural Grasslands types are UK BAP priority habitats: lowland and upland hay meadows, lowland dry acid grassland, purple moor-grass and rush pastures, and lowland and upland calcareous grasslands. In terms of area, upland Acid Grassland is an important component of both UK and England’s Semi-natural Grasslands, but it is not considered a priority habitat, as it is often the result of overgrazing of moorland, and is relatively extensive.

The distribution of these habitat types varies across England, with the South West region containing 44% of England’s Semi-natural Grasslands, including 61% of Calcareous Grassland and 57% of purple moor-grass and rush pastures, whilst upland hay meadows and upland calcareous grasslands are largely confined to North Lancashire, Cumbria and the North Pennines. The New Forest and Breckland are important for lowland dry acid grasslands, which often occur in association with lowland heathland (Natural England 2008). A history of the impacts of agricultural intensification on grasslands in Great Britain is provided by Green (1990), but in England and Wales, a 97% loss of semi-natural enclosed grasslands between 1930 and 1984 has been reported (Fuller 1987). This was primarily due to conversion of grassland to arable or intensification by ploughing, drainage and reseeding and improvement with fertilisers and herbicides, driven by Government incentives and grant aid. Atmospheric deposition of nitrogen is also thought to have impacted upon grassland diversity in a similar way to agricultural improvement (Stevens *et al.* 2004). A sample survey of about 500 non-SSSI Semi-natural Grasslands sites in England showed that 24% of sites more closely resembled agriculturally-improved grassland types, indicating a significant loss of Semi-natural Grasslands between 1980 and 2003 (Hewins *et al.* 2005). This is reflected in the Countryside Survey 2007 findings (Carey *et al.* 2008)

that in England there was a significant increase (12.6%) in the area of Neutral Grassland between 1990 and 2007, but a significant decrease in plant-species richness in botanically-rich Neutral and Acid Grasslands between 1998 and 2007. Also, in the Neutral Grasslands there was a significant reduction in the number of food plants for butterfly larvae and farmland birds and a significant increase in more competitive, nutrient-demanding plant species. There was a significant decrease in the area of Calcareous and Acid Grassland between 1990 and 1998, however, there was no significant change in their extent between 1998 and 2007. These two component habitats have experienced the greatest average loss of plants in Semi-natural Grasslands over the last 40 years (Preston *et al.* 2002).

Semi-natural Grasslands support a rich flora and fauna and many types are typically plant-species rich and provide habitat for important and rare species. Of the 1,150 species of conservation concern named in the UK BAP, lowland Semi-natural Grasslands are home to 206 of them, whilst upland grassland priority habitats are home to 41. Declines in individual species have been linked to certain aspects of agricultural improvement (Green 1990), for example, bird losses have been attributed to the intensification of agriculture, which has substantially reduced the suitability of grassland as a feeding and breeding habitat for grassland birds (Vickery *et al.* 2001). The switch from hay making to silage has had a strong impact on some bird species, with earlier cutting dates resulting in nest destruction before the chicks have fledged (e.g. yellow wagtail *Motacilla flava*; Nelson *et al.* 2003) or the loss of important feeding sites during the breeding season (e.g. twite *Carduelis flavirostris*; Raine *et al.* 2009). Also, specialist butterflies (Section 6.2.4.1) strongly associated with agriculturally managed Semi-natural Grasslands declined in England by 26% between 1990 and 2007.

Sixty-eight per cent of Semi-natural Grasslands lie within SSSIs and 40% are designated as SACs, of which Salisbury Plain SSSI and SAC make up just under half (Natural England 2008). About 6% of upland Acid Grasslands are in SSSIs,

because of their importance for breeding birds. The status and condition of the Semi-natural Grasslands habitat types varies (**Table 17.5**), but the trend for all of the BAP habitats is declining, apart from upland calcareous grasslands, which are stable. The main issues for the lowlands are undergrazing and scrub encroachment, whilst overgrazing is the main cause of unfavourable condition in the uplands, with atmospheric nitrogen deposition as another pressure. In England, the Environmental Stewardship Higher Level Scheme (HLS) is the principal mechanism for maintaining, restoring and creating Semi-natural Grasslands, and 60,733 ha of grassland is entered into the maintenance and restoration of grassland options of either the 'Classic schemes', i.e. Countryside Stewardship, Environmentally Sensitive Areas (ESA), or the HLS. In the HLS, 2,373 ha have been entered into the creation of the species-rich grassland option (Natural England 2009c). There are also various forms of specific funding for the uplands, including LFAs established by the EU in 1975 as a means for providing aid specifically to socially and economically disadvantaged areas in the uplands. In England, some 2.2 million ha of land is classified as LFA and of this, 1.8 million ha are in agricultural production (approximately 17% of the total agricultural land in England). The LFAs are predominantly found in the northern and south-western areas of England and in areas of the Welsh Borders. There is also the new (2010) Upland Entry Level Stewardship, which rewards farmers for the provision and maintenance of landscape and environmental benefits, thus ecosystem services.

There are regionally differentiated targets for the restoration and expansion of various grassland habitats (**Table 17.6**), with the South East and East of England being particularly important in this regard for lowland dry acid and calcareous grassland.

17.4.2.2 Ecosystem services

There are many services provided by Semi-natural Grasslands. Some, like biomass energy, water regulation and carbon sequestration, are complementary whilst others,

Table 17.5 Status and trends of Semi-natural Grassland habitats. Sources: *UK BAP Target Review (2006), †Countryside Survey (2009), ‡Natural England SSSI information system (ENSIS), §Hewins *et al.* (2005). **Percentage of SSSI area in favourable or unfavourable recovering condition. ††Percentage of stands considered to be in favourable condition based on mandatory non-statutory condition assessment targets.

UK BAP priority habitat*	Area (ha)	Condition (%)		Factors affecting condition
		SSSI (2009)† **	Non-SSSI (2005)††	
Lowland calcareous grassland	38,687	92.4/47.4	28	Agricultural intensification, undergrazing and lack of scrub control
Lowland dry acid grassland	20,142	84.5/26.1	21	Agricultural intensification, undergrazing and lack of scrub control
Lowland meadows	7,282	76.2/44.1	16	Agricultural improvement, abandonment and supplementary feeding
Upland hay meadows	870	91.3/65.3	7	Over-intensive management, particularly grazing levels and excessive input of nutrients from both organic manures and artificial fertilisers
Purple moor-grass & rush pasture	21,544	78.1/34.7	35	Agricultural improvement, abandonment and inappropriate management
Upland calcareous grassland	16,000	92.4/27.2	no data	Overgrazing, too heavy and too light grazing, quarrying
Other Semi-natural Grassland				
Upland acid grassland†	376,000	85.2	no data	Overgrazing and poorly timed grazing, particularly by sheep, burning and inappropriate stock feeding

such as productivity and diversity, may be antagonistic (Section 17.8.1), although with appropriate management they can be complementary.

Regulating services. Semi-natural Grasslands contribute to climate regulation, but the amount of carbon storage reported varies according to methods of recording and calculation. Bellamy *et al.* (2005) estimated that between 1978 and 2007 there was no consistent change in soil carbon in Neutral and Acid Grasslands in England and Wales, whilst Chamberlain *et al.* (2010) estimated that there had been net gains in England between 1998 and 2007 in topsoil carbon stocks of 5.6 Tg C and 10.5 Tg C respectively. This means that they account for 21% of soil carbon in Countryside Survey 2007 broad habitats in England.

Semi-natural Grasslands potentially deliver pollination and pest control services to agriculture, as they provide habitat for the relevant species. For example, Ricketts *et al.* (2008) showed that proximity to semi-natural habitat increased pollination by native bees of field beans (*Vicia faba*), whilst Goulson *et al.* (2004) attributed bumblebee declines and associated loss of pollination directly to the loss of Semi-natural Grasslands during the 20th Century. The effects of Semi-natural Grasslands on harbouring the natural enemies of pests have been less studied, although declines in carabid beetles (not all of which are predatory) may also be related to losses of Semi-natural Grasslands or related habitats (Kotze & O'Hara 2003).

Semi-natural Grasslands can provide valuable water purification services. Within the Peak District, Calcareous Grassland accumulated up to 89% of deposited nitrogen, while Acid Grassland stored up to 38% (Phoenix *et al.* 2008). The soil is able to store significant amounts of this deposited nitrogen and perennial grasses appear to play a dominant role in maintaining low inorganic nitrogen leaching rates, and are likely to be most important in providing the service of clean groundwater. Information about the impact of Semi-natural Grasslands on water quantity and quality, however, is generally in relation to its conversion to alternative land uses, such as intensive grazing, where compaction causes

decreased infiltration and increased runoff, which both lead to localised increased flood risk and reduced aquifer recharge (Weatherhead & Howden 2009). Measures of streamwater quality across gradients from low-intensity grassland to arable and between intensive livestock pastures in upland and lowland Britain showed how intensive grassland use by livestock can increase nitrogen and phosphorus inputs into streams (Jarvie *et al.* 2008, 2010).

Provisioning services. An analysis of sheep numbers (not differentiated by habitat) has shown that between 1950 and 1990 they have more than doubled in Wales and England (181% and 142% increase respectively), whilst in Scotland (32%) they have been relatively stable (see figures from Fuller & Gough 1999). The increase has been primarily since the mid-1970s, with a modest decrease in England and Scotland since 1990. There are regional differences, with the most marked recent decreases in the lowland regions of south and east England. The pattern of change in East Anglia and the south of England has been especially volatile, with sharp recent declines following very high rates of increase between 1980 and 1990. Stocking densities have been highest in Wales and the Welsh borders, followed by South West England, northern England, the southern Midlands, and Kent. Major ecological impacts of increased grazing pressure from sheep are expected to be focused on Wales and the Welsh borders, but also include parts of upland northern England's semi-natural grasslands, moorland and heaths.

The level of production from unfertilised Semi-natural Grasslands has been shown to range from less than 20% to about 80% of the production that might be expected from agriculturally improved and intensively managed grasslands and the metabolisable energy values of herbage cut for hay from 10 to 40% less (Tallowin & Jefferson 1999). Also, the levels of nitrogen, phosphorus and magnesium are either below the metabolic requirement of livestock or inadequate to sustain high individual animal performance.

Stocking levels, therefore, are much lower on Semi-natural Grasslands (Tallowin *et al.* 2005). Nevertheless, the quality in terms of flavour, protein and low fat content of lamb raised on

Table 17.6 Regional targets (ha) for grassland restoration and expansion. Source: data from Measures (2008).

	Lowland meadows		Lowland dry acid grassland		Lowland calcareous grassland		Purple moor-grass and rush pasture	
	Restoration by 2015	Expansion by 2015	Restoration by 2015	Expansion by 2015	Restoration by 2015	Expansion by 2015	Restoration by 2015	Expansion by 2015
North East	25	25	17	10	25	285	10	10
North West	45	25	23	20	10	100	15	25
Yorkshire & Humber	40	35	23	15	50	450	15	15
East Midlands	50	35	34	30	50	430	10	10
West Midlands	100	35	28	35	15	60	10	10
East of England	40	25	57	60	100	1,200	20	20
South East	70	30	52	55	190	2,575	10	10
London	5	15	10	10	5	25	-	-
South West	110	35	46	40	280	3,300	40	50
England Total	485	260	285	275	725	8,425	130	150

species-diverse pastures is better (Whittington *et al.* 2006). It was suggested that rare or traditional breeds were better for grazing Semi-natural Grasslands, but Isselstein *et al.* (2007) showed that the traditional breeds had a lower performance at sites in North Devon and France, but not in Germany. Fraser *et al.* (2009) also found that liveweight gains were consistently higher on improved permanent pasture. A comparison of Semi-natural Grasslands and improved permanent pasture showed that cattle grazed on Semi-natural Grasslands had more Vitamin E in the meat and lower concentrations of most fatty acids. It is probable that rare breeds on Semi-natural Grasslands can provide dual benefits for the conservation of the breed and the habitat, but one is not essential to the other. Rare breeds are valuable, therefore, in providing aesthetic, cultural and historical benefits, as well as genetic resources for future breeding programmes (Anon 2006).

Many traditional garden plants used to be sourced from Semi-natural Grasslands, e.g. bugle (*Ajuga reptans*), clustered bellflower (*Campanula glomerata*), but nowadays they are sourced from abroad (Dehnen-Schmutz *et al.* 2007). However, a significant amount of seed from Semi-natural Grasslands is used in creating species-rich grasslands under agri-environment schemes and other conservation initiatives. The Natural England's GENESIS database indicates that of the 2,486 (April 2010) Higher Level Stewardship agreements which involve maintenance, restoration or creation of species-rich grassland, 421 receive a supplement for using native seed sourced from Semi-natural Grasslands.

It has been suggested that hay from Semi-natural Grasslands could be used as biomass for fuel, but there are no UK studies, and those from elsewhere provide conflicting results on its effectiveness (e.g. Tilman *et al.* 2006; Richter *et al.* 2010). A field experiment on the biomass potential of Semi-natural Grasslands at six sites in Germany showed that its fuel composition was less suitable for combustion than that of perennial energy grasses, but comparable to that of cereal straw. Whilst currently not suitable for use in small boilers, it could provide synergies between bioenergy production and conservation (Tonn *et al.* 2010).

Cultural services. A survey of the cultural services derived by people from landscapes showed that positive attitudes to certain of England's National Character Areas (NCAs) were related to grassland or pastoral farming, e.g. the Devon Redlands; the North Downs; the Cotswolds; the Eden Valley and the Yorkshire Wolds (Anon 2009). Although grassland is often regarded as uninteresting in landscape terms, it can contribute to open views from high ground (Natural England 2005a). National Parks, which are valued for recreation, greenspaces, education, etc., all contain significant areas of Semi-natural Grasslands, which contribute to their wildlife, historical and landscape value (e.g. the Yorkshire Dales and South Downs National Parks).

A European overview of the implications of environmental schemes and subsidies for conservation and restoration of Semi-natural Grasslands in terms of their value for biodiversity, cultural heritage, a vital countryside, and effects on the economy, concludes that a broader landscape perspective is required in order to improve the long-term preservation of values associated with Semi-natural Grasslands (Lindborg *et al.* 2008).

Many archaeological sites and monuments are better preserved on Semi-natural Grasslands, as they have been subject to less intensive management. English Heritage's Monuments at Risk Initiative showed that of the 19,709 scheduled monuments in England, only 23% are in optimal condition, and that 35% are in grassland (Semi-natural Grasslands and improved). A number of distinctive regional features have disappeared following post-World War II agricultural intensification, including Iron Age 'banjo enclosures'—a form of prehistoric stock corral, which were characteristic of the Wessex chalklands. In the East Midlands, a survey up to 1996 confirmed that of the 2,000 (township) settlements identified, only 104 retained more than 18% of their original coverage of ridge and furrow and of these, only 43 townships retained significant areas of ridge and furrow (Hall 2001).

Salisbury Plain Defence Training Estate is the largest (38,000 ha) and most important military training area in the UK, and about 56% of it consists of Semi-natural Grasslands. The Defence Estates undertake widespread conservation activities and Salisbury Plain was chosen for the re-introduction of the great bustard (*Otis tarda*; Osborne 2005).

17.4.2.3 Valuation

The Culm grasslands in Devon and Cornwall are species rich and host rare species, such as the marsh fritillary butterfly (*Eurodryas aurinia*). An investigation of willingness to pay found that the total benefits of conserving and expanding the Culm grasslands by 10% were in excess of £136 million, with costs ranging from £5 million to £35 million, depending on how conservation and expansion are achieved (Natural England, 2008).

A 2003 study of the South Downs showed that they received about 39 million visitor days per annum, that visitors spent about £333 million and that about 8,000 jobs were supported (Chapter 6).

17.4.3 Enclosed Farmland

17.4.3.1 Status, trends and condition

The two main components of Enclosed Farmland: Arable and Horticultural, and Improved Grassland, cover 60% of England and are divided up into a patchwork by field boundaries of hedgerows, walls and fences. In 2007, Arable and Horticultural land (**Figure 17.8**) accounted for 30.4% of England's land cover (Countryside Survey 2009), compared with 3.4% of Wales, 3.5% Northern Ireland and 6.5% in Scotland (Carey *et al.* 2008). It is more prevalent in the drier south and in East Anglia, with between 80 and 100% of annually tilled land, as a percentage of total farmed area, in many eastern counties (Figure 7.2, Section 7.2.1.1). Improved Grassland covers 21.7% of England, 34.4% of Wales, 40.5% of Northern Ireland and 11.2% of Scotland, and in England is predominantly found in the north and the South West. England also has the majority of the UK's other farmland habitats, including about 97% of traditional orchards and about 69% of hedgerows (Natural England 2009a).

Various changes in farming practices, such as increases in winter-sown instead of spring-sown cereals since the 1970s, a switch from haymaking to silage production

(Chamberlain *et al.* 2000) and the removal of subsidies for the 274,000 ha of set-aside land in 2007, have had important consequences for biodiversity. In response to the latter, the voluntary Campaign for the Farmed Environment has been set up, with the aim of retaining and exceeding the environmental benefits that used to be provided by set-aside.

The area of Arable and Horticultural habitat decreased significantly by 8.8% between 1998 and 2007, whilst the area of Improved Grassland has increased by 5.2%, with a significant 14% increase in the easterly lowlands (Countryside Survey 2009). These changes are likely to be a consequence of alterations in economic and technological drivers and policy (e.g. CAP reform). The distribution of some arable flowering plants has decreased dramatically during the last 50 years and they are now amongst the most threatened elements of England's flora (Rich & Woodruff 1996; Preston *et al.* 2002); 18 of the 30 vascular plants that have shown the greatest relative declines across Britain and Ireland are characteristic of arable and other cultivated ground (Preston *et al.* 2002). Declines in farmland birds, particularly specialists, were also associated with changes in agricultural practices, including increased specialisation and mechanisation, switching to autumn sowing of cereals, intensification of grassland management, increased use of agrochemicals and loss of field margins and hedges, but recent declines in some species are more complex and not solely due to agriculture. The smoothed farmland bird index for 19 species in 2009 was 53% below the 1966 starting level (Defra 2010b), but farmland specialist species, such as the goldfinch (*Carduelis carduelis*) and whitethroat (*Sylvia communis*), have increased by 39% and 31% respectively since 1994. One or two farmland specialist species, such as the wood pigeon (*Columba palumbus*), may have benefited from changes, such as an increased area of oilseed rape production (Defra 2008a). The loss of semi-natural landscape elements in farmland, however, has also been identified as a key driver of pollinator declines (Tscharntke *et al.* 2005).

The Enclosed Farmland Broad Habitat contains two BAP habitats with the number of BAP priority species shown in brackets: arable field margins (65) and ancient and/or species-rich hedgerows (83). Both habitats are estimated to be increasing in extent, although there are targets to increase them further (Table 17.7).

England possesses 69% of the UK's length of ancient and/or species-rich hedgerows and the focus is on maintaining their extent and species richness and improving their condition, along with halting the decline of herbaceous hedgerow flora. There are also UK targets to achieve an average of 800 km per year net increase in the length of hedgerows between 2010 and 2015, with the percentage increase equally spread across England, Scotland and Wales.

Various regulations, guidelines and agri-environment schemes have been used with some success to enhance biodiversity and ecosystem services. Under the CAP, England has given high priority to the agri-environment measures, allocating 82% of total Axis 2 support payments to them (Farmer *et al.* 2008). There are now over 58,000 agri-environment scheme agreements covering 66% of agricultural land in England, which have improved biodiversity, but not enough time has elapsed to assess their effect on halting its

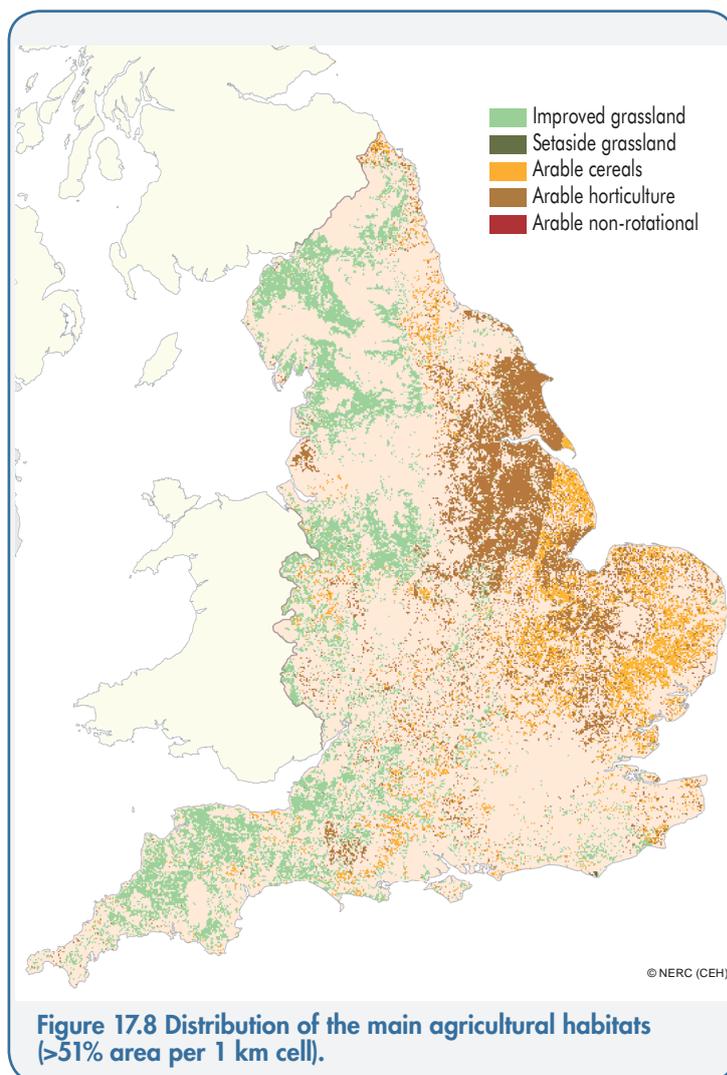


Table 17.7 BAP targets for UK and England for cereal field margins. Source: data from BARS (2008).

Target for expansion	UK		England		
	2005 base (ha)	Change by 2010 (%)	2005 base (ha)	2010 target (ha)	Change by 2010 (%)
Cultivated, low-input field margins	8,859	85	5,381	10,000	92
Margins providing wild bird seed	5,367	289	3,570	18,000	404
Flower-rich field margins	1,858	546	1,858	12,000	546
Permanent grass margins	26,582	1.7	25,178	25,178	0

loss on Enclosed Farmland (Davey *et al.* 2010; McCracken & Midgley 2010a). There is, however, some evidence that farmland birds can recover with appropriate management practices and low(er) inputs (Vickery *et al.* 2004; Henderson *et al.* 2009), as can bumblebees (Carvell *et al.* 2007). A study of the effectiveness of Entry Level Stewardship agreements

(introduced in 2005) showed only limited evidence for short-term effects on lowland farmland bird populations, with only the corn bunting (*Emberiza calandra*) and starling (*Sturnus vulgaris*) showing some landscape-specific positive associations with areas under Entry Level Stewardship management (Davey *et al.* 2010). In 2010, Uplands Entry Level Stewardship replaced the Hill Farm Allowance. It is designed to ensure support for farmers in maintaining historic uplands landscapes, such as the Cumbrian Fells, Dartmoor and the Peak District. Agri-environment schemes also have enhanced the protection of more than 6,000 archaeological features on farmland, including more than half of all scheduled monuments and registered battlefields, and in 2008 enabled more than 170,000 people to make educational visits to farms (Natural England 2009a).

17.4.3.2 Ecosystem services

Most Enclosed Farmland is managed for the production of food, fibre, feed for animals and energy, although it contributes to a number of other services, both positively and negatively (Pretty *et al.* 2000). An overview is provided in Table 7.3 in Section 7.3, and Tscharntke *et al.* (2005) provide a review of positive and negative effects of agriculture on biodiversity conservation, the potential mechanisms of biodiversity-ecosystem service relationships, the role of biodiversity in multifunctional agriculture, and analyses the importance of biodiversity for ecosystem services.

Regulating services. Insects are important in Enclosed Farmland, as pollination is critical for maintaining production in some crops (Section 17.5.2.4). Certain insects are also useful for biological pest control (17.5.2.3), although others can become pests in high numbers.

In the Arable and Horticultural component habitat there have been significant decreases in carbon density between 1978 and 2007 and particularly between 1998 and 2007, whilst in Improved Grassland carbon density has increased, possibly as a result of increased fertiliser usage (Smith *et al.* 2008). Agriculture is a net producer of greenhouse gases, but there are some opportunities to reduce these through improved crop, soil, fertiliser and agrochemical management (Smith *et al.* 2008; Macleod *et al.* 2010), anaerobic digestion and bioenergy crops, and also for carbon sequestration (Smith *et al.* 2008). The industry has recently committed to reducing greenhouse gas emissions through its Greenhouse Gas Action Plan.

Most farmland is well drained and thus it has a low water storage capacity (Foster 2006), although floodplain meadows (or wetlands) can be important for attenuating flood peaks, and their restoration can be a part of adaptation to climate change-induced impacts of flooding (Morris *et al.* 2004a), with benefits for biodiversity (Berry 2009). The flooding of grassland, for example, could potentially reverse the decline of grassland waders (Wilson *et al.* 2004) and thus also contribute to cultural services. Agriculture is more significant in its impact on soil and water quality, with excess application of fertilisers leading to soil acidification and eutrophication (Jarvie 2010), as well as atmospheric emissions.

Provisioning services. England is the main contributor to UK crop production (Table 17.8) and cereals are the

Table 17.8 Percentage of particular farm types in each country in the UK in 2008*. Source: data from June Surveys/Census of Agriculture; Defra (2009a).

Farm type	England (%)	Northern Ireland (%)	Scotland (%)	Wales (%)
Dairy	59.1	19.9	8.2	12.9
Grazing Livestock (Less Favoured Areas)	23.9	26.9	25.6	23.6
Grazing Livestock (Lowland)	78.8	10.6	4.3	6.3
Cereals	83.4	2.1	13.1	1.4
Mixed	68.6	6.6	16.8	8.0

* Farm type is classified by the predominant farming activity taking place on the holding based on an economic measure of profitability (Standard Gross Margin, SGM). The farm type is defined as the activity which contributes more than two-thirds of the total SGM for the holding.

dominant crop, with wheat (1.79 million ha) and barley (584,000 ha) accounting for almost 95% of the UK total cereal area (Table 15.1, Section 15.2.2; Figure 7.8, Section 7.3.1.1). An analysis of increases in UK cereal yields (which will be reflected in England) has shown that winter wheat yields have more than trebled over the last 60 years from about 2.5 tonnes per ha in the mid-1940s to 8 tonnes per ha today. Since 1982, around 90% of all yield increases in wheat and barley have been due to the introduction of new crop varieties, whilst fertilisers, pesticides and machinery have played a minor part, although remaining an important part of crop production (BSPB 2010).

Other crops, such as sugar beet, brassicas, field beans, peas and maize may be grown primarily for food or animal fodder. Potatoes are grown particularly on the silt and peat soils of eastern England, Shropshire and Cheshire, whilst orchards are concentrated in Kent, Herefordshire and Worcestershire; vegetable growing is mainly between Humberside and Essex and flowers are grown in Lincolnshire and Cornwall (including the Isles of Scilly).

Livestock numbers generally rose during the 20th Century until the 1990s, then decreased, although stocking densities have shown a consistent increase (Figure 7.22; Figure 7.4, Section 7.2.1.1). Totals for cattle, sheep and pigs are given in Figure 17.22 (Table 15.2, Section 15.2.3). Production from Improved Grassland is difficult to assess, as some bullocks are raised in intensive indoor rearing units, whilst others graze Semi-natural Grasslands, and many sheep are raised on unimproved upland pastures. Dairy cattle usually graze Improved Grassland and in 2009 the population was 1.8 million, with a yield of about 7,000 litres of milk per cow per year. Sheep numbers increased after joining the EU in 1973, with the increase occurring particularly in Wales. The greatest increases in England were in the north, Peak District, Exmoor and Dartmoor (Fuller & Gough 1999), and were much lower on lowland enclosed farmlands (for more detail see Chapter 7). There are no reported figures for wool production from England alone, but in 2009 the UK was the seventh largest producer of wool in the world, responsible for about 2% of global production (BWMB 2010), and the amount is roughly in proportion to sheep numbers.

In the UK, government incentives have been introduced, e.g. the Energy Crops Scheme (Natural England 2010a), to encourage the establishment of bioenergy crops, and the area of agricultural land under such crops is increasing. In England, approximately 7,500 ha were established under this scheme between 2001 and 2007 (Lovett *et al.* 2009). Kilpatrick (2008) indicated that cereals and oilseed rape straw represent a significant (and the largest) potential biomass resource, although not all would agree with this and a range of other sources are possible, including root crops and short rotation coppice, using, for example, willow. Biomass could also be sourced from straw or energy crops from set-aside land brought into production, the conversion of temporary grassland to energy crops and conversion of permanent grassland and rough grazing to short rotation forestry. De Wit & Faaij (2010) calculated that whilst maintaining food self-sufficiency, CAP reform by 2030 could free up 0–6.5% of land in eastern England and up to 31% in the South West, which potentially could be used for energy crops. Planting on surplus arable land has been calculated as being the best climate change mitigation option (Smith *et al.* 2000), but this would have biodiversity, landscape and cultural service implications.

The likely impacts of biomass crops on ecosystem services and biodiversity are given in Table 7.5, Section 7.3.1.3. A combined GIS-based yield and suitability mapping has been used to identify the areas for *Miscanthus* (*Miscanthus x giganteus*) as a biomass crop and possible locations for expansion under different scenarios (Lovett *et al.* 2009). This showed that the East Midlands and East of England could be particularly suitable, whilst the west was less so. The areas with the highest biomass yields co-locate with food producing areas on high-grade land and thus the potential conflicts that could occur are identified. If such high-grade land and unsuitable areas are excluded, the policy-related scenario for increased planting on 350,000 ha utilised between 4 and 28% of the lower grade land (depending on the region) and would not necessarily greatly impact on UK food security, but would contribute to the climate regulation service.

Wild species diversity, as has been seen earlier, is mainly associated with specific habitats within the Enclosed Farmland landscape, such as cereal field margins and hedgerows. Some are also important for wild foods, e.g. field mushroom, blackberry, sloes and watercress (Mabey 1972). In addition, game birds and mammals are shot as part of crop protection activities (deer, rabbits, pigeons) and recreational shooting of grey partridge (*Perdix perdix*), red-legged partridge (*Alectoris rufa*) and pheasant (*Phasianus colchicus*), although recreational shooting could be considered more part of cultural services. Although technically wild, many game species are subject to some form of management, including release into the wild after captive breeding (Section 15.5) and will be used for food.

Cultural services. Arable and Horticulture, Improved, Neutral (and Acid) Grassland are seen as contributing to the quality of the landscape and giving distinctive character to certain NCAs, such as the Hampshire Downs (arable), Severn and Avon Vales (horticulture), and the Shropshire Hills (improved, neutral and acid grasslands; Natural England 2009a). As seen above, agri-environment schemes include

the maintenance of agricultural landscapes considered to be of cultural value, as well as archaeological features, and encourage public access. In the lowlands, Enclosed Farmland can be important for recreation due to the number of footpaths, their proximity to centres of population and accessibility to people with a wide range of fitness levels. Also, there is increasing interest in green gyms and care farming: the use of commercial farms and agricultural landscapes as a base for promoting mental and physical health (Hine *et al.* 2008).

17.4.3.3 Valuation

The valuation of agricultural habitats is difficult, as there are both costs and benefits involved. A report on the annual environmental costs of agriculture showed that in England the benefits included: broad habitat types (SSSIs): £260 million and linear features: £1.67 million. Annual costs included: river water quality: £45 million, bathing water: £7.95 million, water quality in estuaries: £2.51 million, greenhouse gas emissions: £839 million and air quality pollutant emissions: £434 million (Jacobs 2008). Conversely, the costs of agri-environment schemes to achieve different policy objectives have been estimated at £1,258 million, with nearly half of this being represented by biodiversity (Cao *et al.* 2010). The full breakdown is given in Table 7.6, Section 7.5.3. In England and Wales, the benefits from broad habitat types (non-SSSIs) have been costed as £165 million and linear features as £1.67 million, whilst the landscape value of semi-natural habitats and linear features in agricultural landscapes have been estimated as £143.5 million, and the biodiversity value of habitats (SSSIs) and species as £628.8 million in 2007 (Countryside Survey 2009).

Valuation of individual services suggests that the economic value of traditional orchards in Herefordshire, Worcestershire and Gloucestershire could be in excess of £1.5 million a year (in Natural England 2009a), whilst the annual value of insect pollination in the England in 2007 was estimated to be £367 million (BHS 2008).

17.4.4 Woodlands

17.4.4.1 Status, trends and condition

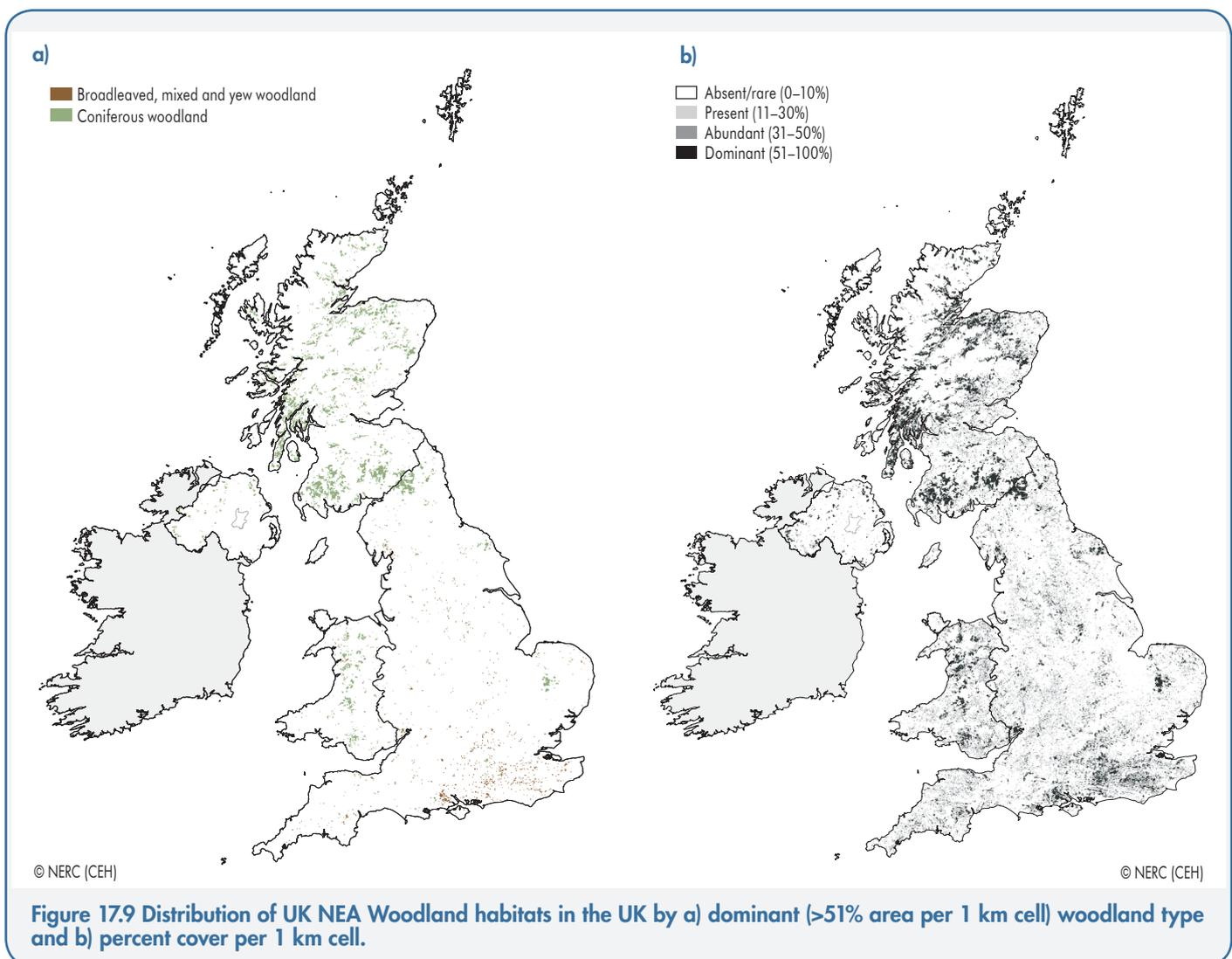
Compared to the rest of Great Britain, and much of the EU, England is poorly wooded, with woodland of all types, including both broadleaved and conifer, covering just over 9% of the country. This is substantially lower than the woodland cover in Scotland (17%) and the 37% average in EU member states. In contrast to other countries of the UK, where conifer woodlands predominate, about 66% of England's woodland is broadleaved, most of which is found in the lowlands.

Broadleaved woodlands are found on a wide range of soils, from alkaline to acid and in all climate zones. As a consequence, they show a very wide range of ecological variation, from base-rich ash-dominated types, to the acid sessile oak woodlands, which particularly characterise the north and west (**Figure 17.9**). The majority of broadleaved woodland is semi-natural and England accounts for 64% of the semi-natural woodland in the UK. England's woodland comprises 206,000 ha of ancient and semi-natural woodland

and 210,000 ha of other semi-natural woodland (Forestry Commission 2009a). In addition to the ancient and semi-natural woodland there are 135,000 ha of plantations on ancient woodland sites and these two make up the category of ancient woodland (i.e. woodland that has been in continuous existence since 1600). The semi-natural woodland is composed largely of native species, with oak (*Quercus* species), ash (*Fraxinus excelsior*), birch (*Betula* species) and beech (*Fagus sylvatica*) making up 24.5, 16.2, 10.8 and 9.9% of the area respectively (Forestry Commission 2003). There is little regeneration of young trees due to the impacts of grazing animals; outside woodlands, grazing and burning mean there is little natural spread of trees (EFTEC 2009). A range of woodland birds, such as nightingale (*Luscinia megarhynchos*), lesser spotted woodpecker (*Picoides minor*), and willow warbler (*Phylloscopus trochilus*) have declined, at least partially, as a result of pressures, notably from climate change, deer browsing and reductions in active management, but also from other activities (e.g. recreation, woodfuel). If grazing pressure from deer, for example, continues, there could be large shifts in woodland bird community composition in lowland England (Fuller 2001), with species such as nightingale being adversely affected (Fuller *et al.* 1999).

Traditional broadleaved woodland management in England tended to rely on vegetative regrowth from coppice stools and pollards. These systems declined during the 20th Century due to the focus on production and plantation forestry using fast-growing, non-native conifer species, leading to the replacement of semi-natural broadleaved woodland. About 40% of the ancient woodland that existed in the 1930s was converted to plantations, mostly between 1950 and 1980 (Harmer & Kiewett 2006). This practice ceased in 1985 and these plantations on ancient woodland sites have been a focus of restoration.

The decrease in coppice and coppice with standards has led to a change in the structural characteristics of woodlands, with an increase in the amount of high forest, with closed canopies, denser shading and a loss of floristic diversity (Kirby *et al.* 2005; Hopkins & Kirby 2007). For example, woodland specialist butterflies declined significantly (74%) from 1990 to 2007 and wider countryside (generalist) butterflies by 65% (Brereton *et al.* 2010). The decline in woodland butterflies is considered to be chiefly due to a corresponding loss of open habitats within woodlands, the decline in traditional woodland management (e.g. coppicing), the reduction in felling areas and the shading of rides and glades. The decline may also



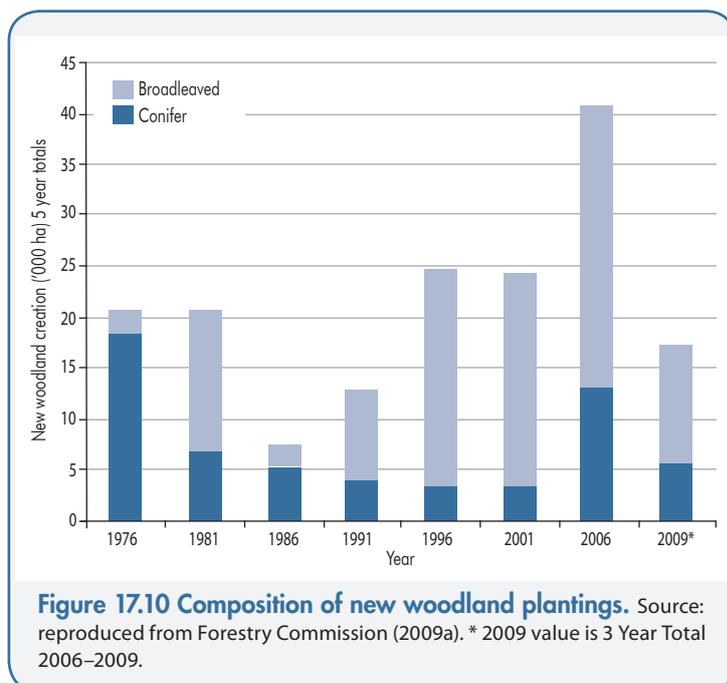
be linked to increasing deer numbers (locally), habitat fragmentation and climate change (Fox *et al.* 2006).

There has been increased interest in the natural regeneration of woodland and more traditional management practices (Evans 1988; Harmer *et al.* 2010). The small area of coppicing in the UK (0.9% by area) is undertaken almost exclusively in England and a further 1% of the woodland is coppice with standards (Forestry Commission 2009a), although maintaining or restoring coppice, as well as natural regeneration, is now severely limited due to deer numbers (Fuller & Gill 2001).

Apart from relatively small stands of yew and juniper scrub, all other conifer woodlands in England are primarily planted, initially for commercial production of timber and other wood products. One-fifth of England's forestry is found in the uplands, most notably in Kielder Forest, Northumberland and on poorer acid soils in the lowlands, often on areas of former heathland, mostly in parts of Dorset, Hampshire, Thetford Forest, Norfolk and the Thames Basin. Scots pine (*Pinus sylvestris*) and Sitka spruce (*Picea sitchensis*) are the dominant species planted, making up 24.1 and 23.5% of the conifer area respectively.

The UK BAP recognises two broad woodland habitats: Broadleaved Mixed and Yew Woodland and Coniferous Woodland, but only the former occurs in England. The Broadleaved Mixed and Yew Woodland broad habitat is split into eight priority habitat types, of which lowland mixed deciduous woodland, lowland beech and yew woodland, wood-pasture and parkland, wet woodland, upland mixed ash woodland and upland oak woodland are found in England. Despite its limited extent, semi-natural woodland remains one of the richest habitats, with about one-quarter (256) of BAP priority species in England associated with woodlands (Webb *et al.* 2009). Coniferous Woodland in the North East have been highlighted as of key strategic importance in sustaining England's red squirrel population (Forestry Commission 2007) and are also developing their own distinctive mixtures of habitats and assemblages.

Since the extensive felling during the Second World War, there has been a 45% increase of woodland area. Whilst between the 1940s and 1960s much of this expansion was due to conifer planting, since about 1980 the increase has been very largely due to the expansion of broadleaved woodland (Hopkins and Kirby 2007). There is, however, some evidence of increased planting of conifers in recent years (Figure 17.10), possibly signalling a greater interest in commercial forestry, but also the recent developments in climate change adaptation/mitigation programmes (Read *et al.* 2009). This may shift the balance more towards conifers and highly productive broadleaved species. One significant woodland development is The National Forest, covering 50,000 ha of the Midlands (Derbyshire, Leicestershire and Staffordshire). It seeks to increase woodland cover to about one-third of the area and already cover has increased from 6% in 1991 to around 19% in 2011, whilst ensuring it delivers multiple services, including commercial forestry with ecological, landscape and public benefit, as well as helping in climate change mitigation (The National Forest 2011). Economic regeneration in the area is through the restoration of mining sites, as well as opportunities for rural diversification.



Woodlands are seen as being subject to a large number of pressures, and the cumulative effects of these pressures may be significant. Broadleaved woodland is sensitive to changes in land management and support through grants, and coniferous woodland to changes in forest and conservation policy and market conditions.

The BAP targets (UKBAP 2007) for the future of native woodland include:

- the maintenance of the current extent and distribution of native ancient semi-natural woodland;
- the restoration of existing plantations on ancient woodland sites such that, by 2020, 85% of them will already be broadleaved, fully restored, under restoration or being actively conserved, and a further 14,000 ha of the coniferous or mixed plantations on ancient woodland sites will be managed so as to conserve and enhance biodiversity;
- increasing the area of broadleaved woodland by 5,300 ha (1%) per annum;
- achieving favourable or recovering condition of 5,300 ha per annum of native woodland by 2015.

This woodland expansion needs to be undertaken in locations where it will enhance existing native woodland, particularly ancient woods, and other priority habitats. It is expected to be achieved by: buffering the margins of woodland or other habitats; expanding small woods; complementing and diversifying the age structure of even-aged woods; contributing to habitat networks and 'ecological connections' across landscapes; developing clusters of interconnected woodland and creating some large new woods. The regional targets for this restoration and expansion are shown in **Table 17.9**.

17.4.4.2 Ecosystem services

Woodlands provide amongst the highest identified number of ecosystem services, including regulating climate, air

Table 17.9 Regional targets for restoration and expansion of woodland. Source: reproduced from Measures (2008).

Native woodland	Restoration (ha by 2015)	Expansion (ha by 2015)
North East	2,700	12,508
North West	3,130	7,426
Yorkshire & Humber	3,780	7,154
East Midlands	3,440	6,923
West Midlands	4,750	5,261
East of England	3,220	6,444
South East	7,840	3,342
London *	-	20
South West	7,140	3,942
England Total	36,000	53,000

*London: priority is on achieving favourable condition of existing BAP woodland resource. A nominal expansion target is suggested based on London Biodiversity Partnership's targets (2006).

quality and water flows, providing timber and other wood products, as well as a range of cultural benefits.

Regulating services. Until recently the regulating services provided by woodland have been little recognised. Woodlands have considerable potential in indirect climate regulation through carbon sequestration. For example, oak forests in England have been measured as removing around 15 tonnes of carbon dioxide per hectare per year, compared with 24 tonnes carbon dioxide per hectare per year for coniferous forest in southern Scotland. The largest vegetation store of carbon in the UK is the woodland of southern England (Milne & Brown 1997), but this is minute in comparison with soil storage, particularly in heathlands and blanket bogs. There have been various estimates of topsoil carbon concentrations, and a study of changes in woodlands in Great Britain between 1971 and 2000–2003 found no significant change from 88 g C/kg (Kirby *et al.* 2005), although Chamberlain *et al.* (2010) estimate that there has been a 0.5 Tg C increase in broadleaved woodland and a 9.2 Tg C decrease in the total topsoil carbon stocks between 1998 and 2007. Woodland planted since 1990, with a woodland creation programme of 23,000 ha per year could, by 2050, sequester 10% of UK carbon emissions.

In addition, trees and woodlands regulate climate through shading and the cooling of evapotranspiration can reduce local temperatures by 3–4°C (Morecroft *et al.* 1998). Shading of rivers streams and other water bodies by trees can deliver similar cooling, with beneficial effects for fisheries and wildlife, and street trees can have a similar effect in urban areas (Handley & Gill 2009).

Provided care is taken during harvesting and other operations, woodland can play a valuable role in preventing soil erosion, maintaining carbon content, free drainage and other aspects of soil quality regulation, as set out in the UK Forestry Standard (Forestry Commission 2009b). They can also be important for flood protection through increased flood storage, decreased flood flow velocity and peak discharge (Thomas & Nisbet 2007; Nisbet *et al.* 2009)

and water quality regulation, although this can be positive or negative, depending on the context.

Trees, especially evergreen species, are effective at scavenging air pollutants such as sulphur dioxide, ammonia and particulates. In urban areas, trees can provide a more valuable role in air quality regulation than other types of vegetation, especially beside roads and near intensive livestock units in the countryside (Pitcairn *et al.* 1998; Bignal *et al.* 2004; Woodland Trust 2010). Whilst nitrogen may increase growth for some trees, a study of beech woodlands showed that local sources of nitrogen can impact ground flora composition (Kennedy & Pitman 2004). Trees and other tall vegetation can play a valuable role in noise regulation due to the absorption of lateral sound waves and damping of sound reflection.

Provisioning services. The historical survival, and most planting, of woodlands in the past have been due to the provisioning services they provide. Since the Second World War, the expansion of woodland was driven by the need for timber production, and currently about 80% of UK wood and timber products are imported. This proportion is likely to be higher in England, as more of the demand is for conifer wood, which accounts for only a small part of the woodland area.

The use of wood as a fuel has declined during the past 60 years, although in recent years the market for woodfuel has been more buoyant due to increases in costs of other fuel types, interest in decreasing carbon footprint and improved domestic and industrial burners. The Woodfuel Strategy for England aims to bring 2 million extra tonnes of woodfuel into the market by 2020, approximately 50% of the annual increment (Forestry Commission 2009c). There is a small but stable production of charcoal, nearly all for domestic use (Sanderson & Prendergast 2002). Elderflowers, sloes, damsons and bullaces, nettles, hazel fences and spars for thatching, fungi, moss and foliage are other locally important products from woodlands, but the quantities used are small (Sanderson & Prendergast 2002).

In the lowlands, woodlands are a critical part of most game shoots, for example, for the location of release pens (Sage *et al.* 2005), and this activity has grown in the past 50 years. Of the 1.9 million shooting days in the UK, 40% is in woodland, accounting for about 28,000 jobs, and a high proportion of this is likely to be in England. In the past 50 years the wild deer population in England has grown dramatically, causing widespread woodland damage. In England, most deer stalking occurs in woodlands and some of the meat enters the venison market, but the income barely covers the costs (Section 8.3.2.2).

Cultural services. Since the mid-1980s, forestry policy has increasingly sought to promote a mix of services (including biodiversity, cultural and regulating), resulting in a widening of the Forestry Commission's remit (Forestry Commission 2007), increased planting of broadleaved tree species and a diversification of plantation structures.

Woodlands contribute to the structural diversity of landscape and many are important in forming the key characteristics of Natural England's NCAs, e.g. the Chilterns, New Forest and Border Moors and Forests. A survey showed that broadleaved woodlands generally were the preferred

type and that externally, deciduous woodlands were key to the aesthetics/colours of a 'whole view' (especially the colours in autumn), whilst coniferous woodlands were valued, but more for recreation, including horse riding, biking and long walks. In some of the NCAs they were also valued as a 'productive' landscape component, associated with the local identity of the place and people's livelihoods (Natural England 2009a, b). Woodlands were seen as delivering many of the cultural services, being most important for calmness/tranquillity/peace/spiritualism (mainly broadleaved) and the leisure side of recreation (mixed and coniferous). In South East England, woodlands provide more than half of the accessible green space (McKernan & Grose 2007), although this excludes much that is in private ownership. A Forestry Commission survey (Carter *et al.* 2009) showed that the public thought that the two main future benefits should be to provide places for wildlife to live (over 45%) and places to walk (just under 45%).

In England, over half the area of woodland has public access, and currently, 55% of the population have access to woods greater than 20 ha within 4 km of where they live, and 10% have access to woods greater than 2 ha within 500 m of their home, but if inaccessible woods were opened up, then about an extra 26% of the population would have access to each category (Woodland Trust 2004). The England Leisure Visits Survey (Natural England 2006) showed that in 2005, 5% of all leisure visits included a trip to a woodland or forest, where walking was the main activity (62% of respondents). Overall, 62% of people who went to a wood did so to walk and only 9% to cycle (Natural England 2006).

Ancient woodland is also increasingly appreciated for its archaeological content, which may not only reflect its management history, but also retain traces of earlier land uses, as the soil has been relatively undisturbed (Rotherham *et al.* 2008).

17.4.4.3 Valuation

It has been estimated that English-grown timber and woodland management is associated with businesses which contribute £2.1 billion to GDP and employ 64,000 people. Around 16% of these are woodland-based businesses, such as recreation and tourism (Defra 2008b). Given that woodlands can provide multiple services, there would be considerable opportunity for revenue generation from any future payments for ecosystem services schemes, although consideration will need to be given to trade-offs between conflicting services. There is a lack of figures for many of the services, but Sanderson and Prendergast (2002) include various estimated figures for forest products, including hazel spars at £2 million and UK production of charcoal at approximately £1.3 million per year. The annual turnover of Bottle Green, who use wild elderflower for their drinks, was about £5 million.

Woodland creation is a highly cost-effective and achievable form of emission abatement at less than £100 per tonne CO₂e. Whilst conifer plantations and energy crops may be the most cost-effective options for carbon sequestration, mixed and broadleaved woodlands deliver a wider range of other benefits were only valued at about £41 per tonne CO₂e. (Matthews & Broadmeadow 2009).

A survey of the contribution of forests to tourism showed that forest-related tourism expenditure for day visits in England is just over £2 billion, compared with £2.3 billion for Great Britain (Willis *et al.* 2003), whilst the Natural England study (2009) valued trips to woods/forests at £1.8 billion. Biodiversity is also an important value of forests and the marginal benefits per household per year for an increase of 12,000 ha was estimated at 84p for lowland new broadleaved native forest and £1.13 for ancient and semi-natural woodland (Willis *et al.* 2003).

17.4.5 Freshwaters – Openwaters, Wetlands and Floodplains

17.4.5.1 Status, trends and condition

England has approximately 136,000 km of rivers and streams, 2,624 km of canals, 54,330 km of roadside ditches and over 97,000 ha of standing waters. Within standing waters, there are approximately 234,000 ponds and around 5,710 permanent lakes and reservoirs greater than 1 ha in size (Hughes *et al.* 2004; Countryside Survey 2009; **Figure 17.11**). In addition, there are an estimated 528,884 ha of wetland habitat in England. The wetland area is roughly 4% of England's land area, and of this, 47% (247,298 ha) is under SSSI protection.

The character of freshwaters varies, depending on the underlying geology. Eutrophic waters, draining soft rock or glacial drift catchments with higher levels of nutrients, make up approximately 60% of England's waters. The remaining 40% are split almost evenly between oligotrophic waters, draining from areas of hard rock geology and low in dissolved nutrients, and mesotrophic waters, often draining from sedimentary rocks. Of these, oligotrophic-mesotrophic base-rich waters and lowland oligotrophic waters on acid sand deposits are internationally significant and are poorly represented in Europe outside of the UK. Similarly, England's 3,900 km of chalk rivers are the longest in European extent and a key habitat for water crowfoot (*Ranunculus*) species. In addition, there are six standing water types in England that are found in Annex I of the EC Habitats Directive (92/43/EEC). Although canals are not recognised as a habitat under this Directive, they have been shown to offer temporary refuge for species driven from their natural habitats by declines in water and habitat quality. The Rochdale Canal in northern England, for example, supports several EC Annex II species. Recently changes in pressures, such as land use and management, have led to hydromorphological modification, flow alteration and quality changes in open waters (Chapter 9).

Wetlands, which include UK BAP priority habitats blanket bogs, coastal and floodplain grazing marsh, lowland fens, lowland raised bogs, reed beds and upland fens, flushes and swamps, comprise the largest proportion of designated SSSIs and are represented in numerous SACs. Wetlands cover just under half the total area of England's SSSI series and include 90% of the available fenland and raised bog, whilst only 16% of grazing marsh is SSSI designated (Natural England 2008). Blanket bog and grazing marsh comprise 93% of the total wetland area, and are especially prevalent along the Pennines, and in the North West and South West (**Figure 17.12**). The other three habitats (fens, reedbeds and

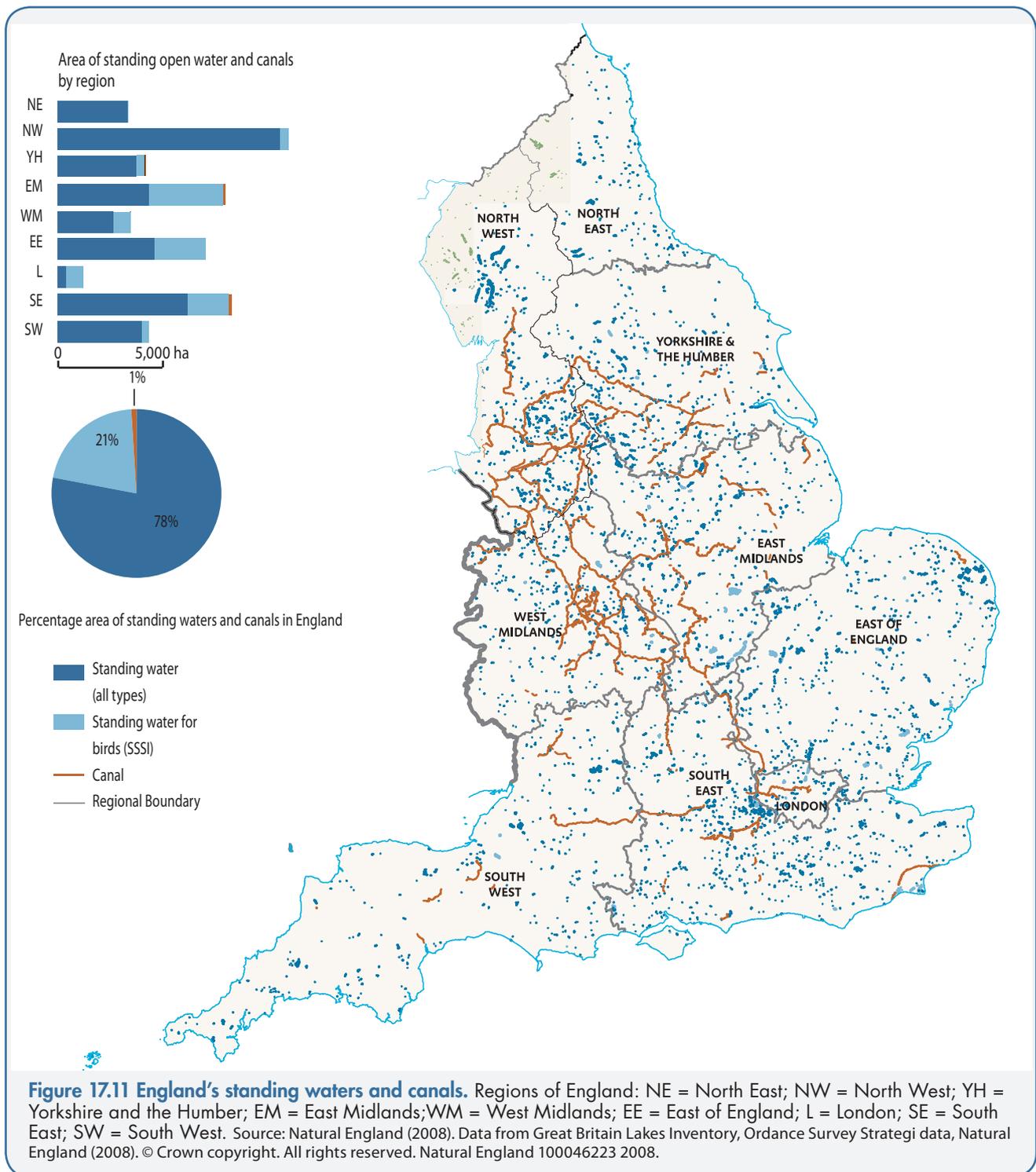
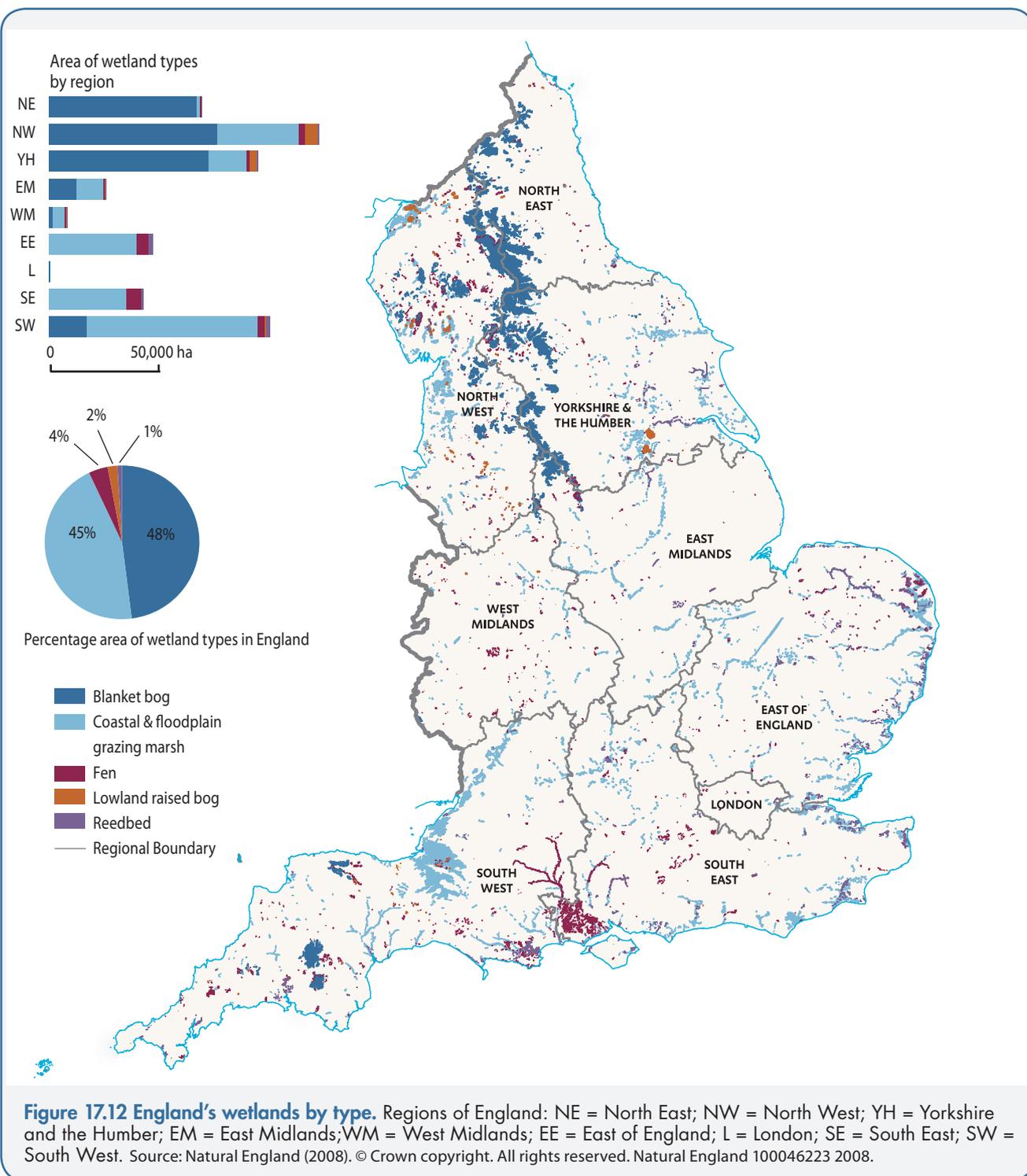


Figure 17.11 England's standing waters and canals. Regions of England: NE = North East; NW = North West; YH = Yorkshire and the Humber; EM = East Midlands; WM = West Midlands; EE = East of England; L = London; SE = South East; SW = South West. Source: Natural England (2008). Data from Great Britain Lakes Inventory, Ordnance Survey Strategi data, Natural England (2008). © Crown copyright. All rights reserved. Natural England 100046223 2008.

lowland raised bogs) combined contribute 7% of the total area. Both the type and extent of wetlands vary between regions, with those with extensive upland/coastal areas or major fluvial floodplains supporting the greatest area of wetland. The South West holds the largest proportion of lowland wetlands, of which the majority is coastal and floodplain grazing marsh on the Somerset Levels. Other important wetland areas are concentrated in the South East and East of England.

The status of SSSI freshwaters provides an indication of water conditions: 44% of SSSI open waters are classified as favourable and 11% as recovering. Eutrophication is the cause for the majority of freshwaters classified as unfavourable,

due to inputs from point source pollution in 70% of the cases (e.g. sewage outfall) and diffuse pollution sources in 40% (e.g. agricultural fertilisers) with overlap in some locations (Countryside Survey 2009). This is an issue particularly in standing water, with a sample of 100 SSSI lakes showing that 80% were affected by eutrophication (Carvalho & Moss 1998; **Figure 17.13**). In addition, phosphate pollution was identified as a risk for 41% of water bodies in England and Wales in terms of the Water Framework Directive (UKTAG 2005) and there is growing concern that airborne pollution (acidification and atmospheric nitrogen) and climate change pose significant risks to vulnerable ecosystems, such as shallow ponds (Mountford & Strachan 2007).



In terms of the Water Framework Directive 75% of rivers and a similar proportion of lakes in England are not in good condition and 80% of ponds are in poor condition. For SSSI wetlands 21% are classified as being in favourable condition and 48% as recovering (Natural England 2008). Unfavourable conditions in recorded SSSI sites are caused by overgrazing (58%), burning (36%) and drainage (23%) in the uplands, and by water pollution (29%), drainage (21%) and inappropriate water levels (17%) in the lowlands (Natural England 2008). Information is scarce about England's wetlands' condition outside of SSSIs. Dutt (2004) suggests that two-thirds of grazing marsh are in good condition for breeding waders, whilst the Norfolk Wildlife Trust (2006) found that only 31%

of non-SSSI fens in Norfolk were in favourable or recovering condition, compared to 51% in SSSI fens. However, it is expected that 1,500 ha of fens in England (19% of the 8,000 ha) will undergo restoration of former habitat by 2015, especially in the East (400 ha) and North West (360 ha; Measures 2008). One thousand hectares of lowland raised bogs are expected to be restored in England by 2015, especially in the North West (760 ha), and there is a planned expansion of 1,900 ha of reedbeds, especially in the East (740 ha; Measures 2008).

Semi-natural freshwaters provide valuable habitats for diverse plant, fish and invertebrate communities, whilst man-made pits and reservoirs are important for birds and can also support uncommon plants and invertebrates.

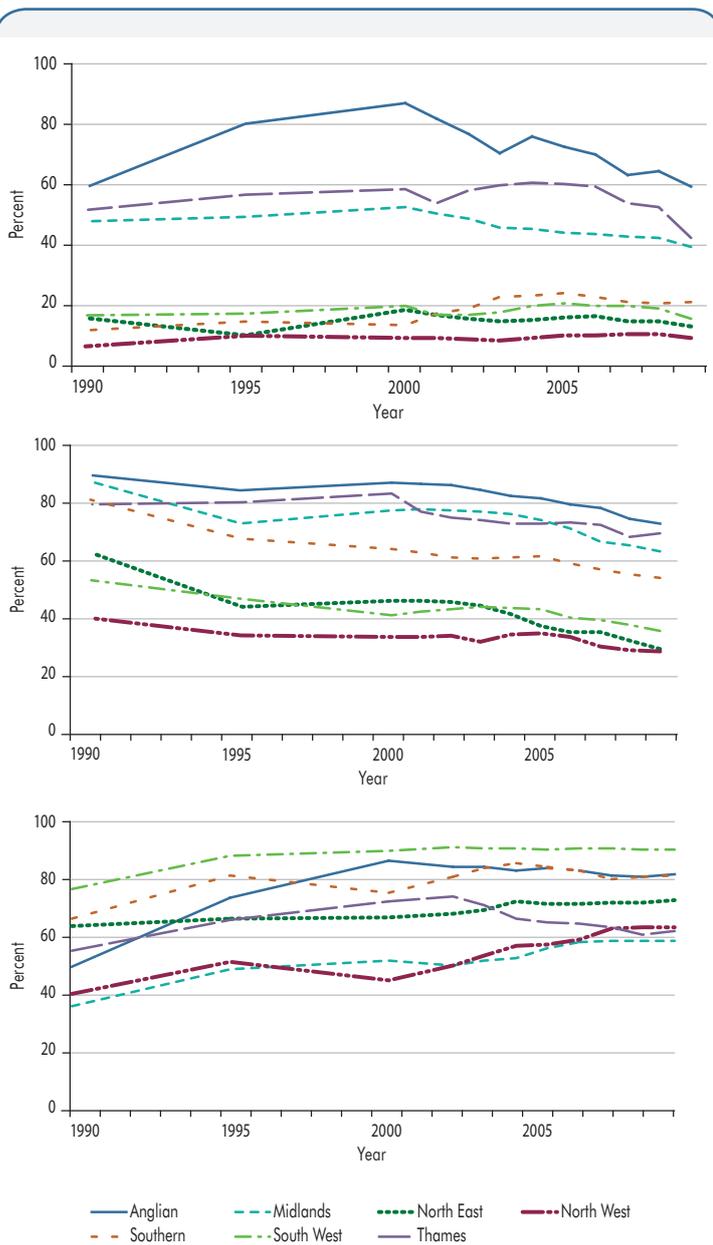


Figure 17.13 Percentage of total river length in England with a) average nitrate concentrations of over 30 mg/l, b) average phosphate concentrations over 0.1 mg/l and c) total river length of good biological quality in England. Source: data from Environment Agency; Defra (2010c) © Crown copyright 2010.

England's wetland areas have disproportionately large biological diversity per unit volume and support over 3,500 species of invertebrates, 150 species of aquatic plant, 22 species of duck and 33 species of wader (Merritt 1994). There are several restricted birds species, such as the marsh harrier (*Circus aeruginosus*), bittern (*Botaurus stellaris*) and bearded tit (*Panurus biarmicus*), particularly associated with reedbed/marsh habitats. Birds such as the common sandpiper (*Actitis hypoleucos*) and dipper (*Cinclus cinclus*) may be good indicators of habitat quality in rivers. Conversely, the spread of cormorants (*Phalacrocorax* species) to inland freshwaters has been perceived as a problem for freshwater fish populations.

Of particular interest are English populations of floating water plantain (*Luronium natans*), stoneworts, white clawed

crayfish (*Austropotamobius pallipes*), freshwater pearl mussel (*Margaritifera margaritifera*), great crested newt (*Triturus cristatus*), natterjack toad (*Epidalea calamita*), salmon (*Salmo salar*) and vendace (*Coregonus albula*), all of which are recognised as internationally significant and, in some cases, are protected under the Habitats Directive. Furthermore, approximately 25% of all beetles are dependent on wetlands, and bogs and fens provide habitat for a variety of other invertebrates, including the fen raft spider (*Dolomedes plantarius*), the swallowtail butterfly (*Papilio machaon*), and dragonflies.

Relatively few mammals are directly associated with freshwaters with the exception of the water vole (*Arvicola amphibius*), water shrew (*Neomys fodiens*), some bats, otter (*Lutra lutra*) and American mink (*Mustela vison*). Water voles were England's most rapidly declining mammal due to predation by American mink and habitat deterioration (Strachan & Moorhouse 2006), but they are now slowly expanding their range. Otters were lost from many catchments across England in the 1950s to 1970s, but have been recovering and have now spread into northern rivers as water quality improves (Crawford 2003). Water voles may benefit from otters recolonising much of their former range and displacing mink (Bonesi & Macdonald 2004).

All amphibian species in England have declined, especially severely in the case of species with specific habitat requirements. These include the natterjack toad, which has lost over three-quarters of its former English range since 1900 (Beebee 1976; Banks *et al.* 1994); the great crested newt, which was lost from around half of its former English breeding sites (Beebee 1975), but now may be locally numerous in parts of lowland England, though it is absent or rare in Cornwall and Devon (Langton *et al.* 2001); the common toad (*Bufo bufo*), which declined by up to 50% in parts of southern and eastern England between 1985 and 2000 (Carrier & Beebee 2003); and the pool frog (*Pelophylax lessonae*), which became extinct in England during the 1990s and was reintroduced during 2005–2008.

Freshwater fish populations have also declined due to overfishing, eutrophic waters, habitat loss, etc. Salmon have declined since the 1970s and have remained at low levels since the 1990s. Elver (*Anguilla anguilla*) recruitment is down 95% and the current population is 5% of 1970s levels. Vendace populations have also declined, with low populations noted in Bassenthwaite Lake, but a stable population with some recruitment in Derwent Water (Winfield *et al.* 2004).

General environmental quality trends for rivers are positive, with long-term monitoring data showing a major improvement in the 40,000 km of English rivers. The patterns in recovery vary significantly within the UK, with biological recovery in English (and some Scottish) rivers, and continued biological decline in Wales (Chapter 9). The Thames, for example, where stretches were 'biologically dead', now supports over 125 species of fish, including the internationally important smelt and shad, and record numbers of salmon and sea trout have been found in the Thames, Mersey and Tyne. Concentrations of nitrate, however, have increased in 4,000 km of English rivers (Section 9.3.8) and phosphorus levels remain elevated in many areas, contributing to prolonged eutrophication (Mainstone *et al.* 2008). On

the other hand, chemical evidence shows recovery from acidification to be underway, although there is less evidence for recovery in biological systems (Davies *et al.* 2005). Lakes show similar trends to rivers with respect to acidification, with some showing evidence for biological recovery of macrophytes and invertebrates (Monteith *et al.* 2005).

Problems with pesticides have declined over recent decades and increases in sensitive species, such as the otter, illustrate how threats from organochlorines, such as dieldrin, have now been effectively eliminated. Sediment-related problems have increased in the most intensively used catchments, with increased sediment fluxes over the last 40–100 years, particularly in areas where no active management has taken place to reduce them. Increasing evidence shows that even surprisingly low levels of input can impact sensitive organisms, particularly in upland regions where loads exceed natural exposure rates. Dissolved organic carbon shows a widespread increase with average trends exceeding +90% in some upland locations (Evans *et al.* 2005; Worrall & Burt 2007a). Positive trends in fish populations have been seen in the re-establishment of native Atlantic salmon populations in the formerly polluted Tyne and Tees. Some concern remains over shifts in the demographic structure of Atlantic salmon populations in rivers from many sea-winter fish to 1-year grilse, commensurate with the impacts of overexploitation on lifecycles. Furthermore, in some catchments, juvenile populations of brown trout (*Salmo trutta*) and Atlantic salmon have declined by 50–60%, and there are major declines amongst other species (e.g. eels). Invasive species of fish and other organisms are also a growing concern; examples include the North American signal crayfish (*Pacifastacus leniusculus*), which has spread along many English rivers.

Various estimates suggest that as much as 90% of the national resource of English wetlands has been lost since Roman times, with as much as 13% of the floodplain resource degraded or completely disconnected from river channels. In the Thames Estuary, for example, two-thirds of the coastal and floodplain grazing marsh was lost between the 1930s and 1980s, and of 44,000 ha of grazing marsh within the North Kent, East Essex, Foulness and Inner Thames area, 28,000 ha were converted to other land uses (Ekins 1990; Thornton & Kite 1990). Originally covering 38,000 ha in England, peat bog now covers less than one-tenth of that area, mainly due to losses in the lowlands (English Nature 2002). In the case of lowland raised bog, the area retaining a largely undisturbed surface has declined by 94%. Data from The Countryside Survey in 2007 showed that there had been a small decrease in reedbeds since 1990, but also showed a significant increase in the extent of bogs, from 78,000 ha to 117,000 ha from 1990 to 2007 (Countryside Survey 2009).

17.4.5.2 Ecosystem services

Regulating services. Regulating services for freshwater often impact upon provisioning services. These include aquifer recharge (important, especially when water is continually extracted for irrigation), water quality (the dispersal and dilution of pollutants and purification of water) and vegetation growth (which may act as both as a purifier and hazard regulator).

In addition, freshwater plays significant roles in regulating flooding, erosion, sedimentation, local climates and water quality (Chapter 9). In England, there are a number of examples of freshwater systems, both man-made and natural, providing a range of ecosystem services, especially regulation. Examples include the town of Upton in the East Midlands, where a series of ponds and wetlands is used to capture runoff, regulate flooding and purify water. They also provide habitat for biodiversity and greenspace for local residents (Natural England 2009d). Another example is peat bogs, where waterlogged conditions and a lack of oxygen prevent biomass from fully decaying, thus they act as stores for carbon. The extraction of peat for fuel and fertiliser releases the stored carbon and decreases the habitat available for specialist species. Due to action taken by the government, however, locations such as Humberhead Peatlands and Wedholme Flow have been secured against continued peat extraction by large companies (English Nature 2002).

Provisioning services. Floodplains are the most important freshwater habitat for food and fibre production, with 57% of Grade 1 agricultural land in England being on the indicative floodplain (Section 9.2.1.3). Freshwaters provide for both consumptive and non-consumptive uses of water, including all forms of wetland-related crops, plants, livestock, fish (wild and domesticated), and energy, whilst crops dependent on irrigation rely on freshwater supplies. For example, parts of East Anglia are considered semi-arid, and require irrigation through dry months (Weatherhead & Knox 2000). This will continue, and may increase, as climate change affects rainfall totals and variability during growing months. Floodplains also play an important role in provisioning, due to their high soil fertility (Box 9.1, Section 9.2.1.3).

Wild fisheries provide species, such as salmon, brown trout and eel, which depend on freshwater as habitat and for breeding and nurseries. Aquaculture supplies fish and invertebrate species for a number of uses, including nursery-reared fish and invertebrate species such as freshwater white clawed crayfish, freshwater pearl mussels, brown trout and Arctic char (*Salvelinus alpinus*) for conservation restocking. Overall, England produces annually approximately 11,373 tonnes of farmed fish and invertebrates (James & Slaski 2009).

In addition, trees, standing vegetation and peat are important energy sources created or fed by freshwater systems. Other provisioning services include potable, domestic and industrial water and hydropower.

Cultural services. Rivers, lakes and wetlands have significant cultural value, especially in terms of recreation, tourism and education. Furthermore, they play a key cultural role as an inspiration for the arts and religion.

Tourism continues to focus on water-based holidays, advertising leisure activities such as sailing, swimming and fishing. Recreational fishing is of importance as a free-time activity, with over 1.3 million fishing licences being sold in 2009 (Environment Agency 2010a). Birdwatching can be especially gratifying around freshwater environments, as wetland habitats are particularly important for a number of species, especially ducks and waders.

Regions featuring freshwater have played an important role in English history and culture. For example, the Romantic

poets William Wordsworth and Samuel Taylor Coleridge based themselves in the Lake District in the early 1800s. Much of their writings were influenced by the surrounding landscape, which featured lakes, waters and mountains (Icons 2006). Writers, such as Ted Hughes, have used rivers as a source for their work.

Housing along or on rivers and canals is in high demand, and often priced at a premium. Currently, construction along the Thames in London is set to provide increased housing (both competitively priced and at affordable prices), as well as increasing access to the riverside for leisure (Environment Agency 2009).

17.4.5.3 Valuation

An accurate valuation of all the benefits provided by the freshwater resource is difficult, but it has been estimated that the mean average benefits of inland lowland wetlands in England are between £3,400 and £5,240/ha/yr and between £1,700 and £2,630/ha/yr for all inland lowland and upland wetlands in England (Chapter 22). A 2005 survey reviewing England's Leisure Visits demonstrated that leisure visits to water locations result in expenditure of £1,060 million annually in locations with boats and £793 million in locations without boats. Fishing is the most widespread participatory sport in the UK, with in excess of 4 million anglers across all social strata. Coarse fisheries alone contribute £1,030 million to the economy out of a total spend exceeding £3 billion by rod fishermen in England and Wales (Environment Agency 2004). For migratory salmonids, the capital value of fishing rights alone is estimated at £165 million (Aprohmanian *et al.* 2010). In addition, reservoirs like Rutland Water in the East Midlands also provide monetary value, with 64% (£79–138 million) of its total annual value of £123–215 million attributable to functions other than its primary purpose as a reservoir.

A study undertaken by NERA provides an indication of the value placed by case study households in England and Wales on their freshwater environment. Participants were asked how much they would be willing to pay to improve water quality to a situation where 95% of water bodies reached good ecological status and an average of between £45–167 per household per year was stated (NERA 2007). The money raised by the Great Fen Partnership in East Anglia also demonstrates the value local partners placed on the environment, with £17 million being raised in six years, 80% of which came from private sources or charitable grants, such as the Heritage Lottery Fund. This money enabled the partnership to secure 1,700 ha of farmland adjacent to NNRs in the area to create an enveloping 'waterland' around them, stimulating socioeconomic benefits for people, including much increased local community involvement and opportunities for access and recreation. An £18 million government grant was used to buy out the peat producers at Thorne and Hatfield Moors (which together cover over 3,300 ha) in Yorkshire and the Humber Region, thus preventing further habitat deterioration and loss of carbon regulation.

17.4.6 Urban

17.4.6.1 Status, trends and condition

There is no consensus regarding how urban environments

are identified. The Land Cover Map 2000 (LCM 2000) identifies 10.6% of the land area in England as 'built up areas', whilst 14.2% is similarly described by the Office of National Statistics Output Area (GLUD 2005), which defines 'urban' as contiguous physical settlement areas containing 10,000 or more people. This is far greater than the 'built up' or 'urban' areas in Scotland (1.9% and 3% respectively), Wales (4.1% and 7.9%) or Northern Ireland (3.6% and 3%). Understanding the habitats within Urban boundaries becomes complex, especially when the dominant features within Urban boundaries tend to be the built environment and the people it houses.

Within Urban boundaries, however, many habitats and services may be identified. These range in size and complexity and include public parks and gardens, private gardens, semi-natural green spaces, such as woodland, scrub and grassland, urban trees and outdoor sports facilities. Allotments, urban farms and community gardens also play large roles in people's interaction with land. Previously developed land (PDL or brownfield), cemeteries, churchyards, and burial grounds further contribute habitat for native species within Urban boundaries. Increasingly, interest in biodiversity conservation has led to wildlife gardening, including pond creation, hedgehog, bird and bat houses, and specially chosen plants for invertebrates. Many of England's residents provide feed for birds, which may help winter survival.

It has long been understood that cities have a larger impact on the surrounding ecosystems than rural communities (Folke *et al.* 1997). Though limited in extent, whatever greenspaces exist within city boundaries do contribute to ecosystem services. Therefore, it is important to inventory and protect the greenspaces and the benefits they provide, as well as their accessibility to residents, to ensure that increasing demand for housing and other development in cities does not lead to a loss of greenspace. The outward sprawl of cities in England has been limited by the Green Belt Policy, which covers 13% of England's land area, and green belts surround some of the most densely populated urban areas (Natural England/CPRE 2010e). Whilst this policy provides people with limited access to open greenspace outside cities, much of it is private farmland. Green belts can also be important habitats for biodiversity, though the promotion of biodiversity conservation and recreation are not explicitly stated purposes of this land. Recent policy has encouraged the re-use of PDL or brownfield within cities, as opposed to continuing the outward sprawl. However, city densities are projected to increase, which may force cities to expand their borders as well as increasing construction within existing boundaries, impacting both green belts and inner-city greenspaces. For instance, in London, population projections estimate an increase from 7.5 million in 2006 to 8.5 million by 2026 (Natural England 2009d), which will require the provision of additional housing, infrastructure and jobs, as well as greenspace. Domestic gardens and brownfield have proven to be good habitat for invertebrates and local plant species, and losing these habitats to accommodate an increase in population would negatively impact species' populations which depend on already limited space (Angold *et al.* 2006; Natural England 2008). In an effort

to protect gardens from ‘garden grabbing’ and development, Planning Policy Statement 3 was passed in 2010, increasing their status to above brownfield equivalent (Clark 2010).

In England, local authorities were required to develop Green Space Strategies in order to decide how they intended to plan use of greenspace and the resources, time and methods required. A study of four English cities (Newcastle, Northampton, Coventry and Liverpool) showed that the total mapped public greenspace covers between 17 and 24% of the Urban area (Box 10.1, Section 10.1.3). Often the distribution of greenspace is not even across the individual cities and not all of it is freely accessible to the public. For instance, golf courses and school playing fields are often privately owned and not publicly accessible (CABE 2010).

Table 17.10 inventories greenspace in urban authorities in England based on a variety of sources; however, it does not include private gardens, which contribute to a wide range of provisioning, regulating and cultural benefits.

17.4.6.2 Ecosystem services

There is no doubt that cities require more services than they can provide. Current estimates for London suggest that it requires 293 times more land than its geographical area in order to sustain itself, equivalent to twice the productive land in Britain (Best Foot Forward 2002). The services provided by most habitats in Urban environments are limited, primarily providing cultural and regulating services, although increasingly allotment and community farm space is contributing to local food production (Garnett 2000).

Regulating services. Greenspace in urban environments helps to regulate climate, decrease runoff from paved surfaces and improve air quality. Temperatures are often much higher within cities than in surrounding areas—it is estimated that the temperature difference between London and its surrounding suburbs may be as high as 9°C (GLA 2006a). These urban heat islands can be mitigated by increased greenspace—urban trees, green roofs, woodland, community farms and allotments and brownfield can all help in the regulation of heat due to direct shading and cooling by evapotranspiration,

whilst reducing wind speeds helps to prevent heat loss from buildings in winter (Woodland Trust 2010). Green roofs can also dramatically reduce energy demand from buildings and decrease maximum surface temperature (Gill *et al.* 2007), as well as providing high-density buildings with localised greenspace. It has been projected that by 2050 the temperature in Manchester will have risen by 3°C due to climate change. This could be avoided by increasing greenspace by 10% (Handley & Carter 2006).

Trees have the added benefit of effectively filtering pollutants, including gaseous components, such as oxides of nitrogen and sulphur, as well as particulate matter, especially Particulate Matter up to 10 Microns in Diameter (PM₁₀) (Tiwarly *et al.* 2009). In addition, trees and other woody vegetation mitigate noise by absorbing both reflected and laterally transmitted noise, especially at high frequencies.

Runoff is another problem that can be mitigated by urban greenspace. Green roofs, parks and gardens, urban woodlands, allotments and farms and even stand-alone trees can all reduce runoff from paved surfaces (Gill *et al.* 2007) and many Urban areas now promote sustainable urban drainage systems (Section 17.4.5).

Provisioning services. Allotments and community farms comprise 1,829.6 ha of urban land in England (CABE 2010). These sites provide crops and sometimes livestock to local communities, and require a minimum of transport to deliver products to consumers. In 1975 the Royal Horticultural Society estimated food production on allotments and community gardens at ‘best practice’ to be around 21.4 t/ha. Garnett (2000) halves this estimate to 10.7 t/ha, a more conservative estimate which allows that not all farmers or gardeners can grow at optimal conditions. Using a conservative estimate, the potential urban food production in England is about 19,576 tonnes of fruit and vegetables. Crop production from these sites could theoretically feed over 100,000 people their recommended daily intake of 0.4–0.5 kg of fruit and vegetables (WHO & FAO 2004).

Private gardens in England are estimated to cover over 400,000 ha of land (Gilbert 1989) and also contribute to crop

Table 17.10 Public Urban greenspace in England (does not include private gardens). Source: reproduced from Commission for Architecture and the Built Environment (CABE 2010).

Greenspace type	Number	Area (ha)	Data
Allotments	997	1356.8	Allotment sites 2004–2005
Cemeteries	1,643	3,679.1	Burial grounds 2006
Community farms	197	472.8	Community gardens and city farms 2004–2005
Country parks	72	5,765.9	Country parks
Doorstep greens	82	140.3	Doorstep greens
Golf courses	361	5,720.6	Golf courses
Grass pitches	10,243	8,170.4	Sport England/Fields in Trust
Millennium greens	91	164.5	Millennium greens
Nature reserves	663	14,308.0	National nature reserves; local nature reserves
Parks	1,770	52,243.2	Registered parks and gardens 2008; Public parks assessment; Green Flag parks 2006–2007
National Trust	128	14,537.0	National Trust
All types	16,247	106,549.6	

growth and genetic resources. Although 70% of the plants used in domestic gardens are non-native, of the 20 most commonly used species 55% are native (Natural England 2008). Gardens, allotments and community farms also contribute to cultural and regulating services, by providing local greenspace for residents and making unfriendly habitats permeable for local species.

Cultural services. About 80% of the population of England lives in Urban areas (CABE 2010) and although access to greenspace increases the health and happiness of residents (Fuller *et al.* 2007), it is inevitably limited in cities, because of restricted space and high land prices. Proximity to accessible greenspaces, especially those encompassing a variety of plant and animal species, has physical and psychological benefits and increases social cohesion (Fuller & Gaston 2009). Green patches in the urban environments may act as valuable corridors into and through cities, especially if the pathways are targeted toward and designed for a specific species or group of species (Angold *et al.* 2006). In this way urban greenspaces may be able to fill a number of niches, supplying habitat to species within cities and increasing the value of that space to urban residents. In England, some species, including the common frog (*Rana temporaria*), song thrush (*Turdus philomelos*) and hedgehog (*Erinaceus europaeus*), that have declined in the wider countryside have found urban greenspaces, especially domestic gardens, suit them well. Brownfield sites have also contributed to urban wildlife conservation, along with providing open space and accessible educational opportunities for urban residents. For example, Canvey Wick, Essex was an oil refinery and is now a post-industrial SSSI site. It has become a habitat for a number of Red Data Book and UK BAP priority species, including herb-rich grassland, early successional habitat and scrub edge and brackish habitats, and provides habitat for the nationally important shrill carder bee (*Bombus sylvarum*), as well as a wide array of plants (English Nature 2005; Natural England 2008).

Access to open greenspace, however, is varied. In the North East, for instance, only 8% of homes are within 300 m of a greenspace larger than 2 ha (Figure 17.14). And although the overall amount of greenspace for urban residents in England is on average 1.79 ha per 1,000 people (CABE 2010), the quantity of greenspace available in areas with high concentrations of minority groups is significantly lower, negatively impacting access to such facilities as outdoor sports fields (CABE 2010). This can have severe harmful impacts on community cohesion and residents' health, whilst greenspaces that are accessible and connected are valuable both to wildlife and human users. Utilising space along waterways and disused railway lines can offer a range of benefits, including interconnectedness, accessibility and, in the case of derelict land, affordability.

17.4.6.3 Valuation

The benefits of urban greenspaces have been touched upon in the previous sections, and are explored in Section 10.1.3. Health, social cohesion, opportunities for engagement in outdoor activities and accessible educational opportunities are all provided for residents by urban greenspace. Additionally, the quality and economic value of the local

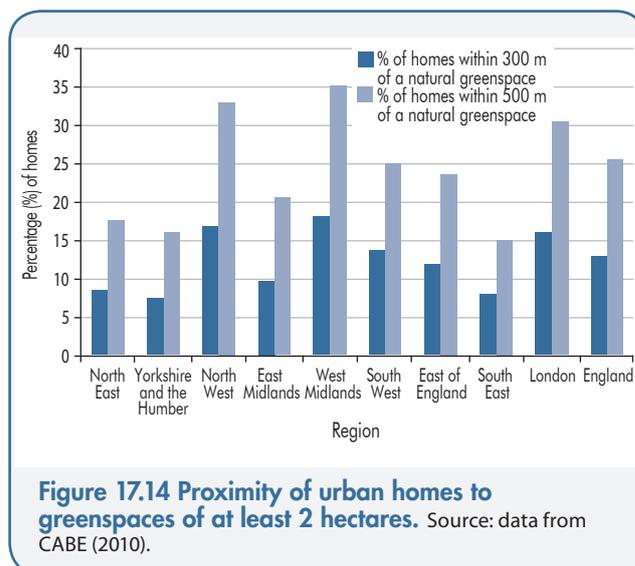


Figure 17.14 Proximity of urban homes to greenspaces of at least 2 hectares. Source: data from CABE (2010).

environment (including air, water, noise and climate) are improved by proximity to greenspace (CABE 2005). Proximity to, and views of, high quality greenspaces can increase house prices by 6 to 15%, whilst views of apartment blocks can reduce value by up to 7% (CABE 2005).

CABE (2010) measured how urban residents assign value to greenspace, asking whether 'access to nature' and 'parks and open spaces' are important to them. Responses varied across the country, with parks and open spaces considered more important in highly urbanised regions (for instance, London and the North West), and less so in more rural regions (for instance, the East Midlands and the South West). Interestingly, London residents had amongst the lowest concern for 'access to nature', whilst residents of the South West considered it comparably more important.

17.4.7 Coastal Margins

17.4.7.1 Status, trends and condition

In England, the Coastal Margins comprise five UK NEA component habitats (Sand Dunes, Saltmarsh, Shingle, Sea Cliffs and Coastal Lagoons); the sixth, Machair, is found only in Scotland and Ireland. Sand Dunes and Saltmarsh are the most extensive, although at a UK scale Shingle is also important, with England holding 73% and 86% of the national resource for Saltmarsh and Shingle respectively (Table 17.11; Section 11.2.7.2). Figure 17.15 shows the distribution of the principal soft coast habitats around England. Sand Dunes and Saltmarsh are particularly important in the North West from Merseyside up to Cumbria, and on the east coast around the Wash and Essex coast. As with the rest of the UK, considerable loss of sand dune area has occurred due to agricultural land claim, golf courses and development for housing and tourism, and at some sites, afforestation. Development along the Sefton coast, illustrated in Figure 17.16, is typical, with losses probably comparable to the UK figure of 30% loss since 1900 (Jones *et al.* 1993; Delbaere 1998). Habitat quality has also declined, with most dunes becoming overstabilised since 1945 (Radley 1994).

Saltmarsh incurred major losses prior to the 1980s due to widespread, large-scale reclamation for agriculture or development (Morris *et al.* 2004b). In the Wash, 3,000 ha of

marsh were reclaimed in the 20th Century alone (Doody 2008). The current major losses in Saltmarsh extent are in the South East of England. Between 1973 and 1998, over 1,000 ha were lost (Cooper *et al.* 2001). However, in larger estuaries, such as Morecambe Bay, Saltmarsh has extended seaward due to vegetative colonisation of mudflats, often by *Spartina anglica*, and the net change in area since 1945 is uncertain.

Shingle borders approximately 30% of the coastline of England, with well-known examples such as Chesil Beach, Dorset and Dungeness, Kent. The extent of vegetated shingle has declined since 1945 due primarily to infrastructure development, for example, as recently as the 1980s at 'The Crumbles', East Sussex, and aggregate extraction.

Hard cliffs are widely distributed along exposed coasts, occurring principally in South West and South East England (the latter area having the bulk of the 'hard' chalk cliffs), whilst soft cliffs are more restricted, occurring mainly on the eastern and central south coasts of England. It is assumed that the length of cliff is largely unchanged. However, cliff habitat quality has declined since 1945, not so much due to armouring, but due to agricultural encroachment at the cliff-top and reductions in grazing and traditional forms of management, leading to excess scrub development.

There are 177 saline lagoons in England, comprising approximately 25% of the UK total lagoon area. It is assumed there has been no net change in lagoon area as losses are largely balanced by creation of new, artificial lagoons.

The coastal margin habitats contain a very wide diversity of ecological niches (e.g. Howe 2002; Whitehouse 2007; Howe *et al.* 2008; 2010; Everard *et al.* 2010). The dynamic nature of these habitats means that they provide amongst the best examples of early successional environments in England. Due also to the harsh environmental gradients associated with proximity to the sea, they support a wide range of highly specialised species. Lundy cabbage (*Coincya wrightii*), for example, is only found on cliffs on Lundy Island and is host to the endemic Lundy cabbage flea beetle (*Psylliodes luridipennis*) and the Lundy cabbage weevil (*Ceutorhynchus contractus pallipes*), whilst the fiery clearwing (*Pyropteron chrysidiformis*) is restricted to the chalk cliffs of Kent and Sussex, and a water beetle, *Ochthebius poweri*, occurs predominantly in small seepages on red sandstone cliff faces in South West England (Natural England 2008).

England's Sea Cliffs are important breeding grounds for internationally important numbers of birds, including gannets

(*Morus bassanus*), guillemots (*Uria aalge*), and kittiwakes (*Rissa tridactyla*), with the cliffs at Flamborough supporting the largest known kittiwake colony in the North Atlantic, as well as England's only, and Britain's largest, mainland gannet colony (Natural England 2008). Sand Dunes, Saltmarshes and Shingle beaches hold important breeding colonies of gulls and terns. England hosts about 36% of the global population of the *graellsii* race of lesser black-backed gull (*Larus fuscus*), and is also important for a number of other species, including Sandwich tern (*Sterna sandvicensis*) and shag (*Phalacrocorax aristotelis*), little tern (*Sternula albifrons*) and puffin (*Fratercula arctica*; Brown & Grice 2005). England supports some 4.3–4.7 million non-breeding waders in winter (approximately 70 to 80% of the GB total), with The Wash alone supporting a peak of 400,000 birds in winter (Brown & Grice 2005). England's coastal habitats also provide vital stopover sites for large numbers of waders on migration between their breeding grounds in the high Arctic and wintering areas in southern Europe and West Africa.

The general unsuitability of coastal habitats for agricultural development means that they form important refugium habitats for species lost from other lowland habitats. This diversity supports a number of services: directly via provisioning of wild food and commercially harvestable resources, and through the ecosystem level processes underlying the regulating services including, to a greater or lesser extent, sea defence and pest control and pollination. A large proportion of the area of Coastal Margin habitats is designated as SAC under the Habitats Directive, is SSSI, or comes under other designations such as AONB. Therefore, protection and maintenance of the biodiversity, geomorphological interest and unspoilt character remain primary objectives. This biological diversity and the underlying geomorphological processes are part of the reason for the high proportion of total land area under statutory protection. They also form a major part of the cultural value attached to these systems, and underpin the basic processes upon which the supporting services depend.

The major drivers of change in the English coastal margin habitats, as discussed above, include changing tourism patterns and interests and land use demands, as well as nitrogen deposition and sea-level rise. Nitrogen deposition ranges from approximately 10 kg nitrogen per hectare per year on the west coast reaching up to about 20 kg nitrogen per hectare per year on the east coast (Jones *et al.* 2004), reflecting prevailing wind directions and accumulated pollution from industrial, vehicular and agricultural sources. Deposition loads have increased considerably since 1945 (Fowler *et al.* 2004) and this increase is likely to have caused reductions in plant species diversity and altered soil processes in coastal habitats (e.g. Jones *et al.* 2004; 2008). Isostatic adjustment is negative along the south and east English coasts, but positive in the North West. Nonetheless, sea level rise will have impacts on all English coastal margin habitats, with a sea level rise of 26.3 cm predicted for London under a medium emissions scenario by 2060 (Lowe *et al.* 2009). There are regional targets to restore various coastal habitats, including 200 ha of sand dunes by 2015, with 37.5% of this being in the North West region (Measures 2008). There is also a target of a 200 ha expansion by 2015 of maritime

Table 17.11 Area of Coastal Margin habitats in England, and as a proportion of UK total. *Cliffs are measured as length (km). Trends: ↓ weak decline, ↓↓ strong decline, ? trend unknown, = stable. Source: data from JNCC (2007).

	Area (ha)	% of UK total	Trend
Sand dunes	11,897	16.6	↓
Saltmarsh	32,462	72.9	↓↓
Vegetated shingle	5,023	85.8	↓
Maritime cliffs*	1,082	23.8	?
Saline lagoons	1,205	23.2	=

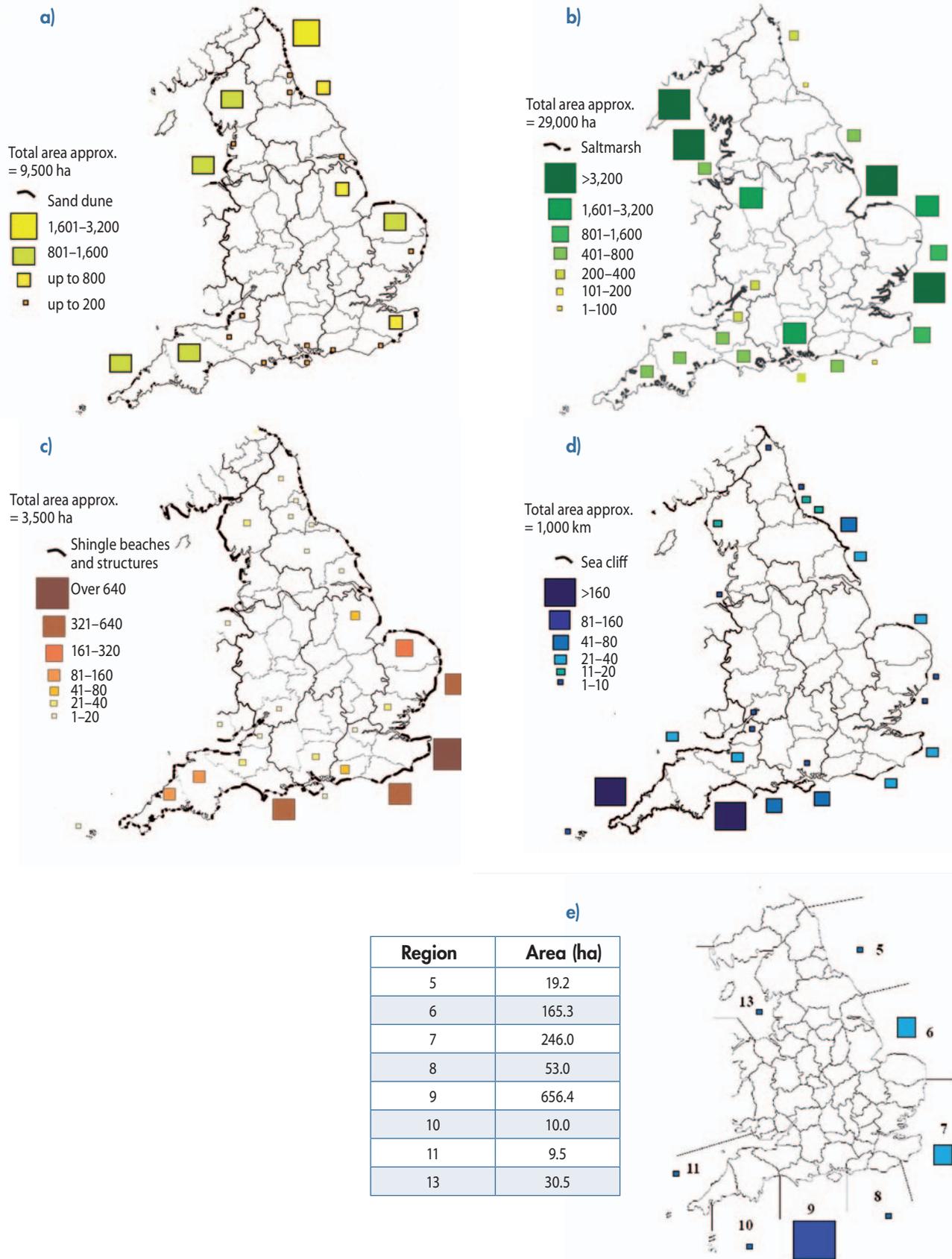


Figure 17.15 Distribution and approximate extent of Coastal Margins in England, based on JNCC data circa 1990: a) Sand Dunes, b) Saltmarsh, c) Shingle, d) Sea Cliffs (more than 20 m high), e) Coastal Lagoons. Note: figures (ha and km) are based on 1:50000 maps and are meant to facilitate comparisons. Field survey since they were drawn up have greatly increased our knowledge of the resource which is bigger than indicated by the figures. Source: all maps provided by JP Doody; Coastal Lagoons map includes data from Barne *et al.* (1995–1998).

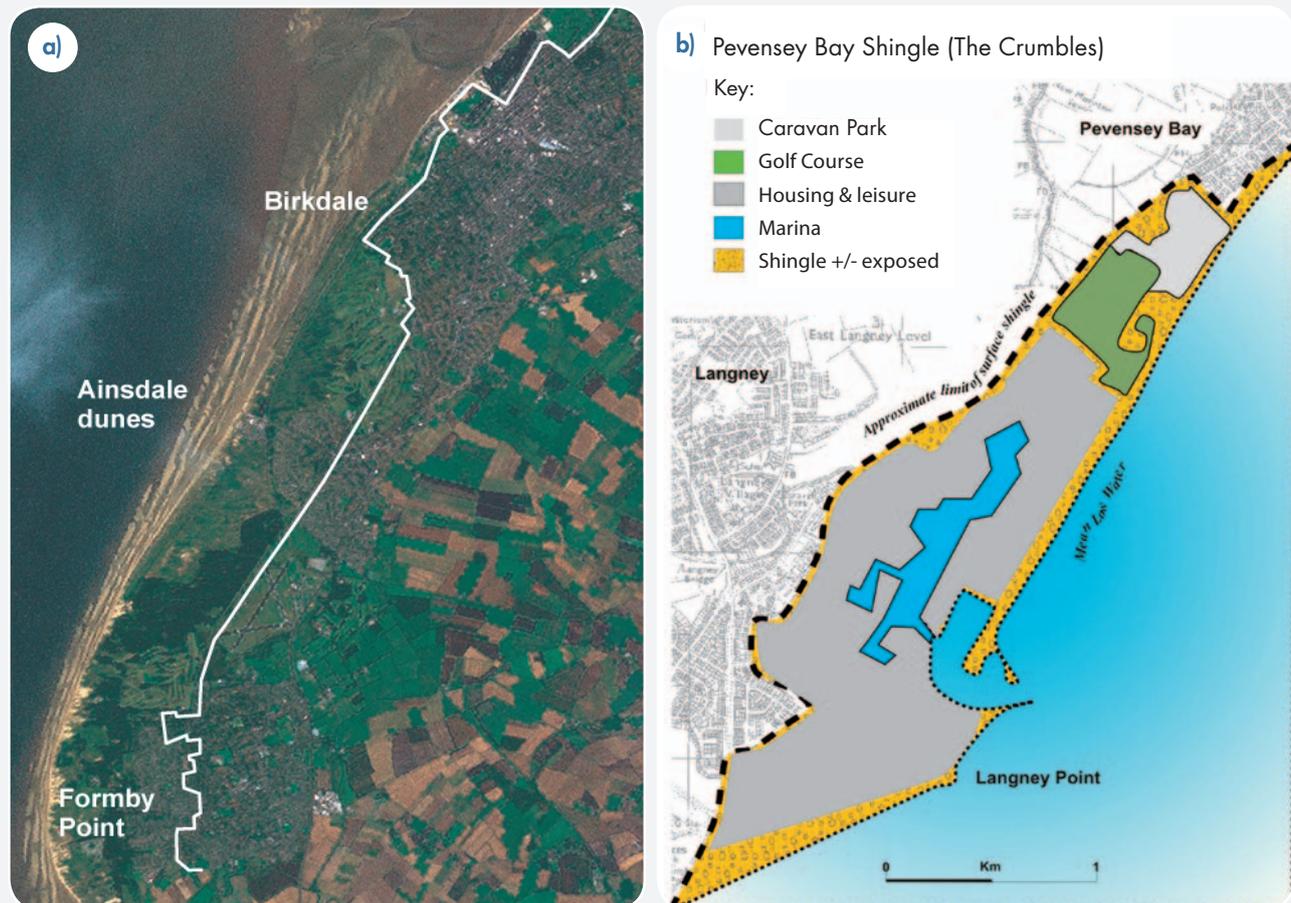


Figure 17.16 Examples of habitat loss: a) Sand Dunes on the Sefton coast, north-west England, lost to urbanisation, forestry and golf courses; and b) almost complete loss of Shingle due to development pressures at The Crumbles, East Sussex. The white line shows seaward limit of urban extent in 1945. Note the subsequent development at Ainsdale and Formby. Golf courses and afforestation of dunes pre-date 1945. Source: a) ArcGIS World Imagery Map: ESRI, i-cubed, USDA FSA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGP; urban extent courtesy of Sefton Borough Council. b) Map courtesy of JP Doody.

cliffs and slopes, with just over 40% of this in the South West region, and a 100 ha expansion of saline lagoons.

17.4.7.2 Ecosystem services

Regulating services. The principal regulating service is sea defence, which is of high importance, as 30% of the English coastline is eroding and 46% has some form of sea defence works (Masselink & Russell 2008). Saltmarshes dissipate energy, reducing the size of landward defences needed: up to 50% of wave energy is dissipated in the first 10–20m of vegetated saltmarsh (Moller 2006), and 370 km of the 440 km (84%) of Essex seawalls rely upon fronting saltmarsh to maintain defence integrity. Dunes protect residential areas and high quality farmland, particularly in north-west England and along the Norfolk Broads (Everard *et al.* 2010). Shingle provides important natural defence structures on the south and south-east coasts, such as Chesil Beach, Hurst Spit and Pevensey. Many of these features are now maintained by artificial nourishment, re-shaping or reuse to retain shingle in front of human assets. Estimates vary, but together the soft coasts provide £3.1–33.2 billion worth of sea-defence service in England alone (Chapter 11, Key Findings; Section 11.3.2).

Carbon sequestration rates are high in Saltmarsh and Sand Dunes due to rapid soil development or sediment

accumulation. West coast UK sand dunes store 0.58–0.73 t C/ha/yr (Jones *et al.* 2008), whilst saltmarsh stores 0.64–2.19 t C/ha/yr (Cannell *et al.* 1999). However, the net benefit in England is small due to the low total area of these habitats.

Provisioning services. Goods relating to provisioning services in the English coastal margins are relatively minor. The most important are meat and wool on Saltmarsh. There is some commercial stock grazing on dunes in the North West (e.g. Walney Island); grazing on cliffs is minimal, and occurs primarily for conservation purposes on land owned by the National Trust. The harvesting of samphire (*Salicornia* species) is a traditional, but small-scale industry predominantly in Norfolk. There is some timber provision from the larger extents of afforested dunes at Ainsdale, but both wood quality and economic returns are low, so amenity uses linked with biodiversity enhancement tend to be more important. Other non-food provisioning services include use of land for power stations requiring cooling water, e.g. Dungeness, and military uses of dunes in Devon.

Cultural services. As an island nation, the coast has an important place in our national psyche. Negative associations include the threats of invasion, flooding and sea-level rise, whilst positive connotations include an empire based on naval strength, livelihoods such as fishing,

and seaside holidays. The coast is highly valued by the public for a variety of reasons (Section 11.3.3), but social and cultural services are the most important ecosystem services provided by coastal margin habitats in England. The seaside accounted for 24% of all overnight domestic tourism spend in England in 2009, having a value of £4.1 billion (UKTS 2010), and generates more spend than overnight trips to the countryside and villages combined. The pattern of tourism has changed over time and there has been a general decline in overnight leisure visits to the coast since the peak in the 1960s, replaced to some extent by day visits. In 2002 there were around 200 million day visits to the English coast, of which around one-third are to natural habitats such as beaches, sand dunes, shingle and cliffs (UKLDVS 2004; VisitBritain 2007). The annual estimated total recreational value of visits to the coast is between £121 and 149 million (Chapter 22, Table 22.21). Demand for specialist activities, including coastal hiking, birdwatching, whale-watching and extreme sports such as cliff climbing, sand yachting and coasteering that require specific habitats, has increased (Mintel 2005, 2008).

17.4.8 Marine

17.4.8.1 Status, trends and condition

The broad Marine habitat covers all English areas that are either permanently immersed in seawater or are inundated with saline water at some stage in the tidal cycle. This includes estuaries, beaches, coasts and all subtidal habitats out to the limit of England's marine area (Figure 12.2, Section 12.1). England and its larger islands have over 10,077 km of coastline (Frost 2010) and a wide range of Marine habitats (Hiscock 1996). These habitats support a high diversity of animals and plants, ranked as one of the highest in Europe (Defra 2005).

Information collated for the Charting Progress reports (Defra 2005, UKMMAS 2010) form the basis of our understanding of the status and trends of England's Marine habitats and species.

Intertidal Rock habitats are widespread except in south-eastern and north-western coasts, where the intertidal zone is dominated by sandy beaches or intertidal mudflats. Large stretches of coastline in England (and Wales) are composed of Intertidal Sediments. Within estuaries, intertidal muddy sediments are particularly prevalent, with saltmarshes typically occurring landward of intertidal muds.

In the subtidal zone, sedimentary habitats such as sand, gravel, muds and mixed sediments cover almost all the continental shelf. Shallow Subtidal Sediment, which can be regularly disturbed by surface waves, is widespread in the Irish Sea, the Eastern Channel and the Southern North Sea; they also occur in Coastal Lagoons, particularly in southern England. Shelf Subtidal Sediment is only rarely disturbed by surface waves because of its greater water depth, and therefore supports more stable communities. Shelf Subtidal Sediment occurs throughout offshore areas of most regional seas, but also much closer to coasts where the water deepens rapidly, such as around Cornwall. Subtidal Rock habitats, including biogenic reefs, occur extensively in South West England. Deep-sea Habitats (below 200 m,

beyond the edge of the continental shelf) are found only in the extreme south-west Celtic Sea and are under pressure from deep-sea trawling (Benn *et al.* 2010).

England's Marine habitats have been subject to the same pressures over the last 10 years as those for the rest of the UK, although 30% of the English coast is subject to erosion compared with 17% for the UK. This has led to 46% of the coast being protected by engineering structures, compared with only 12% in Scotland (MCCIP 2010). Other pressures include adverse effects on some local Intertidal Rock communities from the harvesting of edible shellfish, and the occurrence of non-native species, as well as changes in species composition in the Channel and Celtic Seas likely to have been induced by warmer waters (Benjamins 2010). Intertidal sediment, such as mudflats and saltmarshes, is impacted by historical land claim from the sea and the construction of coastal defences and other structures which cause widespread habitat loss. These actions have particularly affected England. In the southern North Sea and Eastern Channel, the spread of non-native species, such as common cord-grass (*Spartina anglica*), has led to changes to Saltmarshes and mudflats. Although water quality levels have improved overall, there are still some small inshore areas (particularly within the North Sea and Irish Sea) where pollution and nutrient enrichment are a problem. Beach litter levels remain high and have been increasing in almost all areas except the eastern English Channel. The pressure on this habitat has increased over the last 10 years.

Large areas of subtidal sediments in most areas have been adversely affected by mobile fishing gear, such as bottom trawls and dredges, with less severe impacts in the Eastern Channel. Locally, extraction of aggregates has altered small areas of the seabed in the Eastern Channel, southern North Sea, Bristol Channel and Irish Sea. There is also pressure from wind farm developments, particularly on shallow sandbanks, and this is likely to increase in the future. Some estuaries and subtidal coastal habitats along the south coast and in the Irish Sea continue to experience nutrient enrichment and hazardous substances pollution.

Over the past two decades there has been a large increase in phytoplankton biomass in offshore waters, large changes (a 'regime shift') in the plankton community, particularly in the North Sea, and in the seasonal occurrence of phytoplankton taxa; and since the mid-1980s there has been an increase in the abundance of planktonic larvae of benthic animals in the North Sea (Reid & Edwards 2010). It is likely that warming sea temperatures, as well as fishing pressure, have driven these changes.

There have been improvements in diversity and overall abundance of demersal (bottom-dwelling) fish populations in the last five years (Pinnegar *et al.* 2010). However, demersal fish populations are severely depleted compared with 50 or 100 years ago, especially in the southern North Sea, the Western Channel and Celtic Sea, and there has been a long-term trend of overexploitation impacting fish communities as a whole. The situation for most estuarine and marine fish communities seems to have improved recently, but certain vulnerable fish have continued to decline, including sharks, rays and skates, and transitional/diadromous species that

move between fresh and salt water, such as the European eel and sturgeon.

Commercial fisheries continue to exert a significant pressure on target and non-target fish populations, but there are improvements in the proportion of stocks being harvested sustainably. In the North Sea and eastern Channel the total fishing effort (kW days) of the international fishing fleets has declined by around 27% since 2002. In contrast, fishing effort in the western Channel appears to have increased since 2000 (UKMMAS 2010) although there has been a steady decline in the number of UK vessels operating out of ports in the South West. Climate change is also beginning to have a detectable impact on fish populations, with marked changes in distribution, the timing of migration, overall reproductive output (recruitment) and growth rates.

Populations of charismatic species are often highly valued (e.g. to the local tourist industry). Although harbour seal (*Phoca vitulina*) populations in England are very small, pressure on these individuals is considered significant (Duck *et al.* 2010). Abundances of cetacean populations are more difficult to assess, and although it appears that the five most abundant species have a favourable conservation status assessment, the status of others is largely unknown (Pinn *et al.* 2010).

Seabird and waterbird populations have increased in size over the last century as a direct result of increased protection from hunting and persecution (Mitchell 2010). Generally seabird populations are stable, except in the eastern English Channel where there has been a decline in numbers of breeding common tern (*Sterna hirundo*) due to natural causes (i.e. predation and storm events). The status of waterbirds has been improving since the mid-1970s, except in the Irish Sea where populations are moving east, away from traditional sites. The reasons for this change are unknown, but may be due to climate change.

17.4.8.2 Ecosystem services

Marine habitats and their diversity of organisms provide a wide range of ecosystem goods, services and benefits of significant value, which are described in more detail in Section 12.3.

Regulating services. Humans use rivers, estuaries and coastal water for direct and indirect disposal of various types of waste materials. Marine ecosystems that receive human waste materials are therefore providing a waste breakdown and detoxification service. The deleterious effects of recently introduced and less well-studied environmental contaminants and chemicals such as nanoparticles and pharmaceuticals which pass through sewage treatment plants is of concern, and the capacity of ecosystems to break down and detoxify these products is largely unknown (Celiz *et al.* 2009; Readman 2006). Localised problems of eutrophication occur in some estuaries and coastal waters in the east, south and North West, where nutrient enrichment derives from urban wastewater and agricultural runoff, such as fertilisers, manures and slurries.

The chemical composition of the atmosphere and ocean is maintained through a series of biogeochemical processes regulated by marine living organisms. The maintenance of a healthy, habitable planet is dependent on processes such as

the regulation of the volatile organic halides, ozone, oxygen and dimethyl sulphide, and the exchange and regulation of carbon by marine organisms. For example, marine organisms play a significant role in climate control through their regulation of carbon fluxes, by acting as a reserve or sink for carbon dioxide in living tissue and by facilitating burial of carbon in seabed sediments. Of all the carbon dioxide captured in the world by photosynthesis and stored as living or dead material of biological origin, over half (55%) is captured by marine living organisms (Nellemann *et al.* 2009). However, there is no readily available data for England that quantifies total living biomass in marine and estuarine sediments and the water column, or the total amount of non-living sequestered carbon in marine ecosystems, or the role of coastal and shelf marine organisms in sequestering carbon further offshore into deeper water and sediments. Fowler *et al.* (2008) have estimated that in England energy related activity overall contributes to about 80% of greenhouse gas emissions, with agriculture and land use change contributing about two thirds of the remainder.

Living marine flora and fauna can play a valuable role in the defence of coastal regions by dampening environmental disturbances (Beaumont *et al.* 2007, 2008). A diverse range of species in England bind and stabilise sediments and create natural sea defences, for example biogenic reefs, seagrass beds, mudflats and salt marshes.

Provisioning services. Provisioning services include finfish and shellfish stocks for consumption both from wild capture and aquaculture; fishmeal and fish oil as inputs for aquaculture and food supplements; algae and seaweed as inputs into pharmaceuticals and biofuels, and bait used during sea angling. Fisheries are an important socioeconomic activity in South West England, providing employment for fishermen in aquaculture farms and in fish processing and associated industries.

Landings of fish for England and Wales are divided into three separate fisheries statistics categories: 1) demersal fish species which live on or near the sea bed including cod (*Gadus callarias*), haddock (*Melanogrammus aeglefinus*), plaice (*Pleuronectes platessa*), whiting (*Merlangius merlangus*), pollack (*Pollachius pollachius*), and sole (*Solea solea*); 2) pelagic fish species, such as herring (*Clupea harengus*) and mackerel (*Scomber scombrus*), which are typically found in mid and upper waters; and 3) shellfish including scallops (*Pecten* species), oysters (*Ostrea* species), mussels (*Mytilus edulis*), cockles (*Cerastoderma edule*), octopus (*Octopus vulgaris*), squid (*Loligo subulata*), cuttlefish (*Sepia officinalis*), prawns, crabs, and lobsters. Since 1956 there has been a decline in landings of demersal finfish, pelagic landings have shown instability, whilst shellfish landings have increased and the value of demersal fish and shellfish landings has increased (**Figure 17.17**).

The trends in demersal and pelagic finfish landings can be attributed to a number of factors including declining fish stocks due to fishing and environmental change; catch quotas; restrictions on the number of days allowed at sea; a shift to shellfish harvesting; and latterly decommissioning schemes that have seen reductions in the size of the overall fishing fleet. The increase in scallop fishing is partly due to stringent quotas being placed on demersal and pelagic fish

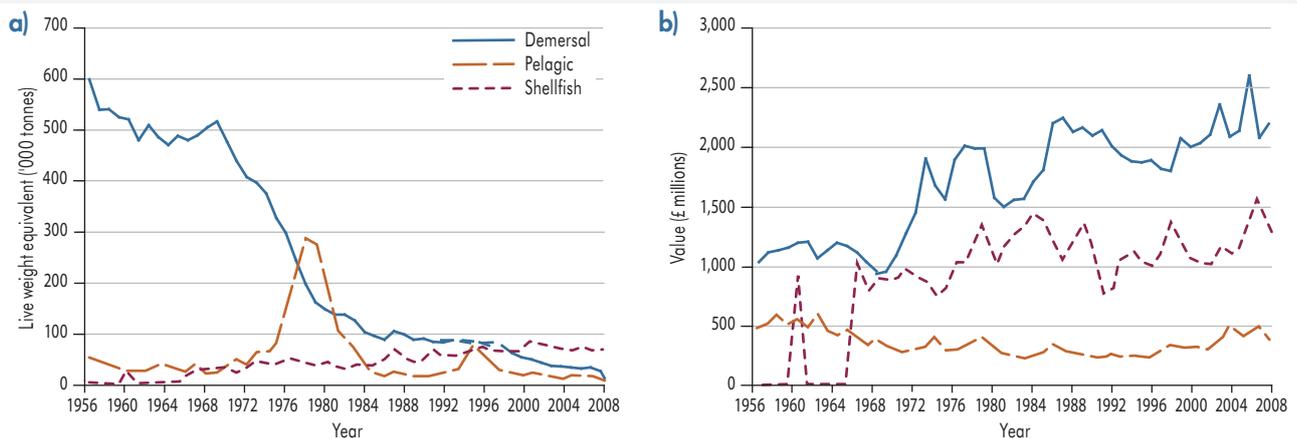


Figure 17.17 Landings into England and Wales by UK and foreign vessels from 1956 to 2008 by a) live weight equivalent and b) value of three categories of landings: demersal, pelagic and shellfish. Values were adjusted to 2008 prices using the Retail Price Index. Source: extracted from Marine Management Organisation (MMO 2010).

species, but also the ease by which boats fitted for demersal trawling can be converted to activities such as scallop dredging. In addition, most shellfish species are not under quota restrictions.

Wild fish capture for food generates employment both for fishermen and in secondary services associated with fishing (MMO 2010). In 1960 there were 12,712 regular fishermen; by 2009 this number had fallen to 4,768 (Figure 17.18). In 2009 the English fishing fleet consisted of 3,169 vessels with the number of small vessels greatly exceeding that of larger vessels, although the catching power of the latter fleet (indicated by engine power) is considerably greater (Table 17.12).

Much aquaculture data is reported for England and Wales and cannot be disaggregated: in 2008 there were 518 registered fish and shellfish farms, of which 197 were trout and other finfish farms (marine and freshwater fish are not separated) and 128 shellfish farms; the remainder were coarse fish farms (Shellfish News reports, CEFAS 2008, 2009). Shellfish farm production has been gradually

rising (Figure 12.11, Section 12.3.1.1). A total of 3,905 tonnes of shellfish worth £4.5 million were produced by English aquaculture in 2007, comprising mainly mussels with small quantities of Pacific oyster (*Crassostrea gigas*) and native oyster (*Ostrea edulis*), and very small quantities of clam and cockle (Saunders 2010).

Shellfish aquaculture is often considered relatively sustainable, especially where spat collection results as a consequence of natural settlement (as is the case of many mussel farms) and where harvesting is based on hand collection or raking. Where bottom cultivation is used and harvesting (including spat collection) is undertaken by dredging (e.g. for mussels and oysters) there are concerns regarding the physical damage and environmental impact harvesting could cause. Other concerns over shellfish aquaculture include localised depletion of phytoplankton where overstocking has occurred and the introduction of non-indigenous species.

Large amounts of bait worms are dug from intertidal sediments each year, both commercially and for personal use, to support recreational sea angling, but little of this activity is recorded or declared.

Cultural services. As an island nation, the English population has a strong affinity for the sea, and much of our heritage is linked to maritime activities. Reminders of this maritime heritage are still in existence today (e.g. fishing villages, fish and chips, the navy, lighthouses, and museums and literature on smuggling and sea adventures). In a UK-wide poll undertaken by The Wildlife Trusts in 2007, 78% of respondents stated that the UK's seas are important to their personal quality of life (The Wildlife Trusts 2007).

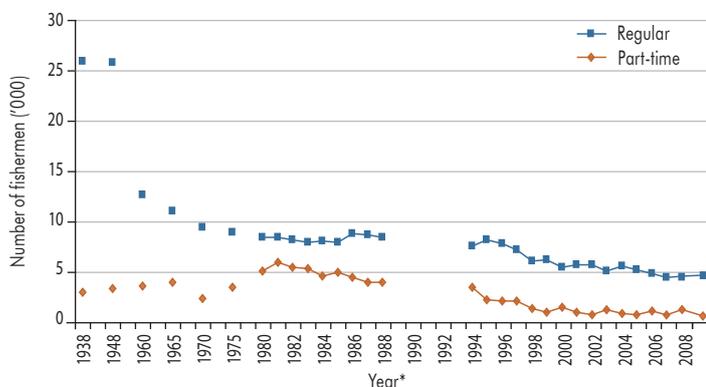


Figure 17.18 Changes in total number of regular and part-time fishermen in England. Data not collected from 1989 to 1993. From 1966 these figures exclude 'hobby' fishermen, i.e. fishermen who do not fish commercially. Source: data extracted from MMO (2010) *1987 includes 1986 figures for Newlyn and Plymouth.

Table 17.12 Fleet capacity in England in 2009. Source: data extracted from MMO (2010).

Length of vessel	Number of vessels	Capacity (gross tonnage)	Engine power (kW)
Greater than 10 m	570	53,253	169,952
Less than 10 m	2,599	9,142	141,759

Even though much of the marine environment is hidden from view, it has been a source of artistic inspiration over the centuries, leading to a wealth of literature, works of art and schools of artists (e.g. The Newlyn and St. Ives Schools), as well as underwater film documentaries and children's cartoons (e.g. Popeye, Captain Pugwash, Spongebob Square Pants).

The marine environment presents a number of educational opportunities; school trips to the beach and/or aquaria are common, particularly in coastal communities, but people living some distance away from the coast are also able to learn about marine life through visits to aquaria and sea-life centres throughout England (e.g. Birmingham and Alton Towers). There is significant investment in marine research in both the public and private sectors, but the proportion of research that is focused entirely on UK seas, let alone the English component, is unknown.

Advancements in understanding the marine environment have led to a corresponding increase in interest amongst the public for underwater heritage resources (Kaoru & Hoagland 1994) and wider marine issues. To date, no assessment of the heritage value of the marine environment in UK or English waters has been undertaken, but a growing number of marine sites are receiving protected status because of their historical importance.

Currently protection of the marine environment falls short of that on land. For example, only two Special Protection Areas designated under the Birds Directive (1979) are entirely marine (the Outer Thames Estuary and Liverpool Bay). Although there are a small number of ASSIs/SSSIs below the low water mark, for example The Wash and Morecombe Bay, many coastal ASSIs/SSSIs do not offer protection to subtidal marine life (JNCC 2010a). The sea around Lundy Island was designated as England's first, and currently only, Marine Conservation Zone in January 2010, which includes a no-take zone of 3.3 km² in which all fishing is prohibited.

Not all protected areas are protected by statutory designations. The Royal Society for the Protection of Birds (RSPB), for example, owns a number of reserves around the coast which provide protection for important seabird colonies (e.g. Hayle estuary, Arne, Bempton Cliffs); the Wildlife Trusts also own a number of coastal nature reserves. Neither of these organisations has dedicated marine reserves, however, largely because of the inability to purchase the seabed and designate it as a reserve. Protection within the marine environment around the UK will see dramatic change in the near future, as the Marine and Coastal Access Act (2009) requires the designation by 2012 of an ecologically coherent network of Marine Conservation Zones. More details of the legislative changes affecting the UK are given in Section 12.5.1.

The most obvious cultural benefit that society receives from the marine environment is the opportunity for leisure and recreational activities. The England Leisure Visits 2005 Survey (Natural England 2005b) reports 0.07 billion leisure visits (trips occurring within one day including, for example, dog walking but also including tourism visits of more than 3 hours) to the coast during that year: approximately 2% of all England leisure visits. In 2005, 37% of the adult population

had visited the seaside coast and 62% had visited a seaside city or town. Expenditure at the coast was £1.4 billion and in seaside cities and towns was £4.7 billion, which comprised approximately 2% and 5% respectively of total spend on leisure trips. The most popular activities were walking and visiting the beach (**Table 17.13**). Natural England, Defra and the Forestry Commission are undertaking a new survey called Monitor of Engagement with the Natural Environment (MENE) to provide baseline and trend data on how people use the natural environment in England.

It is difficult to account for the contribution of the marine environment to these figures as there is little quantitative documentation, but anecdotal evidence suggests that wildlife-watching, including rockpooling, is an increasingly popular activity at the coast (Crabtree *et al.* 2005).

Recreational sea angling, however, is a popular activity and is comparatively well quantified in terms of number of participants, their expenditure and the jobs associated with this leisure industry. In 2003, 1.1 million households in England and Wales contained one or more members who partook in sea angling and the mean number of sea angling days per year was 11.3 (Defra figures in Crabtree *et al.* 2005). The industry was estimated to have a value of £538 million per year and to support 18,889 jobs (FTE). Estimates from the South West alone (Invest in Fish South West 2005) suggest that 240,000 residents participate in sea angling, plus an additional 750,000 angling days by visitors. The value of the industry is estimated at £165 million and supports more than 3,000 jobs. All of these studies found that the majority of anglers fished within 80 km of their homes. Visiting anglers make a considerable contribution to the total angling

Table 17.13 Main leisure activities. Source: reproduced from Natural England (2006).

Leisure activities	Seaside coast (%)	Seaside town/city (%)
Walk, ramble	33	19
Visit beach, sunbathe, paddle in the sea	23	12
Visit friends, relatives at their home	8	9
To eat or drink out	7	17
Hobby or special interest	4	10
Take part in sports or active pursuits – indoor, outdoor field, water	4	7
Drive, sightsee, picnic, pleasure boating	4	4
To go shopping (not food and not regular)	3	8
Visit leisure attraction, place of interest, special event/exhibition	3	2
For entertainment (e.g. cinema, theatre, club)	2	5
To take part in informal sports, games, relaxation and well-being	2	3
Swimming	2	2
Cycling, mountain biking	2	-
Visit park or garden	1	1
Watching live sport or attending a live event (not on TV)	1	1

expenditure. Crabtree *et al.* (2005) estimated this as £192 million per year or 35% of the total for 2002, which equates to 1% of all tourism spend in 2002 for England and Wales (UKTS 2002).

Supporting services. The essential supporting services, such as nutrient cycling and provision of biologically mediated habitats, are not well quantified for UK or English waters and are, therefore, described in more detail in Section 12.3.4. Marine microbial organisms in the water column and seabed habitats play a key role in cycling storage and supply of nutrients, such as carbon, nitrogen, phosphorus, silicon and iron, which are essential for the maintenance, growth and production of marine organisms. This supporting service underpins all of the other marine ecosystem services and benefits they provide. Microbial processing of nutrients in the sediment is mediated by the activity of invertebrates that disturb and irrigate the sediment.

Many marine organisms provide structured space or living habitat for other organisms through their normal growth; for example, reef-forming invertebrates, meadow-forming seagrass beds, marine algae forests and networks of burrows and holes in the sediment (Beaumont *et al.* 2007). These biogenic marine habitats can provide essential feeding, breeding and nursery space for other plants and animals, which can be particularly important for the continued recruitment of commercial and/or subsistence fish and shellfish species. Such habitat can provide a refuge for plants and animals, including surfaces for feeding and hiding places from predators. Living habitat plays a critical role in species interactions and regulation of population dynamics, and is a prerequisite for the provision of many goods and services. Specific examples of living habitat include kelp and seagrass beds, maerl grounds (calcified red seaweed), mussel patches and coldwater coral reefs. These living habitats, especially reefs, are vulnerable to damage from seabed fishing with trawl nets and dredging fishing gears. Shallow water and intertidal living habitats are vulnerable to invasive macroalgae species (Milneur *et al.* 2008) as well as smothering by opportunistic algae such as *Ulva* species, particularly in nutrient-enriched areas (Fletcher 1996). At a more local level they can be damaged by boat anchoring, propeller scarring and channel dredging.

Wild species. Marine flagship species occurring in English waters are mainly the large megafauna, such as turtles, seals and cetaceans (whales, dolphins and porpoises), as well as smaller species such as seabirds and seahorses. Flagship habitats include saltmarsh, seagrass beds and maerl beds (Hiscock *et al.* 2005). Some smaller invertebrate species can also be flagship species. For example, closure to benthic trawls and scallop dredging in an area of 60 km² of Lyme Bay in south-west England in 2008 was prompted by the need to protect marine biodiversity, including the fragile reefs of the pink sea fan (*Eunicella verrucosa*; Rees *et al.* 2010).

The significance of flagship species is that their importance goes beyond their ecological function, being related primarily to their appeal to the wider public. For example, relatively small populations (in some cases fewer than 10 individuals) of the harbour seal on the south and west coasts of England may not have a huge ecological impact, yet the populations are well known to locals and

popular with tourists, thus providing a significant boost to the local economy.

On a larger scale, the economic benefits of well-established populations of flagship species are derived from a wide range of activities linked to their presence, including diving and snorkelling, rockpooling, boat trips (i.e. whale- and dolphin-watching, shark-spotting and visits to seal colonies) and aquarium visits. Seabirds are also hugely popular and a major factor in encouraging wildlife tourism. Spectacular seabird 'cities' and particular species such as the Atlantic puffin (*Fratercula arctica*) draw many visitors, providing an important source of income for local economies (RSPB 2010a, b; Mitchell 2010).

17.5 Ecosystem Services

17.5.1 Supporting Services

Supporting services provide the underpinnings of all other ecosystem services through the functions of soil formation, primary production, decomposition and nutrient and water cycling (EASAC 2009). The provision of supporting services is dependent on a myriad of complex biological, chemical and physical processes and is further influenced by anthropogenic environmental pressures.

The timescales at which supporting services operate range from short-term (days to months in the case of decomposition) to long-term (decades to millennia in the case of soil formation). Therefore, the repercussions of anthropogenic environmental pressures might not be immediately observed in the supporting system of interest. Since supporting services provide the foundational processes that underpin other ecosystem services, human-induced pressures might not be readily apparent in the supporting services themselves; rather, they might manifest themselves in changes to linked provisioning or regulating services.

Despite the above, our understanding of the mechanisms by which ecological interactions influence ecosystem processes and the delivery of supporting services is limited, as is our knowledge of their contribution relative to abiotic factors as drivers of supporting services at the landscape scale (Bardgett & Wardle 2010).

17.5.1.1 Soil formation

Measured and modelled rates of soil formation vary widely, but typically are in the range of 0.04–0.08 mm/yr or less than 1 cm per century (EASAC 2009). However, considerable uncertainty exists around the details of soil formation processes. Soil erosion is a natural process that is commonly exacerbated by land use. Wilkinson and McElroy (2007) estimated the global mean natural erosion rate over the past 542 million years to be 0.4 t/ha/yr, with a peak of 1.4 t/ha/yr in the Tertiary period. Rates of soil loss can be much higher than soil formation rates. Estimates of erosion rates in England are scant, however, Verheijen *et al.* (2009) cite erosion rates of 0.02 to 1.27 t/ha/yr for non-peaty soils. Agricultural practices have the potential to significantly

increase erosion rates; for example, soil loss due to tillage erosion can be as high as 10 t/ha/yr (Verheijen *et al.* 2009).

A wide range of soil-forming factors interacting over various spatial and temporal scales has resulted in the diversity of soil types in England (Figure 13.2, Section 13.2.1). Luvisols, cambisols and gleysols dominate much of England due to its lowland topography. These mineral soils with lower organic carbon content support most of England's agricultural production. The less extensive upland soils of England have surface horizons rich in organic matter and thus harbour a disproportionately large part of the country's carbon.

Data on the status and trends of England's soils have received little attention, however, three issues are particularly relevant: 1) the loss of soil to urbanisation, 2) the impact of agricultural activity on soil and 3) loss of peat soils (histosols), due to their importance as a carbon sink. The net rate of conversion of agricultural land to built development is estimated at 5,000 ha/yr (DCLG no date), a practice which destroys or seals the soil, effectively halting most soil formation. A range of agricultural activities influence soil formation, including ploughing, fertilising, draining and grazing, which can cumulatively change the properties of soil over decadal timescales. This is particularly the case where it results in nutrient enrichment and related reductions of soil carbon. Peatland carbon stocks in England have only been estimated to 1 m depth, giving 296 Mt C (Bradley *et al.* 2005), which places England below Scotland and Wales in terms of total carbon stocks. The current rate of carbon fixation for English peatland is difficult to determine, but is likely between 0.27 Mt C/yr and 0.7 Mt C/yr for peatlands in good condition (Cannell *et al.* 1999). Losses due to land management practices (draining, agriculture and peat cutting) have been estimated at 1 Mt C/yr and fluvial losses at 1 Mt C/yr (Cannell *et al.* 1999).

17.5.1.2 Nutrient cycling

The severity of changes in nutrient cycling varies, but the predominant problems associated with semi-natural terrestrial, freshwater and marine habitats relate to nutrient enrichment. Increased nutrient levels can influence the composition and diversity of plant communities and soil biota, with consequences for a range of ecosystem services via mechanisms that are poorly understood. Whilst nutrient cycling data for the various UK habitats are sparse, the Countryside Survey (2009), the UK Environmental Change Network (ECN) and RoTAP (2011) have provided information on key trends. Nitrogen and phosphorus are generally the most significant nutrients limiting ecosystem productivity. However, high levels of anthropogenic enhancement of these two elements can result in significant disruption of ecosystem processes, with consequent effects on a range of ecosystem services.

Nitrogen: Nitrogen mineralisation occurs as soil microbes break down organic nitrogen and convert it into inorganic forms. It is a critical process in many habitats as it determines the availability of nitrogen for primary production. Significant differences in nitrogen amounts and rates of mineralisation in topsoils (0–15 cm) of England's terrestrial habitats relate generally to the total amount of organic matter present and the intensity of agricultural improvement (Emmett *et al.* 2010; Figure 13.6, Section 13.3.1.1).

Atmospheric nitrogen deposition has significantly enriched England's habitats since 1960 and declines in nitrogen deposition have not been observed during the period 1984–2005, despite declines in oxidised (50%) and reduced (24%) nitrogen emissions (RoTAP 2011). United Kingdom NEA Broad Habitats are, therefore, still subject to nitrogen deposition and remain at risk of damage. Most of England's habitats are nitrogen limited and it is possible that a moderate proportion of anthropogenic nitrogen will be sequestered in soil organic matter (Phoenix *et al.* 2004), thereby moderating the negative impacts of nitrogen deposition (Aber *et al.* 1989). Data from the Environmental Change Network between 1993 and 2007 (Morecroft *et al.* 2009) suggest that nitrogen is being retained within the terrestrial system or lost as nitrogen gas. Findings of the Countryside Survey support the idea that nitrogen enrichment has increased plant production leading to carbon fixation and its transfer to soil (Emmett *et al.* 2010).

Of importance to aquatic nitrogen cycling is the trend of declining nitrate concentrations in rivers over the last 10 years. In 2000, most river segments in the Midlands and the East of England exceeded 30 mg nitrate per litre (this limit roughly corresponds with a 95 percentile limit of 50 mg/l used in the EC Nitrates Directive and the EC Drinking Water Directive). The proportion of river segments exceeding this threshold has declined since 2000 from 90% to 60% and from 50% to 40% in the Anglian and Midlands regions respectively (Figure 13.7 (a), Section 13.3.1.1). The proportion of rivers in the West of England exceeding 30 mg nitrate per litre is relatively low (10–20%) and has remained constant (Environment Agency 2008). The Irish Sea has been found to contain raised levels of anthropogenic nitrogen (Gowen *et al.* 2008) with a trend of increasing nitrate concentrations from 1960 to 1980, followed by a decline in the 1990s (Evans *et al.* 2003).

Phosphorus: Phosphorus has been reported to be accumulating globally at rates between three and 10 times higher than during the industrial era due largely to agricultural activity (Lavelle *et al.* 2005). However, the UK Countryside Survey (Emmett *et al.* 2010) reported that the amount of soil phosphorus available to plants has decreased from 1998 to 2007. The average decline across all English habitats is about 16%, with some habitats exhibiting more pronounced declines (e.g. heathland and Acid Grassland) than others (e.g. agricultural habitats). The cause of this general decline has been linked to increasing prices of phosphorus fertiliser and so decreased usage (Cordell *et al.* 2009) and the steady decline in livestock numbers (Defra 2009a). Despite reductions in fertiliser use and livestock numbers, the Countryside Survey (2009) was cautious about attributing the decline in soil phosphorus to agriculture.

Environment Agency (2008) data suggest a similar trend between 1990 and 2008 of decreasing phosphate concentrations in rivers in arable regions of England and Wales (Figure 13.7 (b), Section 13.3.1.1). The observed declines are consistent with reductions in soils, yet it is unclear whether the two are causally linked. Other sources of phosphorus are significant, for example the water industry (White & Hammond 2009). Data from the Countryside Survey have identified a clear link between changes in riparian vegetation, lower phosphorus concentrations, and an improvement in

headwater quality (Dunbar *et al.* 2010). In the Irish Sea there is evidence of increased phosphate concentrations during the period 1960–1980, also followed by a decline in the 1990s that paralleled observed trends in rivers that feed into the Irish Sea (Evans *et al.* 2003).

Soil acidity and trace elements: The Countryside Survey revealed that the mean pH of surface soils increased in habitats across England from 1979 to 2007 (Countryside Survey 2009; Emmett *et al.* 2010). Similar results have been observed by various soil monitoring programmes (Morecroft *et al.* 2009; Kirk *et al.* 2010; RoTAP 2011). Significant declines in soil solution sulphate concentrations have also been detected in surface soils (i.e. in the surface A horizon) of some ECN upland sites, although no trends were apparent for most sites. Despite the lack of evidence for declining soil sulphate concentrations within the ECN data, widespread increases in soil pH have been associated with reductions in habitats exceeding critical loads of acidity, which fell from 71% to 58% from 1996 to 2006, a trend that is projected to continue (RoTAP 2011). These trends seem likely to be related to the increased rainfall pH as a result of emission controls in the mid-1970s (Morecroft *et al.* 2009).

Soil concentrations of trace elements are related to parent material and also to soil pH. Most trace elements become more available to plants and microbes in neutral or slightly acid soils, although others (e.g. molybdenum) become more available in alkaline soils. In England, boron, copper and zinc can be deficient within particular soil types. With acid sulphate deposition, sulphur nutrition in UK crops was adequate. However, the recent decline in sulphur deposition, and the development of high yielding crop varieties, has meant that it is now necessary to add sulphur fertiliser to UK soils (Zhao *et al.* 2002). Evidence from the British Survey of Fertiliser Practice reports (Defra 2009b) indicate that use of sulphur fertiliser has increased in England from 1998 to 2009 for cereal crops and oilseed rape, but has remained largely static for grassland management.

17.5.1.3 The water cycle

The water cycle is most appropriately considered with respect to major water fluxes (rainfall, evapotranspiration,

river-flow) and major water storages (soil, groundwater, lakes) that combine to determine the availability of water in time and space. Pathways that move water between the major storages are also important, as is water quality, because poor chemical and/or microbiological quality can render the water effectively unavailable for supporting some services.

Spatial variation in average rainfall across England is high: annual totals can exceed 3,000 mm in parts of the North West and South West, whilst totals in the driest parts of lowland England can be an order of magnitude less (Section 17.2.2).

National rainfall assessments for England and Wales are available back to 1766; however, no significant trend is apparent (Alexander & Jones 2001; **Figure 17.19**).

The UK Met Office Rainfall and Evaporation Calculation System (MORECS) provides assessments of potential and actual evaporative losses for 40 km squares throughout Great Britain and indicates that over 40% of rainfall is lost to evaporation and in the driest parts of the English Lowlands this rises to nearly 80% (Hough & Jones 1997).

River flows integrate precipitation and evaporation processes. Measured runoff represents the most appropriate variable upon which to assess overall water resources; however, it must be noted that river flows in England are profoundly affected by abstractions and river regulation. Trend analysis of annual runoff over the period 1973–2002 at the UK Benchmark Catchments indicates predominantly non-significant increases in runoff (Hannaford & Marsh 2008) for most monitored catchments in England, with a few exceptions in the South West and North West, although the recent past has been characterised by notable year-on-year variability (Hannaford & Marsh 2006). Low flows (30-day minima) at the Benchmark Catchments over the period 1973–2002 indicate little evidence of decrease in low flows across the UK (Hannaford & Marsh 2006).

Groundwater storage provides a significant component of water resources used in England and aquifers are generally replenished by winter rainfall. The longest continuous record of groundwater level in the England dates back to 1838 at Chilgrove in West Sussex. A drought index, representing cumulative departures from mean monthly levels, shows no consistent trends over this period, but reveals distinct patterns of change or quiescence at decadal scales. Trends at decadal timescales most often result from changes in historical abstraction.

Water quality is considered in detail under regulating services (Chapter 14, Section 9); however, a few key trends are mentioned here. One important aspect of water quality with respect to the supporting services (i.e. water cycle and nutrient cycling) involves the trophic status and biodiversity of waters. As noted above, two key chemical elements affecting the trophic status are nitrogen and phosphorus. Evidence of long-term trends in river and lake phosphorus concentrations from Dorset generally indicate a decline in recent years, mainly as a result of policy initiatives to reduce phosphorus fluxes from sewage outfalls in response to the EU Urban Wastewater Directive (Bowes *et al.* 2009). There is also widespread evidence of ongoing recovery of UK freshwaters from the effects of acidification, with reductions

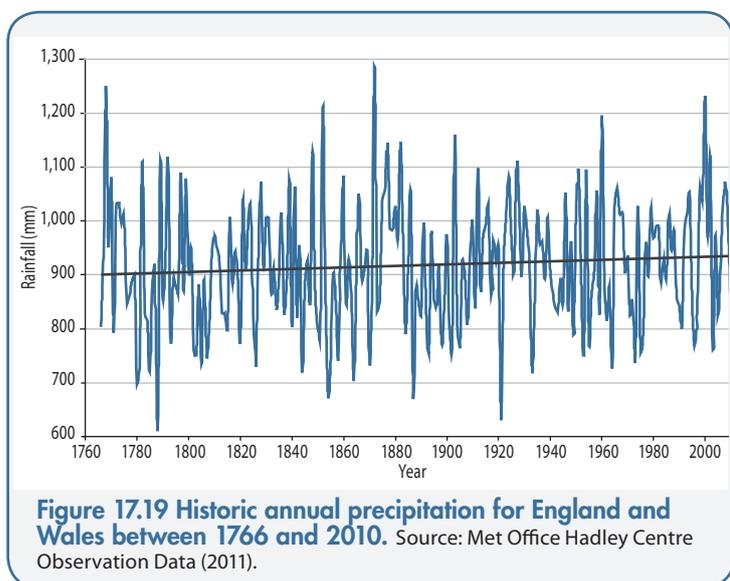


Figure 17.19 Historic annual precipitation for England and Wales between 1766 and 2010. Source: Met Office Hadley Centre Observation Data (2011).

in acidity and labile aluminium (RoTAP 2009). For example, trends in rainfall acidity across the UK show significant declines over the monitoring period and for most of the country, with more polluted regions such as eastern England improving dramatically.

17.5.1.4 Primary production

Primary production typically refers to the fixation of atmospheric and/or aquatic carbon dioxide. Only a proportion of fixed carbon dioxide is retained, whilst the rest is lost through respiration. The overall amount of organic carbon fixed is described as gross primary production (GPP), whilst the amount retained after respiration is defined as net primary production (NPP). Net primary production provides the foundation of food and timber harvesting in managed systems, food webs in semi-natural and natural ecosystems, and underpins climate regulation by removing carbon dioxide from the atmosphere.

Primary production data in England are limited as direct measurements are only possible at local scales. Currently there are significant limitations to estimates of fixed carbon below-ground in terrestrial systems, the magnitude of organic and inorganic carbon fluxes to surface waters and the response functions to different climate, soil, ecological and management variables. These issues limit our ability to upscale primary production estimates in both time and space.

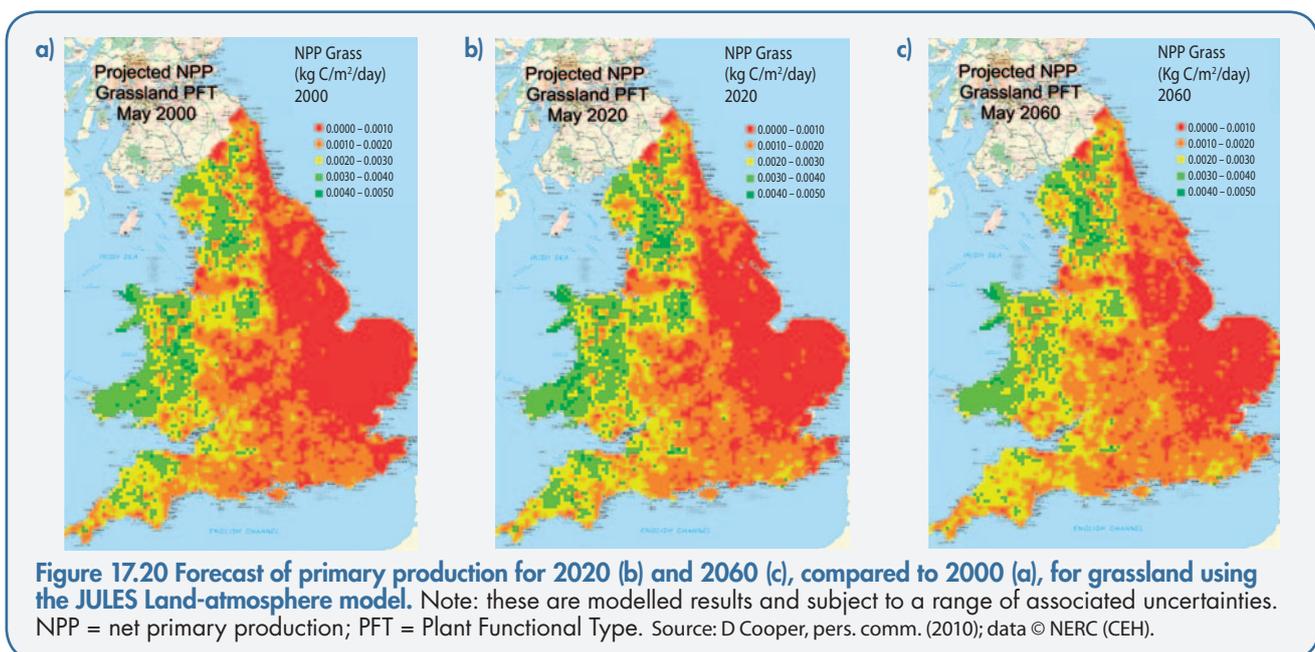
Various approaches have been employed to bypass these issues and provide estimates of primary production at a range of scales from plot to catchment, to regional and national levels. These include the use of net ecosystem exchange of carbon dioxide (NEE), net ecosystem productivity (NEP), plant standing biomass or biomass increments, crop, herbage and timber yields (e.g. Jenkinson *et al.* 1994), carbon accumulation rates and remotely sensed absorption by plants and algae. Each approach involves many assumptions and various limitations (Lovett *et al.* 2006). Modelling approaches that incorporate field and remotely collected data provide a valuable tool to upscale

and integrate measurements, and can also be used to forecast changes under different climate, pollution and management scenarios. For example, the JULES model (The Joint UK Land Environment Simulator) is a community tool that can produce a range of outputs of which one is primary production (**Figure 17.20**). However, a great deal of testing and development of the JULES model is required before its outputs can be used with any confidence.

In forests, annual stem increment data plus litter fall, and assumptions for below-ground root production, are often used in combination with remotely sensed plant biomass data to derive net primary production values. Current forestry production rates in the UK have recently been estimated to be responsible for removing 15 Mt carbon dioxide from the atmosphere every year with a total stock of carbon of 790 Mt C in trees and forest soils (Read *et al.* 2009; Chapter 8; Chapter 17.4.4; Chapter 12.4.1).

Plymouth Marine Laboratory (PML) produce estimates of net primary production for the seas around the UK. These models do not account for the effects of suspended particulate matter (notably in the Thames estuary, southern North Sea and Bristol Channel) nor for coloured dissolved organic matter (i.e. the optically measurable component of the dissolved organic matter in water) from riverine sources (such as in Liverpool Bay). In these areas, primary production is likely to be overestimated. Work at PML is aiming to improve these coastal estimates.

In freshwaters, primary production is estimated from the surrogate phytoplankton chlorophyll *a* concentration. Primary productivity in most freshwaters systems was thought to be largely phosphorus limited, but there is now strong evidence that nitrogen limitation and nitrogen and phosphorus co-limitation is widespread, especially in UK upland environments (Maberly *et al.* 2002). Long-term historical trends of 36 years are available for four lakes in the Lake District and there is some evidence of suppression of chlorophyll *a* concentration with higher rainfall in small lakes with shorter residence times, but on the whole there



was no overall trend in chlorophyll *a* concentrations (George *et al.* 2004).

17.5.2 Regulating Services

Regulating services provide benefits obtained from ecosystems' regulation of ecological processes and are the largest group within the UK NEA typology. They can act as final ecosystem services or contribute significantly to final ecosystem services, whilst others are primary/intermediate ecosystem services. The regulating services include those ecological processes that influence water quality and quantity, pollination, climate, hazard severity and frequency, soil quality, noise, air quality and diseases and pests. Apart from climate regulation, direct markets for most regulating services do not exist, however methods are available to estimate their economic value to human societies.

17.5.2.1 Climate regulation

Ecosystems and their interactions with the biosphere regulate climate by controlling the fluxes of greenhouse gases (i.e. carbon dioxide, methane and nitrous oxide), aerosols, heat/energy, moisture and momentum (e.g. Bonan 2008). Ecosystems also regulate microclimate more directly by moderating temperature through the provision of shade and shelter. Photosynthesis and evapotranspiration are essential ecosystem processes that regulate carbon dioxide and water vapour, respectively, with evapotranspiration also having local cooling effects. Ecosystems also influence land surface albedo values (the proportion of incoming solar radiation that is reflected from the Earth's surface); a change in albedo can have a cooling or heating effect on the surface climate and may further affect precipitation.

Whilst it is estimated that almost 10 billion tonnes of carbon is stored in UK soils, particularly organic soils (Smith *et al.* 2007), the majority lies outside of England (Figure 14.1, Section 14.2.1). Soil carbon densities are greatest under semi-natural habitats, especially peatlands, and woodlands. Soil carbon densities are relatively low under agricultural land and Urban habitats that dominate much of England. Soil carbon densities can be high in Coastal Margins habitats, which are more abundant in England than peatlands. Also of relevance to England are the considerable carbon stores in the marine habitats, but there are few reliable estimates from the literature.

Because the cropland and settlement land use categories are net sources of greenhouse gases, England is a net ecological source of carbon dioxide, although this diminished between 1990 and 2007, whereas the other countries in the UK are net sinks (Jackson *et al.* 2009a, 2009b). Nitrous oxide emissions from agricultural soils arise from nitrogen application, leaching of fertiliser and manure to ground and surface water, ploughing in of crop residues, atmospheric deposition of ammonia and nitrogen oxides, cultivation of highly organic soils and biological fixation in improved grass. These sources are the largest contributors to nitrous oxide emissions across the UK and contribute 64% of nitrous oxide emissions in England. Enclosed Farmland has the greatest nitrous oxide emissions whilst Woodlands and Mountains, Moorlands and Heaths contribute less than 5% to the total soil emissions (Sozanska *et al.* 2002).

The status and trends in climate regulation by habitat are summarised in Table 14.3, Section 14.2.1.

17.5.2.2 Hazard regulating services

Maintenance of the integrity of land surfaces. Rates of geomorphic change in England are modest and the integrity of land surfaces is rarely threatened; however, there are two significant exceptions. First, the beaches, dunes and saltmarshes of the coast are wasting assets whose capacity to protect hinterlands is declining, particularly in the south and east (Pye & French 1993). It is estimated that 17% of the UK coast is experiencing erosion. Thirty per cent of the eroding coastline occurs in England (Masselink & Russell 2008) and represents a significant loss of important habitat, including estuarine saltmarsh and dune systems, particularly in the south. The second threat occurs largely in uplands, and comprises landslides, debris flows and peat-slides, although much of England is not characterised by the steep slopes required for major landslides (Chapter 14).

Maintenance of soil cover. In the absence of human activity, most of the land surface would be covered by vegetation, resulting in minimal erosional threats to soil cover and therefore low suspended sediment inputs to rivers. Unfortunately, this is not the case in England. English uplands are commonly assessed as being in poor condition, with large areas of bare organic soils (McHugh *et al.* 2002), gullying in peatlands (Evans & Warburton 2006) and high sediment export (Holden *et al.* 2007). Whilst measures have been undertaken to improve upland condition (e.g. reseeding, blocking artificial drains, reduced grazing) their effectiveness is uncertain and their full effects may take years to be realised (Holden *et al.* 2007; Orr *et al.* 2008). In uplands, semi-natural grassland and coastal sand dunes there has been evidence of an increased exposure of subsoil due to footpath erosion and high grazing density.

On arable land, water, wind and tillage erosion have accelerated over the last half-century. However, quantification of these processes at regional or national scale remains a challenge. Wind erosion has been observed to be more common, especially where soils with a high organic content are subject to cultivation in areas with a high desiccation potential (e.g. East Anglia). Advances in the measurement of soil redistribution have revealed that tillage erosion is commonly of equal or higher magnitude than water erosion. This is of particular significance since considerable areas of agricultural land in England occur on modestly sloping lands. Tillage erosion is, therefore, resulting in the development of a heterogeneous soilscape on sloping agricultural land (Quine & Zhang 2002; Quine & Van Oost 2007).

Water retention, storage and delayed release. Landscape changes that promote water erosion, notably the reduction of vegetation cover, simultaneously promote lower water retention and more rapid water release, which increases the likelihood of flooding events. Furthermore, increases in soil compaction and associated reductions in soil infiltration on grasslands have been linked to high grazing intensity. In the uplands, changes in flood frequency have been attributed to the creation of rapid flow pathways such as grips to drain moorland (Longfield & Macklin 1999)

in Yorkshire. Changes in flood frequency and magnitude have been analysed with respect to climate change, but a clear link has not been identified (Wilby *et al.* 2008). However, land management measures which reduce flood risk seem prudent against such a future scenario given current scientific uncertainties, yet these measures are often expensive and their effectiveness is uncertain.

Climate change trends. Climate change might lead to an intensification of the hydrological cycle and an increase in floods in many parts of the world. In England, increased winter precipitation could increase the risks of flooding events (Hulme & Dessai 2008). Considerable uncertainties still exist in projections of extreme events. Therefore, a greater emphasis must be placed on the climate models to be fit-for-purposes with particular regard to changes in the frequency and severity of extreme events.

17.5.2.3 Disease/pest regulation

The role of biodiversity in regulating diseases and pests.

England has relatively few agricultural insect pests, the main group being aphids. Approximately 250 aphid species feed on agricultural and horticultural crops, causing significant damage and transmitting viruses including Barley Yellow Dwarf Virus (BYDV). Natural enemies, such as predators, parasitoids and pathogens, are key regulators of aphids and their exclusion can result in reduced crop yields. Other research indicates that natural enemy species diversity and abundance, habitat diversity and maintenance of arable field margins are all commonly associated with reduced pest and disease incidence. Whilst the evidence base from England is sparse, agri-environment schemes may have improved species and habitat diversity in some regions and thereby increased the regulation of pests and diseases.

Specific components of biodiversity may be responsible for the regulation of disease. For example, Lyme borreliosis (Lyme Disease) is caused by the bacterium *Borrelia burgdorferia*. The principal vector in the UK is the sheep tick (*Ixodes ricinus*), which also feeds on a range of wild vertebrates. The incidence of Lyme Disease has increased dramatically over the last decade. Deer numbers have been positively associated with the abundance of the tick vector, as deer are key reproductive hosts for ticks (Scharlemann *et al.* 2008).

Specific components of biodiversity may also act as a reservoir of disease, so providing 'an ecosystem disservice'. Bovine Tuberculosis (bTB) is caused by *Mycobacterium bovis* and has considerable economic and human health consequences. Infection rates have risen since the mid-1980s (Krebs *et al.* 1997) with human-to-human transmission being reported relatively recently (Evans *et al.* 2007). It is rare or absent in many cattle-raising areas where there are no major wildlife reservoirs of disease (Krebs *et al.* 1997), however, the European badger (*Meles meles*) has been implicated as an important wildlife reservoir (Woodroffe *et al.* 2006), notably in the west of England where badger numbers have been increasing (Bourne *et al.* 2005). The distribution of the incidence in cattle now encompasses most of the south-west and mid-west of England.

The role of anthropogenic intervention in suppressing or regulating pests and diseases. The

primary forms of anthropogenic intervention that influence and regulate pests and diseases include the increased application of herbicides and changes in agricultural land use. The composition of arable weed flora in recent decades has been increasingly dominated by grass species, probably as a result of the increasing prevalence of cereal crops that leave fewer opportunities in the cropping cycle for the control of grasses. In addition, the evolution of resistance to certain chemical herbicides has tended to increase the predominance of certain grass weeds. Moreover, during the last quarter century, the number of herbicide applications has increased, and the active ingredients applied act upon a broader range of target species (Marshall *et al.* 2001, 2003). Consequently most of the innocuous weed species, including those supporting the arable food web, have declined (Hawes *et al.* 2009).

Some pathogens have been successfully suppressed through anthropogenic intervention. Bluetongue Virus (BTV) is a midge-borne virus of livestock that has emerged into southern Europe in the last century. Transmission by European midge vectors has subsequently facilitated the establishment of the disease in cooler and wetter areas in Europe. After first being detected in September 2007 in Suffolk, BTV went on to affect 137 premises that year (OIE 2009), but was successfully controlled by the use of inactivated vaccines.

Possible regulatory breakdown when novel pathogens invade the UK.

As with many invasive species, newly introduced pathogens can spread rapidly, which implies that the usual regulatory mechanisms have broken down, a risk which may be increased where components of biodiversity which provide regulation have been lost. The prime examples include 'Dutch Elm Disease' (*Ophiostoma novo-ulmi*) that has been responsible for killing some 30–50 million elms in the UK, and *Phytophthora ramorum* that infects a broad range of plant species, including oaks, causing 'sudden oak death'. The *Phytophthora* pathogen was first detected in the UK in 2002; since then it has increased in north and south-west England. Whilst phytosanitary measures may have contained its spread between nurseries, its spread to adjacent semi-natural habitats remains a significant concern (Xu *et al.* 2009). *Phytophthora kernoviae* has more recently been detected on whinberry/bilberry (*Vaccinium myrtillus*), and other heathland species are known to be susceptible, leading to the suggestion that this is a potential threat for UK heathland (Beales *et al.* 2009). Since the 1990s a stream of such invasive fungal plant pathogens have been entering the UK, which are potentially damaging to trees, natural ecosystems and horticulture (Brasier 2008).

17.5.2.4 Pollination

Pollination services are provided by domestic honeybees and a wide range of wild insects including bumblebees and other bees (approximately 250 species), hoverflies (approximately 250 species) and butterflies (56 species). Pollinator-dependent crops (e.g. oilseed rape, apples, pears and strawberries), which are restricted to enclosed agricultural land, comprised 20% of the cropped area in England during 2007. This represents a 41% increase since the late 1980s (BHS 1999, 2008; Defra 2009a). The production function

value of biotic pollination in England as a contribution to crop market value in 2007 was £367 million (Gallai *et al.* 2009), or approximately 8% of the total value of the market.

The value of pollinators and pollination services to wild flowers is unknown, but in the UK, since 1980, animal-pollinated plants have declined more than either self- or wind-pollinated species (Biesmeijer *et al.* 2006), and 76% of bumblebee forage plants have decreased in frequency (Carvell *et al.* 2007). Pollinators also contribute to the provision of cultural services. For example, several studies indicate that assemblages of wildflowers make important contributions to the aesthetic qualities of landscapes and roadside verges within the UK (Willis & Garrod 1993; Akbar 2003; Natural England 2009a).

Honeybees (*Apis mellifera*) are most often managed by hobby beekeepers, who are primarily interested in honey production rather than providing pollination services. The number of managed honeybee colonies declined by 54% between 1985 and 2005, with the trend expected to continue in the short-term (Potts *et al.* 2010). Declines in honeybee colonies are associated with introduced pests and diseases of honeybees (e.g. Varroa mite) which may become problematic for wild species.

Honeybees are not as effective at pollinating some crops (e.g. field beans, apples, raspberry) as wild pollinators; consequently, Biodiversity Action Plans (BAPs) have been developed to conserve these species and the valuable services they provide. To date 20 bee species, 24 butterfly species and seven hoverfly species have BAPs. Wild bee diversity has declined in most landscapes since 1980 with greater losses of habitat- and diet-specialist species than generalist species (Biesmeijer *et al.* 2006); hoverflies showed mixed shifts in diversity for the same time period, but again specialists fared poorly. Increased atmospheric nitrogen deposition has been implicated in the reduced species richness of grassland habitats in England (Phoenix *et al.* 2003, 2004) which has direct consequences on food availability for wild pollinators. Butterflies, though rarely significant pollinators in the UK, have also undergone major range and population shifts (Asher *et al.* 2001). Moths also are important pollinators and have declined by 33% since 1970 (Conrad *et al.* 2006). The loss of natural and semi-natural habitats, the widespread application of both pesticides and herbicides and climate change have all been implicated in the loss of pollinators in England, although agri-environment schemes and initiatives such as the Campaign for the Farmed Environment have a significant contribution to make to help pollinator services.

17.5.2.5 Noise regulation

Major surveys of noise levels in England have been restricted to Urban areas. A survey of 24-hour urban noise levels outside 1,000 dwellings in England and Wales was conducted in 1990 and 2000 (Skinner & Grimwood 2002). In both studies, daytime levels of noise were typically 8–9 dB higher than during the night. In a comparison of sites measured in both 1990 and 2000, there was a small but significant decrease in daytime noise levels from 57.1 to 56.5 dB, and the level of night-time noise was stable.

Vegetation reduces noise both by reducing its lateral transfer through mainly woody vegetation, and by reducing

its reflection from rough, vegetated surfaces including lawns and other grasslands, effects which are likely to be most relevant in urban areas and close to major sources of noise such as roads.

In rural areas, noise studies have been integrated with visual impact. The proportion of England that suffers from some degree of noise or visual disturbance has been estimated to have increased from 25% in the early 1960s to 50% in 2007. The effect has not been related to specific habitats.

17.5.2.6 Soil quality

Soil quality has a pivotal role in regulating services, along with air and water quality. We are reliant upon our soils to capture and release carbon, nutrients and water, detoxify pollutants, purify water and suppress soil-dwelling pests and pathogens.

Unlike air and water quality, there is no legislation to specifically protect soil quality to maintain regulating services. However, there are national headline indicators on soil organic matter through the Sustainable Food and Farming Strategy in England and Wales in recognition of its importance to a range of ecosystem services. Indicators of soil quality relevant to regulating services have been extensively reviewed for the purposes of UK monitoring and to aid policy decisions (e.g. Environment Agency 2006). Also, the Soil Strategy for England (Defra 2009a) had the vision that: “By 2030, all England’s soils will be managed sustainably and degradation threats tackled successfully. This will improve the quality of England’s soils and safeguard their ability to provide essential services for future generations” p4. It seeks to protect agricultural soils and, on development sites, to protect and enhance stores of soil carbon, prevent soil pollution and build resilience to climate change. Thus it will address various aspects of the loss of soil services. However, the Soil Strategy for England currently has uncertain policy standing as it was published under the last government.

Retention, detoxification and degradation of pollutants, nutrients and carbon. Soil carbon acts as a surrogate measure for soil organic matter content, which is vital for regulation. As well as binding and buffering release of chemicals, soil organic matter affects water retention and infiltration. Since the 1970s, topsoil soil carbon content has shown no significant change in soils under most semi-natural habitats, but small declines in arable soils (Bellamy *et al.* 2005; Carey *et al.* 2008). Of particular importance in England, where arable crops dominate significant portions of the landscape, is increasing evidence that a significant proportion of arable soils are close to or below the critical threshold for soil organic matter (Emmett *et al.* 2010). It must be noted that the quantitative evidence base for critical thresholds for soil organic matter is sparse (Loveland & Webb 2003). However, there is evidence of a desirable range of soil organic carbon covering a wide spectrum of soils, but the quantitative evidence needs considerable development.

Concentrations of heavy metal pollutants in soils reflect historical and current pressures alongside natural conditions. The recent UK Soil and Herbage Survey (Environment Agency 2007) indicates that concentrations of copper, lead, mercury, nickel, zinc and tin are higher in

urban and industrial soils than rural soils. In the main, these reflect inputs from industry and transport. Recent trends in GB-wide topsoil metal concentrations from the Countryside Survey suggest there have been relatively small changes in metal concentrations between 1998 and 2007.

The UK Soil and Herbage Survey results (Environment Agency 2007) indicate that soil dioxin levels increased between 1850 and 1980, predominantly in urban and industrial areas due to industrial processes, but that levels have since dropped by about 70%. Results, therefore, indicate that UK soils are maintaining a capacity to detoxify and degrade organic pollutants.

Many UK NEA Broad Habitats in England are displaying nutrient enrichment through agricultural inputs and from atmospheric deposition, as evidenced by the extensive exceedance of critical loads for several habitats for nitrogen (RoTAP 2011), changes in plant community composition (Smart *et al.* 2003) and changes to soil microbial communities (Smith *et al.* 2003).

Regulating the release of water. Regional changes to soil moisture deficits over the last 30 years reflect changing rainfall patterns (Defra 2003). Broadly speaking, information concerning trends in water release amongst habitats is lacking; however, circumstantial evidence suggests that soil water retention capacity may be at risk. Results on soil bulk density from the Countryside Survey indicate that many arable and horticultural soils (of importance in England) are showing signs of reduced aeration which may influence water flow (Carey *et al.* 2008).

17.5.2.7 Air quality regulation

The main air pollutants of concern to national and international policy makers are particles, ozone, nitrogen oxides, ammonia and the deposition of nitrogen and sulphur. The significant improvements in England's air quality over recent decades have largely been driven by reductions in anthropogenic emissions (Defra 2007a; RoTAP 2011). However, current concentrations and deposition rates still exceed thresholds for effects on human health and ecosystem services over significant areas of England. Substantial areas of exceedance of critical loads and critical levels are predicted to remain in 2020, despite planned policy measures (RoTAP 2011).

Ecosystem regulation can influence concentrations and deposition of air pollutants in three major ways:

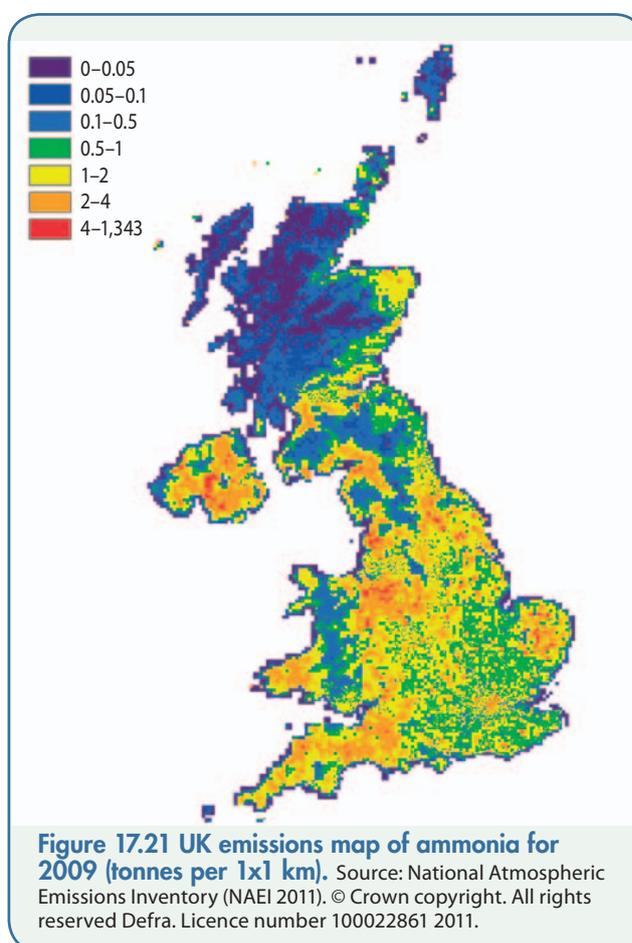
Ecosystems remove pollutants from the atmosphere, reducing local and regional air pollutant concentrations. Evidence indicates that trees are effective at capturing pollutant particles and gases through direct deposition in calmed air within the canopy and uptake through leaf stomata (Fowler *et al.* 1989; Beckett *et al.* 1998). McDonald *et al.* (2007) estimate that the current 7% tree cover in the West Midlands region reduces mean air concentrations of PM10 (particles above 10 µm) by 4%, and that increasing this to a theoretical maximum of 54% would reduce mean PM10 concentrations by 26%. Tiwary *et al.* (2009) used a similar modelling approach in East London and concluded that two deaths and two hospital admissions would be averted each year as a result.

Ecosystems contribute directly to emissions to the atmosphere. The major contributor is emissions of ammonia,

for which over 90% of UK emissions are from the agricultural sector (**Figure 17.21**). Intensive pig and poultry production facilities produce a significant proportion of ammonia emissions, with additional large contributions from grazing animals (primarily cattle), manure spreading and fertiliser use. These national ammonia emissions rose to a peak around 1990, but have subsequently declined, which corresponds to declining trends in livestock populations in England (RoTAP 2011).

Emissions from ecosystems contribute indirectly to air pollution levels via chemical processing in the atmosphere. The most important of these effects is the emission of reactive volatile organic compounds which contribute significantly to the formation of ozone, especially during the summer (AQEG 2009). National inventories of biogenic emissions exist (e.g. the National Atmospheric Emissions Inventory, AEA, 2010), but past and future trends are uncertain (AQEG 2009).

Measures to reduce emissions to, or deposition from, the atmosphere can increase the potential for air quality regulation by ecosystems. This is primarily because any pollutant deposited or absorbed from the atmosphere by ecosystems is more likely to have adverse effects when concentrations or deposition rates are high. An important trend in recent decades is the effect of reduced anthropogenic emissions, leading to decreased urban concentrations of smoke and sulphur dioxide. Emissions of sulphur dioxide in the UK declined from 6,365,000 tonnes to 512,000 tonnes between 1970 and 2008 (NAEI 2009). This reduction has allowed increased planting of conifer species, particularly



in urban areas, which increases interception and deposition of air pollution near its source, hence further improving air quality. At a national scale, there is evidence that the UK landscape has become a more efficient absorber of sulphur dioxide as concentrations have fallen, further decreasing air concentrations (RoTAP 2011).

17.5.2.8 Water quality regulation

Water quality is determined primarily by catchment processes including plant and microbial nutrient uptake, pollutant accumulation in soil organic matter and adsorption onto mineral surfaces, acidity buffering, organic pollutant breakdown and denitrification. Water quality can be further influenced by drainage systems which can dilute, assimilate or transport pollutants. This particular ecosystem service is often confused with the provisioning service for drinking water, which stems from the overlap of definitions of these services.

Unfortunately, there is little monitoring of the ecosystem processes which regulate water quality and only inferences can be made from existing data, which point to ecosystems contributing to a general improvement, which is also influenced by decreased inputs and improved treatment in sewerage works and elsewhere. General Quality Assessments showed that the number of English rivers of good chemical quality increased from 55% to 79% from 1990 to 2008 (Defra 2009c). Concentrations of phosphates were high (>0.1 mg P/140) in 52% of English rivers, whilst 32% of English rivers exhibited high concentrations (>30 mg NO₃/l) of nitrates (Chapter 9; Section 17.4.5, Figure 17.4.5a and b).

Data from the Harmonised Monitoring Scheme (HMS) indicates that organic pollution (measured in terms of biological oxygen demand and ammoniacal nitrogen) have declined in England since the 1980s, leading to increased dissolved oxygen concentrations. Phosphate concentrations have fallen substantially in most areas since the mid-1990s, whilst nitrate has shown little change.

Data from HMS monitoring in England further indicates that heavy metal concentrations have declined, whilst the large majority of pesticides are below detection limits (Figure 14.6, Section 14.9.1). Faecal indicator organisms (FIOs) are measured routinely at (predominantly coastal) bathing waters. English coastal waters complying with mandatory standards set by the EC Bathing Water Directive increased from 65% in 1988 to 98% in 2007, whilst the stricter Guideline standards, which indicate excellent bathing water quality, were met in 29% of English waters in 1992, but rose to 71% in 2007.

Upland water quality is more strongly coupled to ecosystem processes; however, far fewer data sets are available to infer with the magnitude of water quality regulation by upland ecosystems. As it is relatively unpolluted, water draining the uplands performs a key regulatory service by diluting pollution that enters river systems further downstream. Whilst England-specific data is lacking, general trends from UK-wide data sources show that upland waters experienced elevated acidification during the 1960s–80s. However reports of recent increasing pH and decreasing toxic aluminium concentrations suggest recovery (AWMN 2009). Dissolved organic carbon from waters draining peaty soils has risen

across the UK in the last 20–30 years (Evans *et al.* 2005; Worrall & Burt 2007b), whilst suspended sediment levels are elevated in areas of active soil erosion, notably downstream of eroding peatlands, such as those of the South Pennines, indicating that ecosystem damage is a significant cause of this adverse change (Evans *et al.* 2006).

17.5.3 Provisioning Services

Provisioning services provide the material goods directly (or in the case of genetic resources, indirectly) consumed by humans. Many of these are produced as private goods, for which there are established markets. Consequently, production and trading in recognised provisioning services (e.g. wheat, beef, fresh water, etc.) has often been a major influence on other ecosystem services for which markets do not exist, and which have been substantially overlooked in land management decisions. Perhaps the greatest challenge faced by land managers and policy makers is balancing the high demand for essential provisioning services required by human populations, most notably food and water, and the impacts of this elevated emphasis on provisioning services on the interdependent regulatory, cultural and supporting ecosystem services.

17.5.3.1 Food from agriculture

Approximately 70% of England is managed as farmland and thus agriculture has a major influence on nearly all other ecosystem services. In the past 50 years, there have been major increases in domestic food production. Despite an increase in population, self-sufficiency in food production increased in the UK from 40 to 50% in the 1950s to 60% in the 2000s (Defra 2006a). Most of this increase was due to higher levels of farm production in England. There has been a trend towards farm specialisation, with a loss of mixed farming and its associated matrix of habitats and within-farm nutrient recycling between crops and livestock. This trend has had pronounced impacts on the landscape and the supply of other ecosystem services.

Crops. Between 1940 and 2009, the areal extent of land growing crops in England rose from roughly 3 million ha to 4.2 million ha, or a 41% increase. The extent and types of crops grown has also changed. For example, the area of wheat has risen whilst that of oats has fallen. Yields also increased in all major crops as a result of intensification, most dramatically for wheat, which rose from 2.5 tonnes/ha in 1940 to 8 tonnes/ha in 2008, or a 3.2-fold increase. This has had significant consequences stemming largely from increased inputs of fertilisers, pesticides, energy and tillage, all of which typically exert negative pressures on biodiversity. The area of vegetables increased between 1940 and 2009 (Section 15.2.2), but orchards declined from 102,000 ha to 25,000 ha. Fallow land fell from 2.3% to 0.36% (25,000 ha) of cropped area.

Livestock. English livestock populations of sheep and pigs rose from 1940 to 1980 and then declined, while cattle followed the same trend, but continued to rise until the 1990s (**Figure 17.22**). Whilst the total livestock population has fallen during the period of interest, local densities of livestock have risen significantly due to the development of industrial livestock rearing methods. These

concentrated animal populations, coupled with certain recent husbandry practices, have contributed to periodic outbreaks of infectious diseases, such as Bovine Spongiform Encephalopathy (BSE) or contagious diseases, such as Foot-and-Mouth. Bovine Spongiform Encephalopathy can be spread through the feeding of animal by-products to bovine herds and also can be spread to humans who consume brains or spinal cord materials. Elevated livestock densities are also associated with increased ammonia emissions and its significant impacts on air quality and ecosystem processes. In 2008, cattle farming accounted for nearly 47% of ammonia emissions in the UK (AEA 2010).

Dairy. Dairy production is associated with intensive grassland management. In England, the yield has increased from 3,500 litres per cow per year in 1960 to 7,000 litres per cow per year in 2009 (Capper *et al.* 2009). Genetic selection of higher yielding cows, technological innovation and incentives from agricultural subsidies accounts for increases. Production was capped by CAP reform of 1984 and market forces have driven down farm gate prices in the 2000s. Declines in market prices had the follow-on effect of simultaneously reducing the number of farms and increasing the density of herds. Modern dairy production levels are still above 1940 outputs, though achieved with fewer cows held in fewer, larger farm businesses.

Beef. Rearing systems vary from outdoor suckler cow production on semi-natural habitats (including nature reserves and special wildlife sites) with low input requirements, to intensive indoor rearing and finishing, with environmental impacts at an industrial scale. The UK beef herd saw a modest increase between 1940 and 1970 and there was also a more significant increase in the English beef herd from 1981 to 1995, which grew by 45%. The increases in herd size were accompanied by increases in carcass weights from 267 kg in 1980 to 316 kg in 2003. Since then, the English beef herd has experienced a significant decline due to a reduced numbers of animals entering the beef-rearing sector from dairy herds. The elevated levels of cattle production produced by modern husbandry techniques are not without consequences: diseases such as BSE and Foot-and-Mouth have had significant financial repercussions due to the costs of disease control and the closure of foreign markets, which depressed farm gate prices for beef. Agri-environment payments for grazing on semi-natural habitats locally support low-intensity beef rearing to meet environmental goals, notably biodiversity.

Sheep. The growth in the sheep population in England between 1940 and 1990 was significantly influenced by increased subsidies to hill farmers. The major growth, therefore, took place in upland habitats, prompting concern about the impacts of overgrazing. Declines in the English sheep flock were exacerbated by outbreaks of Foot and Mouth in 2001.

Pigs and poultry. From 1940 to 2009 pig farming evolved from extensive (even household-scale) husbandry towards intensively-reared indoor industrial-scale units. However, issues related to animal welfare and the environmental impacts of high-density pig lots have prompted an opposing trend towards outdoor pig-rearing, on well-drained land that is part of an arable rotation scheme. Whilst environmental

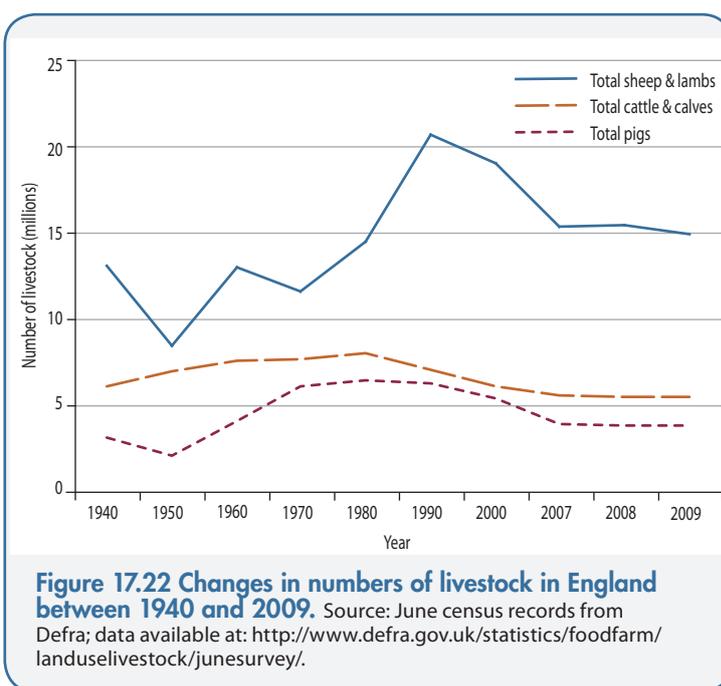
impacts from outdoor pig-rearing are not well understood, there is potential for increased diffuse pollution of surface and groundwater, substantially increased soil erosion and an issue of waste disposal. Most of the 3.8 million pigs in the United Kingdom (2009) are reared in England, especially in the east and in Wiltshire, which is famed for its ham and pork products.

There were about 166 million hens in England in 2008, including 30 million laying hens producing 868 million eggs (Section 15.2.3.4).

Fibre from agriculture. Historically, flax has been produced at low levels since the 1940s, when 11,000 ha of land was used for the production of flax for textiles and rope production. There was a brief surge of flax production in the early 2000s due to increases of the CAP subsidy, but production levels have since declined with its withdrawal.

The UK is the seventh largest wool producer in the world, with some regions of England (e.g. the Cotswolds) noted for their historic wool trade. Other than for specialist suppliers (e.g. fine wool goats), the value of wool to farmers is typically low. The amount of wool produced is proportionate to the numbers of sheep. The trend for wool production has been increasing; 25 million kg of wool was produced in 1950, rising to 49 million kg in 1998.

Biomass and bioenergy. At the end of the 20th Century almost no biomass crops were grown commercially in England. In 2005, 436 ha of short rotation coppice willow was recorded in the UK (NNFCC 2009), and by 2007 this had increased fivefold (Table 15.4, Section 15.2.5). Similar increases were noted in *Miscanthus* (*Miscanthus x giganteus*) and reed canary grass (*Phalaris arundinacea*) over the same timescale, both of which are grown for biomass. Monoculture plantings of *Miscanthus* offer very little by way of habitat and as such, careful consideration must be given to ensure that impacts on local floral and faunal populations are minimised. Plantings for biomass and bioenergy have largely been driven by a combination of market opportunity



and policy. Relevant policies are not necessarily agricultural, but include incentives for energy generators to include a certain proportion of renewable materials in their feedstock, and for some large establishments to have biomass boilers. Oilseed rape is used to produce biodiesel and its increasing popularity stems from EU policies set in 2005 to increase the proportion of renewable fuels used to power Europe's growing fleet of automobiles and lorries.

Fish from marine ecosystems. Interpreting the statistics of marine fisheries is problematic for the purposes of this review, since UK registered fishing vessels do not land all of their catch in UK (or English) ports. Similarly, non-UK registered fishing vessels will land some of their catch in UK ports depending on market conditions. A further problem comes from the methods used to collate fishing statistics, recorded by ICES (International Council for the Exploration of the Sea) rectangles, which are several thousand square kilometres in extent and commonly transcend national boundaries. Finally, landing statistics do not contain landings from small inshore vessels.

Landings into British ports were 883,000 tonnes per annum in 1950 and at a relatively constant level until 1970, when they increased significantly to 1 million tonnes. Since the peak in the early 1970s, fish landings declined to 409,000 tonnes per annum in 2008, its lowest modern peacetime level (outside of the two World Wars), with the total landings into England by UK vessels being 89,313 tonnes. These trends differ amongst demersal, pelagic and shellfish species. Landings of demersal fish (e.g. cod, plaice and haddock) living on the seabed exhibited the sharpest decline, with landings decreasing from 456,000 tonnes to 190,000 tonnes per annum during the period from 1994 to 2008. Pelagic fish (e.g. herring and mackerel) landings declined more modestly, decreasing from 388,900 tonnes to 247,900 tonnes per annum from 1994 to 2008. Landings of shellfish increased slightly between 1994 and 2008, from 114,400 tonnes to 150,500 tonnes per annum (MFA 2009). The trends in fish landings do not necessarily indicate declines in species' populations, as they are also significantly influenced by conservation measures (e.g. the EU Common Fisheries Policy), fishing effort, EU policies concerning the fishing fleet and reductions of fisheries subsidies provided to domestic fleets. Between 1996 and 2008 the number and fleet tonnage of the English fleet had fallen, suggesting the overall level of fishing capacity had declined, despite increases in the power and efficiency of the fleet. These developments can explain a portion of the decline in landings.

Aquaculture. Nearly 80% of marine aquaculture (predominantly salmon) in the UK occurs in Scotland and is, therefore, of minor significance in England, with the notable exceptions of the rainbow trout (an introduced species which has naturalised in some British rivers) farms in southern England and the Pennines that produced 7,294 tonnes in 2006. Shellfish farms produced 14,553 tonnes of mussels and 880 tonnes of oysters in 2006 (Defra 2009a). Aquaculture operations increase the input of nitrogen and phosphorus into aquatic environments, enhancing the local growth of marine plants and algae, and also reducing the diversity of benthic organisms underneath aquacultural facilities (Mayor *et al.* 2010).

Capture of migratory salmon and trout. Catches by rod and fixed engine boats and nets rose between 1956 and 1969 to more than 140,000 fish. Since this period, these totals have fallen sharply to fewer than 40,000 fish (Figure 15.5, Section 15.5.3). Since 2004, more fish have been caught by rod than by net for the first time since records began in 1956. This trend has been influenced by legislative controls and formal agreements limiting 'mixed stock' (from different rivers) fishing on the high seas and ceding control to the catchment scale where licensing of commercial activities can be controlled in relation to escapement of spawning fish. Angling interests, supported by numerous River Trusts, have also been active in buying out estuarine netting and also promoting 'catch and release' recreational angling.

Game species (birds and mammals). Game species are those hunted for food and/or sport including reared and released pheasant and red-legged partridge, wild red grouse and several species of deer. Additional species are culled due to their role as pests (e.g. deer, rabbits and pigeons). Regardless of why they are hunted or culled, the majority end up in the human food chain. Whilst the amount of wild game represents only a very small component of food consumed in England, these species exert a disproportionately large influence on land use, as habitats are specifically managed to improve game bird abundance. Prominent examples of these activities include the management of heather moorland in northern England for red grouse and the management of small woods, hedges and field margins in lowland farmland of southern England for pheasant and partridge.

Trends in the number of birds shot per unit area depend on the species and their management activities. Within the moorlands, there have been wide variations in the number of grouse shot from the mid-1970s to 2007 due to population fluctuations; however, the overall trend has been a decline from 100 birds per 100 ha in 1975 to 30 birds per 100 ha in 2007 (GWCT 2009).

In the lowlands, the amount and extent of habitats supporting game birds breeding in the wild declined throughout the 20th Century, due to intensification of arable farming. The number of grey partridge shot similarly declined from 14 birds per 100 ha in 1960 to one bird per 100 ha in 2005 (GWCT 2009). Pheasant and red-legged partridge are introduced species whose populations are artificially maintained by regular releases of reared birds. It has been estimated that 35 million pheasants were released in 2004, of which 15 million were shot, and 6.5 million red-legged partridge were released, of which 2.6 million were shot.

During the 1960s, bags of roe deer (*Capreolus capreolus*) were restricted to Scotland, north-east England and some southern counties of England. Over the next few decades the deer spread across much of England, and in much of southern England (particularly East Anglia), bag densities exceeded one deer per 100 ha in the 1990s. Few roe deer were shot in the English Midlands during the period 1960–2000, though overall numbers can be seen to have increased (GWCT 2009; **Figure 17.23**).

During the 1960s fallow deer (*Dama dama*) were shot in only a few localities in the UK. By the 1990s, bags of fallow deer had increased significantly across southern England,

particularly in Gloucestershire where bag densities exceeded one bag per 100 ha (Figure 17.24) (GWCT 2009).

During the period 1960–2000 shooting of red deer (*Cervus elaphus*) gradually increased in North West England, East Anglia and South West England. Figure 17.25 shows that no red deer were shot in the Midlands or South East England between 1960 and 2000 (GWCT 2009).

Wild foods. No precise figures for honey production are available for England; however, Jones (2004) has provided initial estimates of honey production based on the number of colonies kept and a mean honey production value per colony (Figure 15.8, Section 15.6). The most desirable plants for honeybees have nectar with a high sugar content and are found in quantities substantial enough to sustain colonies. Crops such as oilseed rape and white clover are particularly important. The one wild, nectar-rich species growing *en masse* is heather, which is the main summer food supply for honeybees in the North York Moors and Devon. Some hives are permanently stationed on moorlands. In other cases, hives are deliberately moved to heather to encourage foraging exclusively from wild flowers. Heather honey has twice the value of other types of British honey, £4.40–£5.50/kg bulkweight compared with £2.20–£2.30/kg (Prendergast & Sanderson 2002).

A number of other wild foods are gathered from English habitats such as edible mushrooms, wild basil, wild marjoram, marsh samphire, watercress, bog myrtle, burdock, common sorrel, garlic mustard, nettle, (non-native) sweet cicely, wild thyme, wood sorrel, the fruits of cowberry, crab apple, hawthorn, hazel, wild blackberry, wild raspberry, rose, rowan, sloe, wild strawberry, whinberry, the flowers of elder, the roots of (non-native) horseradish and tuber-roots of pignut, and the buds of broom (Prendergast & Sanderson 2002). Unfortunately, little information is available on quantities harvested.

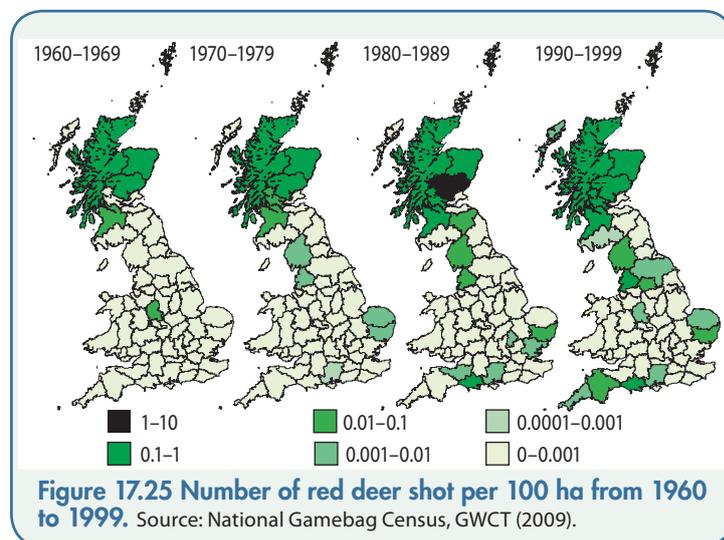
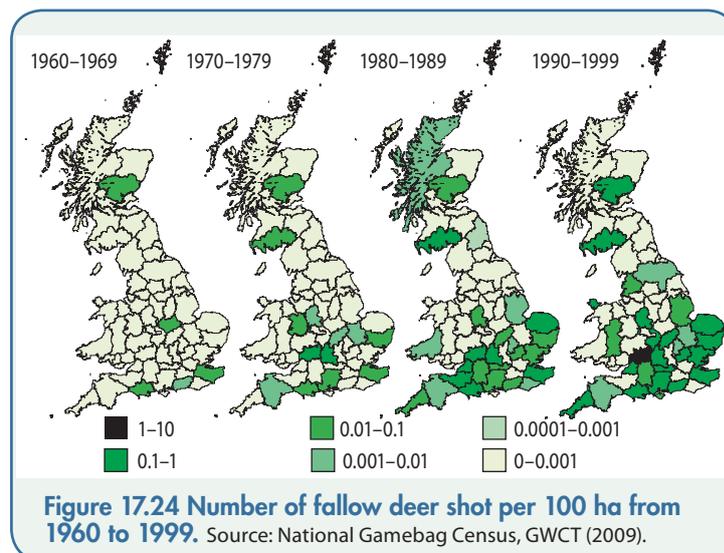
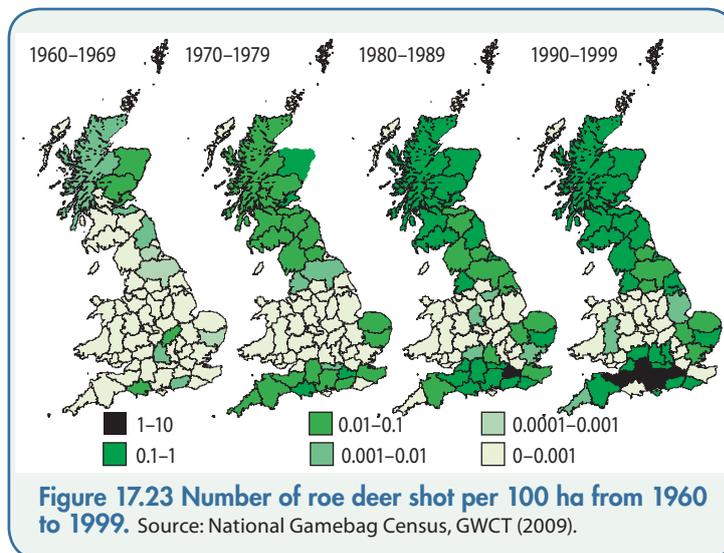
17.5.3.2 Resources

Timber. The harvest of hardwood timber in England accounts for 88% of the UK total, but has been in long-term decline since 1975, unlike in Wales and Scotland, where harvests have remained at low levels (Figure 15.10, Section 15.7.1). In 1975, more than 1,000 green tonnes of hardwood was harvested in England, but by 2008, less than 400 green tonnes were harvested (Forestry Commission 2009d). However, harvested softwood amounts exceed hardwood totals in England (approximately 2,000 tonnes of softwood versus 400 tonnes of hardwoods in 2008), with the softwood total being about one-third that of Scotland's (Figure 15.12, Section 15.7.1). England is not self-sufficient in timber production and relies on imported timber, particularly from Scotland and other timber exporting nations.

The most significant threat to the future supply of provisioning services from woodlands lies in the possibility of disease, particularly sudden oak death, which causes the sudden death of both native oak species (*Quercus robur* and *Q. petraea*), acute oak decline, and red band needle blight (caused by the fungus *Dothistroma septosporum*).

Biochemicals. A number of biochemicals are produced in England, largely from the bark and needles of woodland tree species. These include shikimic acid, which is derived

from spruce needles and is the primary precursor of Tamiflu; taxol, which is derived from the bark and needles of yew and is used to treat a variety of cancers; and Pycnogenol™, a herbal nutritional supplement based upon polyphenolics found in pine needles and bark and reputed to be an effective



antioxidant. Non-woodland species providing biochemicals include *Eryngium* species, whose roots produce potent inflammation modulators.

Roof thatching. Roughly 60,000 thatched properties occur in Britain, mainly in southern and central England, and their popularity appears to be increasing (Hawke & José 1996). For example, about one new property in 50 built by one developer in southern England is thatched, whilst council planners in Dorset are advocating that one in six new houses in that county should be thatched (Maclaren 2000). Roof thatching is most often with common reed (*Phragmites australis*), but saw sedge (*Cladium mariscus*), heather (*Calluna* species) and other traditional species can also be used (Sanderson & Prendergast 2002). Some 365 ha of reedbed are harvested in England, predominantly from Norfolk and Suffolk (Rayment 1995). English reed production has been estimated to be at least 226,975 bundles per year (Bateman *et al.* 1991) with a total value greater than £400,000 per annum. The other main source of thatching is from long straw wheat which is grown over a small acreage in southern England and plays an important role in the conservation of genetically important landrace wheat varieties (Hopkins & Maxted 2011).

Peat extraction. Today, almost all peat extraction in England is for horticultural purposes. Nearly all commercially extracted peat comes from lowland raised bog sites, which are a rare wetland type. Upland peats are extensive, but not suitable for horticultural purposes. Most commercial peat production in Great Britain is located in England and has been declining in recent years. In 1999, 1,224,000 m³ were sold in England, predominantly from sites in the North East and North West. By 2008, 496,000 m³ were sold in England, almost all of which came from the North West (ONS 2000). Production declines can be attributed to industry agreements with Natural England (and its predecessor, English Nature) on extraction from SSSIs, as well as reduced commercial use.

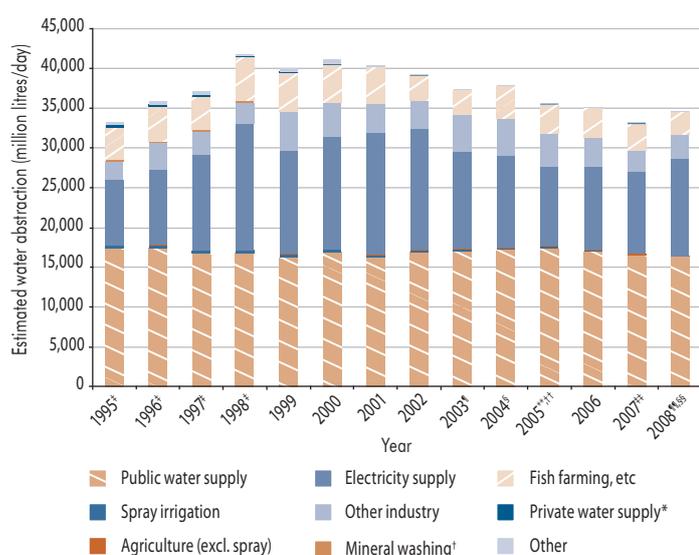
Ornamental resources. During 2006, 4,578 ha of open fields in England were used to produce flowers for commercial markets, predominantly in Scilly, Cornwall and Lincolnshire. This included 3,871 ha of daffodils and smaller amounts for gladioli and pinks. The amount of land used for commercially produced flowers has declined steadily due to cheaper products coming from Europe and Africa. The total area of outdoor flowers and hardy nursery stock (e.g. shrubs, roses and ornamental trees) in England has grown steadily from 6,900 ha in 1940 to nearly 12,800 ha in 2000 due to increased home ownership, greater amounts of personal income and wider interest in gardening (Section 15.9).

17.5.3.3 Water supply

Throughout the 20th and 21st Centuries, demand for water in England has steadily increased due to population growth. Despite this growth, the amount of water put into the public water supply in England and Wales declined modestly between 1990 and 2009, which roughly coincides with the privatisation of the water industry in 1989. The drivers behind the decline are unclear, but enhanced infrastructure and management under private water companies will have had an influence.

It will be noted from **Figure 17.26** that considerable variation exists in the amount of water annually entering the public water supply (Defra 2010h). Another potential driver of this variation is annual change in weather, but looking at the number of drought orders and rainfall totals from the Environment Agency, there is no obvious relationship. Presumably there are complex interactions between climate, regional weather patterns, and economic forces that drive water use and supply patterns.

Another important aspect of water abstraction is that most of this service is consumed downstream away from its source. Therefore whole-catchment management of this and related services is essential for sustainability. Catchment-



*Private abstractions for domestic use by individual households.
[†]In 1999, mineral washing was not reported as a separate category. Licences for mineral washing are contained in "Other industry".
[‡]Under-estimate of actual abstraction during the period 1995 to 1998 due to licences being assigned as industrial cooling rather than electricity supply (North East Region).
[§]Three licences re-assigned in 2003 to other industry from electricity supply (Midlands Region).
[¶]Reduced abstraction in 2004 at Dinorwig and Ffestiniog Power Stations (hydropower) (Wales Region).
^{**}Reduced hydropower abstraction in 2005 (North East & Midlands Region).
^{††}Reduction in agricultural abstraction due to deregulation of licences as of 1 April 2005.
^{†††}Spray irrigation is very sensitive to prevailing weather conditions. This is reflected in a decrease in actuals for spray irrigation due to wet summers in 2007 and 2008.
^{††††}Return requirements were changed from 01/04/2008 whereby licences that abstract under 100m³/day no longer had to send returns back this has mainly affected agricultural, private water supply/other and small industrial licences.
^{†††††}Return requirements were standardised across all regions from 01/04/2008 and requested by financial years. Prior to April 2008 returns were requested by calendar year for the majority of regions. To collect data for all of 2008 two requests were made, at the end of the period January 2008 to March 2008 and end of period April 2008 to March 2009. This may have had the effect of underestimating actual abstraction where returns may have been received for only part of the calendar year.

Figure 17.26 Estimated water abstractions (millions of litres per day) for England and Wales from all sources (except tidal) by purpose. Source: data from the Environment Agency; Defra (2010h).

level management required for the continued provision of clean water might also positively influence flood regulation and reduce soil erosion.

17.5.4 Cultural Services

Since 1945, people's perceptions of and interactions with their local environments have expanded considerably. A wider range of benefits are being recognised and sought after within natural and semi-natural environments including their roles in local and national identity, education, spirituality, art, physical and psychological health and recreation. Changes in mobility, work patterns, social behaviours and consumption have contributed to these altered relations between people and their local natural environment. Generally, more people have a local environment with urban characteristics, but increased mobility allows people to travel longer distances within their local area, increasing the potential opportunities to engage with local places. Satisfaction with local environments, however, has fallen slightly in recent years (Defra 2010e).

Urban settlement patterns have changed considerably since 1950 due, in part, to new transport technologies and the growth of job opportunities in rural areas. Eighty-one per cent of the UK population now live in urban areas (CABE 2010), compared to approximately 70% in 1951. This change has been uneven: larger urban areas and conurbations have become less crowded, whilst smaller settlements and rural areas, especially in southern England, have become more crowded (FLUFP 2010). Rural communities have also undergone changes that will influence the interactions between people and ecosystem services. For example, agricultural workers, who are especially engaged with rural environments, accounted for 5% of the British workforce in 1951, but now constitute fewer than 2% of the total workforce.

These changes in work and settlement patterns have been accompanied by changes in mobility. Defra (2008c) data indicate a modal shift to cars from bicycles and walking. **Figure 17.27** illustrates that the distance travelled has increased by about 25% for commuting/business travel and by over 30% for other journey types. People are increasingly living in or close to urban settlements, but they are also able to travel further regularly to access opportunities, services and work in their local area.

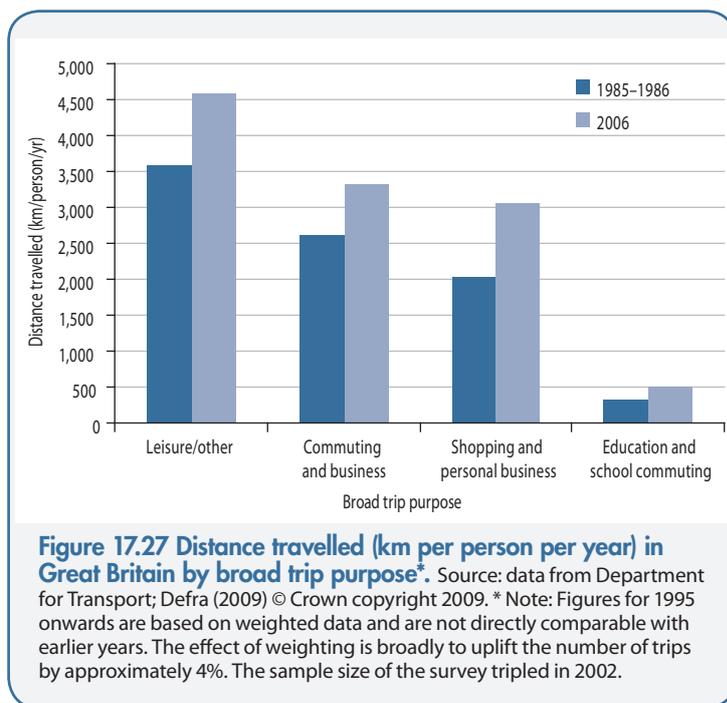
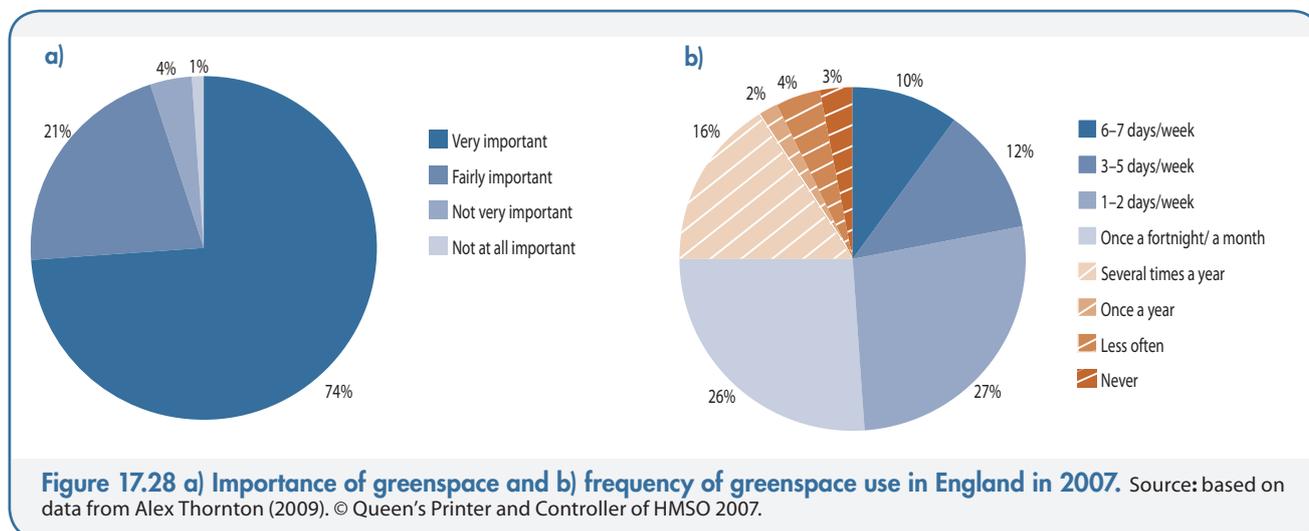


Figure 17.28 indicates that in England people also place considerable importance on the natural environment in the form of greenspace in their local area, with three-quarters of the population considering it to be an important part of the local environment and almost 50% using it at least once a week. Recently national surveys have started systematically to measure people's satisfaction with their local area (Defra 2010e).

17.5.4.1 Environmental settings

The last century has witnessed marked changes in certain landscapes of the United Kingdom, especially those in and around large Urban areas. The State of the Countryside 2008 report for England (CRC 2008) indicates that 8.6% of land cover in England is of built up areas (although a large portion of this land is gardens or greenspace), whilst the Countryside Survey (2009) estimates a higher urban cover at 10.6%. Major conurbations and cities (defined as populations over 100,000) occupy about 5.3% of the land, other urban areas (populations 10,000 to 100,000) cover 2.2%, rural towns 0.8% and villages



and hamlets 1%. Agriculture covers approximately 70% of the land area outside built up areas, with woodland cover and forestry making up about 9% (CRC 2008).

There are 10 National Parks in England and they protect landscapes of particular social value. Other parts of the countryside are protected by conservation designations, most notably Sites of Special Scientific Interest (SSSIs), Special Areas of Conservation (SACs), Special Protection Areas (SPAs), Ramsar sites, National Nature Reserves (NNRs) and Local Nature Reserves (LNRs). On the edge of larger cities in England, considerable portions of the landscape are protected by green belt land, which in 2010 was estimated to be 1,619,835 ha (Natural England 2010d).

Table 17.14 indicates the type, number and spatial extent of several protected landscape designations in England.

The Countryside Quality Counts (CQC) project was designed to provide an indicator of change in countryside quality of England and gives the most comprehensive data on landscape change. Its analysis for 1990–1998 indicated that about 40% of English landscapes were stable, 37% of landscapes experienced changes that did not significantly alter overall landscape character, and 10% of landscapes are being enhanced. Yorkshire and Humberside, the East of England, the North West and the North East landscapes stood out as being the most stable. By contrast, marked and inconsistent change in landscapes was concentrated in the Manchester, Bristol and Birmingham conurbations.

Some measures of landscape change are, however, pessimistic. The Campaign for the Protection of Rural England (CPRE 2003) highlights several changes in land use that it believes will have negative consequences for English landscapes. These include the following points:

- Every year in the 1990s an area the size of Hull was developed (DETR 2001).
- Between 1984 and 1993 there was a 17% net loss of hedgerows (Barr *et al.* 1993).
- Meadows covering an area the size of the country of Bedfordshire were lost between 1992 and 1998.
- Between 1990 and 1998, plant diversity in some meadows fell by 8% (Haines-Young 2000).
- Once extensive ancient woodland cover in the UK is now reduced to only 2% of land use (Haines-Young 2000).

Table 17.14 Number of designated sites in England and their spatial extent. Source: data compiled by T Sajwaj (2010).

Protected Land Designation	Number of sites	Areal extent (ha)
National Parks	10	1,216,000
National Nature Reserves	222	92,000
Greenbelt	n/a	1,638,000
Ramsar sites	31	356,000
SSSIs	4117	1,000,000+
SACs	231	846,000
Special Protection Areas	79	1,051,000
Local Nature Reserves	1280	Circa 40,000

English Heritage has commissioned pilot and demonstration studies to develop a Historic Seascape Characterisation for England. The Defra report *Charting progress: An integrated assessment of the state of the UK seas* (Defra 2005) identified the following key issues:

- Levels of contaminants in the UK seas have decreased significantly.
- Significant contaminated areas are associated with industrial estuaries and are due to a legacy from the past.
- Widespread commercial fishing continues to threaten many fish stocks.
- Whilst the impacts of climate change on marine ecosystems are the subject of considerable ongoing research, our understanding is very limited.

This mixed picture of landscape and seascape change results from the maintenance and enhancement of character in some landscapes and loss or neglect in others. Some of these changes can be attributed to improved legal protection of landscapes (e.g. the implementation of the European Landscape Convention, designation of SSSIs, etc.) whilst others result from greater public awareness of the uniqueness of English landscapes.

17.5.4.2 Leisure, recreation and tourism

Outdoor environments have been one of the most enduringly popular locations for recreation and tourism (Curry 1994), with a variety of ecosystem features and habitats offering a wide range of goods and services. Research for Natural England (2009a) has identified that ecosystem services for recreation are often linked to places where there is a lot to do, such as the local park or stretches of coastline. They are typified by easy access, opportunities for specific physical activity (e.g. scrambling or climbing on rocks and crags), or scenic rights of way (e.g. lanes, roads and pathways). Woodlands are also valued for the multiple benefits they provide, including opportunities for walking and cycling. The recreation and tourism benefits derived from ecosystem services are synergistic with other benefits, particularly education, spirituality and physical health.

Natural England's (2005b) English Leisure Visits Survey (ELVS) provides information on the characteristics of the leisure visit, based on a survey of 23,542 respondents. The findings indicate that in 2005 approximately two-thirds of visits were to inland towns/cities, whilst the remaining one-third were to the countryside, coast and woodlands. Interestingly, the proportion of the adult population undertaking countryside, seaside or urban visits was fairly constant, at just under two-thirds of the adult population. The duration of the visits was split equally between more than and less than three hours, with nearly 60% using a car and 25% walking, suggesting that there is likely to be a fairly even division between visits to meaningful local places and visits to more distant socially valued landscapes.

Many people utilise natural landscapes for active recreation and more passive forms of enjoyment. **Figure 17.29** illustrates data assembled by the Foresight Land Use Futures Project (2010), drawing on surveys carried out since

2000 on the percentages of the adult population in England who visit the countryside and parks and greenspaces, and the frequency with which they visit.

Tourism, recreation, ecosystem services, habitats: Destinations of foreign visitors to England are strongly divided between rural and urban destinations, with rural destinations accounting for roughly 55% of all international visitors (Foresight Land Use Futures Project 2010). Domestic tourism is more problematic to assess as preferences shift considerably for urban, rural and coastal destinations. Recent estimates suggest that rural tourism in the English countryside is worth nearly £14 billion a year and supports 380,000 jobs (GFA-Race & GHK 2004). The importance of these revenues to rural and coastal populations is considerable as they contribute disproportionately large amounts of income to rural economies and quality of life (Deloitte MCS Ltd 2008).

Table 17.15 identifies the habitats/habitat features, opportunities and potential benefits that can be derived from various ecosystems. Whilst not necessarily physically remote from urban populations, these habitats tend to be found in places that are not suited to extensive development, meaning that there are significant constraints in gaining access to them (Curry 1994). These constraints help to limit human impacts, although it is recognised that additional management is often required to prevent degradation of the sites (Keirle 2002). Many habitats offer opportunities for a broad range of recreational activities and include parks, tracks, paths, roads, verges and other elements of the ‘green network’ (Natural England 2009d).

Informal access to the countryside for recreation is both extensive and diverse. In England:

- Country parks created under the Countryside Act 1968 cover nearly 39,000 hectares of land (Urban Parks Forum, undated report).

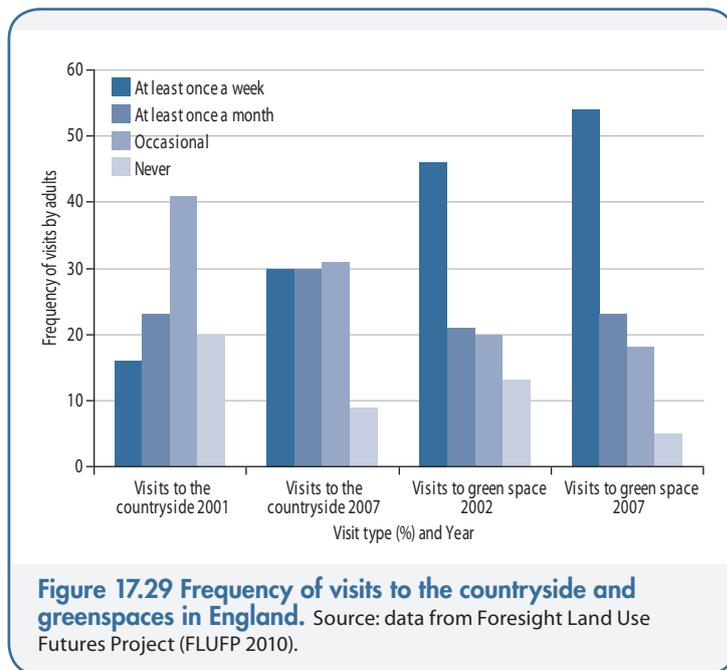


Figure 17.29 Frequency of visits to the countryside and greenspaces in England. Source: data from Foresight Land Use Futures Project (FLUFP 2010).

- There are 188,500 km of public rights of way, of which 78% are footpaths (Natural England 2008); 13 National Trails in England total 3,787 km.
- England has a considerable area of openwaters (Section 17.4.5.1). Whilst some of these waterside features are often accessible by paths or roads, many are not readily accessible.
- About 865,000 ha of land are open country (as in the Countryside and Rights of Way Act 2000) or registered common land. Other locally protected landscapes such as country parks and local nature reserves also offer important nature experiences but do not have well-documented estimates of their extent.

Table 17.15 The opportunities and potential benefits of different habitats for recreation and tourism.

Source: reproduced from Chapter 16.

Habitat/habitat characteristic	Opportunities	Potential benefits
Unique opportunities—landscapes		
Mountains, crags and hills	Vertical and near vertical inclines	Climbing, mountaineering, rock scrambling, long range views and picnicking
Sea	Wind and waves	Surfing, kite surfing
Upland streams	Fast flowing shallow waters	Game angling, white water canoeing and rafting
Limestone rocks	Caves and fissures	Caving and potholing
Unique opportunities—landscapes/local places		
Alpine landscapes	Snow cover	Snow sports
Woodlands	Tree cover with tracks, rides and clearings	Walking, cycling, horse riding, many types of informal recreation
Estuarine environments	Sheltered waters	Moorings, marinas
Lakes	Wind	Sail sports
Beaches	Sand and sea	Outdoor swimming and beach activities
Generic opportunities—local places		
Parks and open spaces	Publicly accessible greenspaces	Walking, dog walking, cycling, running, picnicking and informal recreational activities

- There are 490,000 ha of publicly accessible woodland in England.
- Some form of access exists to some 70% of the coastline of England.

Access to ecosystems for recreation is highly variable throughout England (Curry 1994). Measures to address this issue include Natural England's Accessible Natural Greenspace Standard (ANGSt) and the Forestry Commission's Accessibility of Woodlands and Natural Spaces (O'Brien & Tabbush 2005) amongst others. These documents provide benchmarks for ensuring access to greenspaces near local populations (see Harrison *et al.* 1995; Handley *et al.* 2003). For example, the ANGSt recommendation is that local populations should have:

- an accessible natural greenspace of at least 2 ha in size, no more than 300 m (5 minutes' walk) from home;
- at least one accessible 20 ha site within 2 km of home;
- one accessible 100 ha site within 5 km of home;
- one accessible 500 ha site within 10 km of home;
- statutory Local Nature Reserves at a minimum level of 1 ha per thousand people.

It is recognised that this will be hard to achieve in the short term (LUC 2008), but Natural England advocates that all local authorities improve access through Green Space Strategies (Barker 1997; CABE Space 2006). The interest in green infrastructure may help increase the accessibility of greenspace. In East London, for example, deficiencies in access to various types of parks have been identified, with about 30% of people in the Urban area having no access to a local park of more than 2 ha within 400 m of home (GLA 2006b).

Recent legislative changes have contributed to improving access to some landscapes, with the Countryside and Rights of Way Act 2000 providing access to the uplands, downs and commons and the Marine and Coastal Access Act 2009 promising to do the same for access to the coast. However, those parts of England that are dominated by intensive lowland farming (e.g. East Anglia, Lincolnshire fenland and the Lancashire Plain) continue to offer relatively limited accessibility to outdoor environments.

17.5.4.3 Health

Within the last generation, the number of men and women in England performing 30 minutes of exercise on most days declined to fewer than 40% of men and 28% of women (Craig & Mindell 2008). The proportion of people leading sedentary lives and the prevalence of adult obesity has risen over the past 50 years (Foresight 2007; NICE 2009). Physical inactivity is associated with increased risk of obesity, chronic diseases of later life, and reduced life expectancy. The costs of inactivity in the UK are £8.3 billion per year, equating to £5 million for each Primary Care Trust (NICE 2009). Research by Foresight (2007) estimates that medical conditions associated with obesity have direct costs of £4.2 billion to the National Health Service and £16 billion a year to wider society. This latter figure could rise to £50 billion if current trends continue. Greenspaces and other open spaces can mitigate both the health and economic consequences of

obesity. Urban greenspaces provide important opportunities for, and also play a significant role in encouraging, physical activity (NICE 2009).

Physical activity improves both physical and mental health (Department of Health 2004; Foresight 2007). It is also now well-established that exposure to natural places, whether a view of nature from a window, being within natural places or exercising in these environments, can lead to positive mental health outcomes (Moore 1982; Ulrich 1984; Hartig *et al.* 2003; Pretty *et al.* 2005, 2007; Barton *et al.* 2009). Research on green exercise (i.e. physical activity in the presence of nature) in England has been linked to a range of benefits to human well-being including positive health outcomes (Hine *et al.* 2007; Pretty *et al.* 2007), promoting ecological knowledge (Burgess 1995; Pilgrim *et al.* 2007, 2008; Pretty 2007), fostering social bonds (Burgess *et al.* 1988; Pretty 2007) and influencing behavioural choices (Michell & Popham 2008; Peacock *et al.* 2008). Other research has considered:

- Levels of engagement with nature—the view from the window (Moore 1982; Ulrich 1984; Pretty *et al.* 2005); the role of nearby nature and urban greenspace (Harrison *et al.* 1987; Burgess *et al.* 1988) and the outcomes from countryside activities (Pretty *et al.* 2007).
- Types of engagement with a wide range of activities including walking, gardening, fishing and hunting (Pretty 2007), in different types of environment from the urban built environment to countryside and wilderness.
- Mental health outcomes using a range of measures of self-esteem, mood and stress (Pretty *et al.* 2005, 2007).
- Physical health outcomes using heart rate, blood pressure, body mass index, waist measures (waist circumference and waist to hip ratios) and physical activity level (Pretty *et al.* 2005; Sandercock *et al.* 2009).
- Associations between home proximity to greenspace and health (Mitchell & Popham 2008).

The health benefits of urban greening: Large-scale quantitative studies have shown that the prevalence of psychiatric morbidity is greater in urban than rural areas (Lewis & Booth 1994). Income-related inequalities in health also depend on exposure to greenspace. People who live in greener areas reported lower levels of health inequality relating to income deprivation for both all-cause mortality and mortality from circulatory diseases (Mitchell & Popham 2008). Empirical evidence demonstrates that urban greenspace provides unique outdoor educational opportunities (Kahn & Kellert 2002) and facilitates social networking (Hitchings 2010). It should be noted that considerable controversy surrounds what constitutes robust and reliable evidence for these types of research. Much of the well-being-related research is placed in the context of physical and mental health and has been criticised for not meeting the medical professions' exacting requirements for robust quantitative evidence (Newton 2007). These criticisms should not be used to discount the wealth of qualitative research into greenspace and human well-being, but should alternatively be used to improve the quality of research and the conclusions they produce.

Ongoing research in England on associations between physical access to greenspace, frequency of use, physical

activity and health draws together diverse spatial and social data (see Hillsdon *et al.* 2006; Jones *et al.* 2009; Coombes *et al.* 2010). Research conducted in Bristol indicates that frequency of greenspace use declines with increasing distance from the home, thus suggesting a significant relationship between physical activity and accessible greenspace.

Children's access to nature and its impacts on their health and well-being: Open greenspace and access to nature are important for children (Kahn 1999; Kahn & Kellert 2002; Bingley & Milligan 2004; Michell & Popham 2008) and this consideration has been included in recent education policy. The outdoor environment is perceived as a social space which influences their choice of informal play activities and promotes healthy personal development (Burgess *et al.* 1988). Bingley and Milligan (2004) assessed how recalled childhood play experiences (from ages 7 to 11 years) in the form of memories and imaginings have an influence on the mental well-being of adults. The authors concluded that childhood experience of unstructured play with minimal adult supervision, in woodland areas, significantly influenced the perception of woodlands in adult life and the seeking out of outdoor spaces when stressed.

It is also known that children's social play, concentration and motor ability are all positively influenced by playing in nature. Yet the opportunities for children resident in both urban and rural neighbourhoods to join in safe play are rapidly diminishing, in part because of parental fear of crime and volume of road traffic (Holloway & Valentine 2000, 2003). Children spend less time outdoors today than they used to, a situation whose likely consequence is that children have become more disconnected from the natural environment (Bird 2007).

17.5.4.4 Aesthetics—places and landscapes

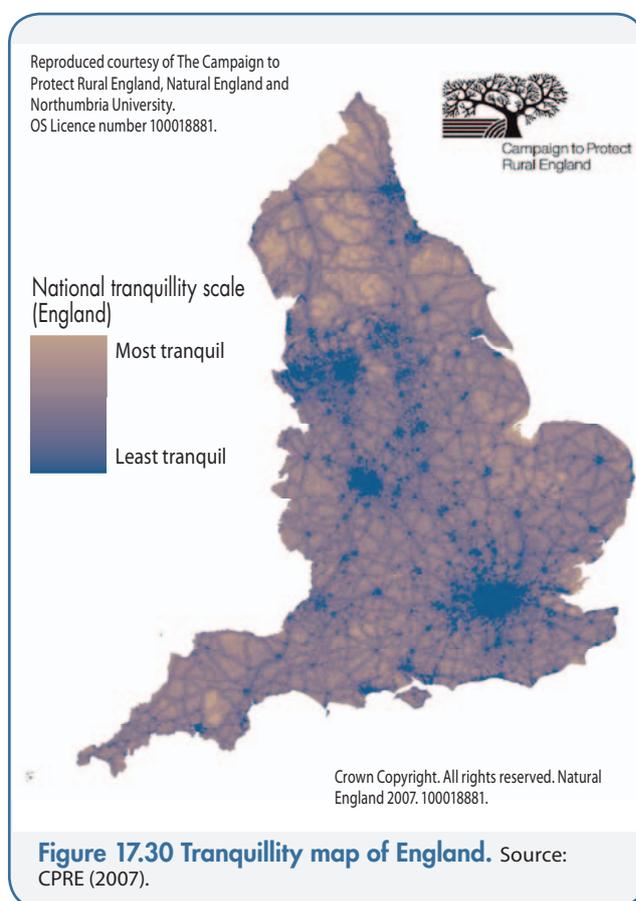
As a cultural service, aesthetic experiences of places and landscapes provide enjoyment, inspiration and contribute to human well-being. This 'good' is produced through people interacting with aesthetic qualities in local places and landscapes. For example, openness and remoteness in landscapes have been linked to feeling calm and relaxed (Natural England 2009a). Aesthetics and inspiration overlap with and potentially support other cultural benefits, by contributing to a distinctive sense of place, to the cultural value of a particular site, to places which have spiritual value, and to the enjoyment afforded by tourism and recreation. Qualitative research investigating how people connect to nature invites participants to compose poems or keep nature diaries in order to express how places are meaningful to them (Natural England 2009a).

Aesthetics and well-being: Research into the basis of aesthetic preferences has shown the importance of natural landscapes for feelings of safety, inspiration, harmony, peace and security (Appleton 1975). Links have been made between aesthetics and environmental ethics, where people potentially show greater care and concern for places that they find aesthetically valuable. For example, motivations of individuals engaged in community gardening and forms of environmental volunteering in various locations in England have been shown to be associated with aesthetic values (Brady 2006). Another example of aesthetic values interacting

with emotions is the feeling of tranquillity and calm that can be engendered by a landscape (Natural England 2009a). The Campaign to Protect Rural England mapped tranquillity in England using a variety of datasets and undertook a nationwide survey to ascertain the experiences people associated with tranquillity (**Figure 17.30**).

In the post-war period, various factors indicated decreasing opportunities for aesthetic and inspirational experiences of local places and socially valued landscapes. Changing patterns in population and work, as well as the expansion of urban settlements, suggest that there are fewer opportunities to interact with rural landscapes. However, the creation of National Parks, Areas of Outstanding Natural Beauty and Landscape Character Assessments, as well as recent efforts to protect marine and coastal areas, have provided protection of landscapes of high aesthetic value and enabled their enjoyment by both visitors and residents. Ecological restoration and re-wilding projects have also provided new opportunities for aesthetic interaction, especially where places have been managed for optimum biodiversity and the restoration of qualities associated with high aesthetic value, such as wildness.

There has also been a rise in local initiatives to protect and manage places (e.g. Wildlife Trusts, community orchards), which have raised awareness and provided more everyday opportunities for aesthetic enjoyment and inspiration within and at the fringes of towns and cities (Clifford & King 2006). Establishing local nature reserves and other local greenspaces will enable more people to be stimulated by natural spaces.



17.5.4.5 Education

One way to increase children's contact with nature is within the formalised educational system, both in terms of the amount of exposure to nature in the learning environment and learning about nature (green education). The Office for Standards in Education (OFSTED 2008) has recently published guidance on learning outside the classroom. Outdoor learning is more than just fieldwork for natural history or geography: it is the notion that outdoor settings facilitate learning in all disciplines (Rickinson *et al.* 2004). Learning through Landscapes (LTL) is a UK national charity running programmes in England that funds independent research to evaluate the success of its interventions and demonstrates the value of outdoor learning. A national survey of 351 schools by LTL (2003) indicated that 75% of school improvements were driven in part by ecological motivations.

17.5.4.6 Religion and spirituality

Evidence, ecosystems, religion and spirituality: We face serious problems when assessing the extent, condition or configuration of English ecosystems as they contribute to spiritual and religious experiences. Cooper (2009), for example, devotes most of his paper to biblical exposition, seeking to explore 'the implications of a Christian worldview for the practice of valuing ecosystem services'. Empirical social scientific evidence of the extent and nature of religious and spiritual beliefs or experiences related to nature are much harder to find. At the risk of gross simplification we can identify two key issues, both legacies of the Reformation. The first is the uncertain status of sacred spaces and species in Protestant theology and ecclesiology. Sacred spaces and their spiritual value have been discussed at great length in contemporary writings (e.g. Brown 2004; Inge 2003; Sheehy 2007; Wynn 2007, 2009). Sacred species have received less attention in England; however, a flavour of their value can be found in the Flora Britannica (Mabey 1996) which assembles folklore, ecology, poetry and anecdotes from varied contributors. The second key issue is the rise of new forms of religiosity and religious pluralism. It is important to note that other religions such as Islam, Hinduism and pantheistic traditions also find spiritual inspiration through natural environments, with some placing particular importance on special species or places.

People, places, landscapes and religious/spiritual goods and benefits: In a religious/spiritual context, ecosystem goods and benefits refer to instances where ecosystems play a positive and formative role in religious practice and faith as well as providing a framework within which human accomplishments and aspirations can be considered. Historically, the Anglican Church has not had a strong tradition of sacred places. However, the 20th Century has witnessed a modest reassessment within the Anglican Church concerning ideas of pilgrimage, retreats and sacred spaces. In the 1990s this movement became a multi-faith phenomenon, with examples emerging from other faith traditions in England. For example, in Manchester at the Cheetham Al Hilal Community Project, the Muslim community has participated in an innovative project to improve the built and natural environment including the

creation of a garden with an Islamic theme. The Sacred Land Project, supported by the World Wildlife Fund and launched by the Archbishop of Canterbury in April 1997, set out to revive and create sacred sites in Britain and overseas and involved Buddhist, Christian, Hindu, Jewish, Muslim and secular communities. Two examples of Sacred Lands Projects from the website are given in **Boxes 17.1** and **17.2**.

Whilst little explicit evidence from England exists, Hay and Hunt (2000) report on people's religious or spiritual experiences in Britain. Based on national survey data, the proportion of the population claiming to have had such

Box 17.1 Cultural services: sacred cave in North Yorkshire.

In Knaresborough in North Yorkshire is the ancient shrine of Our Lady of the Crag, in a cave cut into the rocky crags overlooking the river Nidd (**Figure 1**). According to local legend the shrine was dedicated to Our Lady in the 12th Century by John the Builder in thanks for a miracle that saved the life of his son from a rockfall. Nearly 500 years ago the shrine was suppressed during the Reformation, and became neglected and forgotten. In the early 1990s, a local group formed to renovate the shrine and to create a sacred garden around it, supported by the Sacred Land project. Now a new Madonna and Child, the work of Yorkshire sculptor, Ian Judd and commissioned by Arts and Sacred Places, has been installed in the cave.

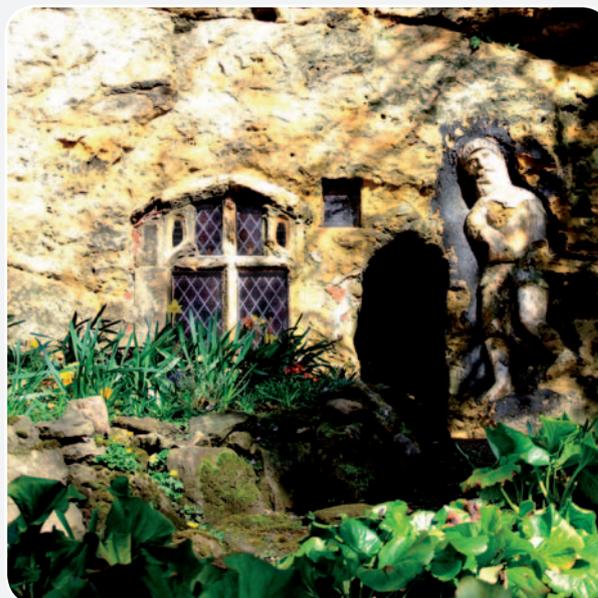


Figure 1 Chapel of Our Lady of the Crag. Photo by R/DV/RS available under a Creative Commons Attribution license.

Box 17.2 Cultural services: sacred gardens in Leicester.

In Leicester, in a predominantly Hindu neighbourhood, a sacred garden was inaugurated in October 2000 beside Rushey Brook in the grounds of Rushey Mead School. The idea for the garden was inspired by Friends of Vrindavan, a Hindu community group whose inspiration comes from the sacred forests of Krishna in Vrindavan, India. The garden is based upon the theme of Krishna's struggle with the serpent Kaliya, who poisoned the sacred River Yamuna in Vrindavan. This theme was chosen to symbolise the struggle to clean our rivers and environment. Pupils of Rushey Mead School have created their own works of art to be placed in the garden.

experiences increased between 1987 and 2000 from 48% to 76%, with awareness of a sacred presence in nature increasing from 16% to 29%. Perhaps the most common natural environments that foster spiritual experiences are churchyards and burial grounds, as evidenced by the Church of England's average weekly attendances of over 1 million (Church of England 2007). Whilst relatively few studies have focused empirically on religious experiences that are linked to particular places and ecosystems, the popularity of nature hymns at family services such as weddings and funerals (e.g. All Things Bright and Beautiful, Morning Has Broken) suggest its underlying importance to spiritual inspiration.

Whilst most research focuses on the built environment, a few academics are focusing on the practice of pilgrimage rather than the destination (Coleman & Eade 2004). The importance of nature and the countryside to English national identity occurs in political, social and literary writings, some of which are explicitly linked to religious discourses. Matless (1998) shows how advocates of organic farming and ruralism both drew from and developed Christian thinking. Moore-Colyer (2001) has examined one of these thinkers, Rolf Gardiner, and his attempts to enlist Church leaders and congregation members in a greater understanding of the spirituality of nature and of rural living. These strands of thought suggest that for some individuals, important spiritual experiences take place whilst interacting with nature via farming, gardening and a rural lifestyle.

Alongside the growth of pilgrimage as 'moving through nature', there has also been a growth during the 20th Century in the popularity of religious retreats to particular places in natural surroundings. There are currently 132 places of Christian retreat in Britain listed by the Retreat Association. David Conradson at Southampton University is researching retreat centres in southern England, using participant observation and interviews with monks and guests. Two Benedictine places of retreat in southern England, Alton Abbey and Elmore Abbey, are explored in Conradson (2008). His work demonstrates clearly the spatiality of these religious places, not just the abbey buildings themselves, but also the surrounding gardens and countryside. So for those on retreat, the 'stillness' they seek may be found in both the Benedictine monastic liturgy and in the abbey grounds and gardens.

It is extremely hard to pinpoint evidence of particular landscapes or ecosystems being conducive to spiritual and religious experiences. The configuration of marine and coastal habitats which appear to contribute to spiritual/religious experiences for some visitors at the holy island of Lindisfarne have to be seen in the context of other highly popular sites of pilgrimage that are inland and not characterised by dramatic landscape/ecological characteristics, such as Walsingham in North Norfolk with its woodlands and understorey of dense snowdrops. There is relatively little evidence on the specific role of nature and religious pilgrimage in human well-being. Conradson (2008) couches his research in terms of the therapeutic role of stillness and so, by implication, religious places are important to human well-being in their provision of 'therapeutic stillness'. Clearly diminution of the qualities (peace, beauty) that characterise journeys of pilgrimage and places of retreat would, potentially, have a marked impact on the well-being of participants.

Wynn (2009) seeks to explain how "our encounter with particular places, each characterised by its own phenomenology and distinctive possibilities for bodily appropriation, may prove to be religiously significant" (p44). He outlines three ways in which this might be the case. First, particular places may come to hold a religious significance because they carry some microcosmic significance, epitomising in some way the nature of things more generally. Second, God is taken to be presupposed in some particular, material context which may be a place or landscape or habitat. Third, specific places represent the meaning of past religious events that occurred there. In all three contexts, the religious experiences can have positive implications for faith, relationships and action. In the first and second of these possibilities, outdoor and open places may be more important than the traditional built or enclosed sites of religious devotion.

17.6 Drivers of Change

The environment is constantly changing as a result of a number of natural and anthropogenic drivers of change. These drivers put pressure on the environment, which affects ecosystems and the services they provide. The drivers may be direct, such as land use, and modify the physical, chemical and biological processes in, and nature of, ecosystems. Indirect drivers are of more anthropogenic origin and affect human impacts on ecosystems through such things as subsidies or policy development. These may then feed back into the direct drivers, for example, by causing changes in land use. Both types of drivers have varied across England and through time in their importance and impacts, which may be represented as threats or opportunities. **Tables 17.16** and **17.17** outline the key post-Second World War drivers and some of their effects, whilst more detailed information can be found in the be found in Section 17.4 (Broad Habitats).

Given that agriculture and forestry affect about 80% of England (Natural England 2008), then changes in farming practices and agricultural policy will have an important effect on the sustainability of ecosystem services through their direct effect on production, and indirectly through the regulating and cultural services. Since the 1950s, there has been increased specialisation and intensification of agricultural land, which has resulted in habitat loss and degradation. This has led to consequent changes in species composition and the loss or reduction in species populations, such as farmland birds, and has damaged soils, depleted aquifers, drained wetland sites and impacted surrounding habitats through agrochemical runoff. There is some evidence that some of these adverse effects are now mitigated by agri-environment schemes (Natural England 2009c), but also by other mechanisms and initiatives, such as the Voluntary, Catchment Sensitive Farming Delivery and Tried & Tested nutrient management plan initiatives. Also, in recent decades more environmentally favourable management practices have been advocated in forestry. An assessment of the environmental and economic

Table 17.16 Direct drivers of ecosystem change in England (continued over).

Main driver	Specific driver	Description
Habitat change	Productive area: expansion, conversion, abandonment	Arable cultivation has expanded significantly in post War years, although the latest Countryside Survey indicates an 8.8% decrease in area in the first decade of the 21st Century (Carey <i>et al.</i> 2008). Coniferous plantations have expanded to accommodate production forestry. In the lowlands, semi-natural habitats, including heathlands, fens and Woodlands are commonly managed less intensively or abandoned. Semi-natural Grassland declined by 97% in England and Wales due to fertiliser application.
	Mineral and aggregate extraction	There has been a long-term decline in coal mining with extensive restoration of despoiled areas. Open cast coal mining has expanded dramatically in the last 50 years most extensively in the North East. English coalfields now account for approximately 50% of production. More complex trends in the mining and quarrying of other minerals have been observed. The amount of marine aggregate extraction has more than doubled in the past 50 years. Although current extraction is concentrated in previously worked areas, a large part of this reserve is a finite resource.
	Urbanisation and sealed surfaces	In recent years there has been a significant switch from building on agricultural land to building on previously developed sites (brownfield), but this can lead to loss of valuable space for invertebrates and plants (Angold <i>et al.</i> 2006; Natural England 2008). Urban sprawl is limited by green belts and their area is stable. Increased paved surfaces lead to loss of services through increased urban heat islands and rapid storm runoff. Cities in England have taken action to increase urban trees and other greenspaces in order to combat some of these effects (Woodland Trust 2010).
	Infrastructure	Increasingly, space in England has been designated support infrastructure for society. The 2010 National Infrastructure Plan describes examples of infrastructure in need of improvement, including the approximately 299,300 km of public sewers in England and Wales. There has also been a rapid growth in demand for goods and travel, which have increased road use by 85% since 1980. If unchecked, congestion could cost England £22 billion in wasted time yearly, and could increase costs to businesses by £10 billion.
	Conservation management	There have been major increases since 1986 in the number of farmed areas in agri-environment schemes. In 2009, there were 42,500 agreement holders enrolled in the Entry Level Scheme and 4,300 agreement holders in the Higher Level Scheme, an increase from 28,500 and 1,200 in 2006 respectively. SSSIs comprise 7% of English land area and as of 2009, 95% were judged to be in favourable condition. There have also been significant increases in the land area managed by conservation NGOs in England (e.g. the National Trust, RSPB and Wildlife Trusts).
Pollution and nutrient enrichment	Pollution emissions and deposition	There have been major reductions of black smoke and sulphur dioxide emissions indicated by increasing extent of lichens and rising soil pH. There has been an improved biological and chemical quality of many of England's rivers since 1990, but increasing anthropogenic nitrogen emissions have led to widespread eutrophication of habitats. Approximately 60% of England's waters are considered eutrophic.
	Nutrient and chemical inputs (fertilisers; pesticides)	Dramatic increases in fertiliser application led to rising nitrogen and phosphorus concentrations, which have been associated with reductions of grassland biodiversity. For nitrogen, the major inputs to soil are from fertilisers and manures. In recent years agrochemical use has declined modestly. While pesticide use increases, as does their toxicity and persistence, usage increases do not directly equate to increased environmental impacts. Pesticides and herbicides are strongly linked with declines of farmland biodiversity.
Main driver	Specific driver	Description
Overexploitation of resources	Livestock stocking rates	Livestock populations have risen and declined over the past 50 years resulting in overgrazed uplands and the intensification of lowland farming. The increases in pigs and poultry have mainly been in housed rearing systems, but mostly have indirect impacts e.g. through the release of ammonia and disposal of slurry.
	Fisheries harvesting	In 2008, the total landings into England by UK vessels was 89,313 tonnes. Aquaculture is playing an increasingly important role in supplying the high demand for fish in the UK, with England contributing 6% of the output, mostly rainbow trout and mussels (James & Slaski 2009).
	Water abstraction	Overall trends in water abstraction amounts do not indicate a clear trend. Water abstraction by agriculture is a small part of abstraction, but has declined in recent years, although it may increase under climate change.
	Timber harvesting	From 1976 to 2009, softwood timber harvests have increased by 54%, while hardwood timber harvests have fallen by 46% (Forestry Commission 2010). Changes in woodland management have impacted forest structure, increasing the density of high forest with closed canopies, denser shading and less floristic diversity. However, a recent revival in traditional woodland practices, including the production of traditional coppice products, may help increase woodland biodiversity.
	Agricultural harvests	Seventy percent of England is designated as agriculture, focused in the lowlands, though pressure for stock grazing has increased expansion into the uplands. Cereals (mainly wheat and barley), oilseeds and other arable crops, such as sugar beets, comprise 71% of the crop area, with potatoes making up a further 2%. Land designated to agriculture in England has fallen by 2.8% from 1990 to 2007 (Countryside Survey 2009; Defra 2009c).

Table 17.16 continued. Direct drivers of ecosystem change in England.

Climate variability and change	Temperature and precipitation trends	Mean annual temperatures have increased across England particularly in East Anglia and the south east. The growing season has increased notably in northern England. Air frost incidence has reduced and there has been a 0.7°C increase in sea surface temperature since 1980. Annual mean precipitation has not changed, but there has been a decrease in summer precipitation.
	Carbon dioxide and ocean acidification	Though other parts of the UK are net sinks, England is a net source of carbon dioxide because agriculture and urban areas are sources of greenhouse gas emissions, although this has declined recently (DECC 2010). The highest emissions come from Greater London, followed by the north west. Carbon dioxide emissions have resulted in increased ocean acidification, with an average pH decrease from 8.2 to 8.1.
	Sea level change	Sea levels have risen 10 cm around the UK since 1900 (Jenkins <i>et al.</i> 2009). This poses threats of coastal flooding and erosion, especially in the south and east of England. It will also increase the salinity of rivers and ground water, impacting fish stocks, recreation, and access to fresh water.
	Extreme weather events	The observed (1960–2006) climate changes are projected to continue, with decreased summer precipitation and increased summer temperatures which may lead to drought, with increased winter precipitation and summer downpours leading to flash floods (Jenkins <i>et al.</i> 2009).
Introductions of invasive species and domestic species	Crop, livestock and forest species introductions	New crop strains have been developed from imported germplasm (e.g. short-straw varieties of wheat), and have helped increase yields for some crops more than threefold. Changes in crop types have also occurred, notably the introduction in the 1970s of oil seed rape as a crop which is now extensively grown, and, more recently, the production of bioenergy from <i>Miscanthus</i> grass and short rotation coppice. Significant genetic changes to livestock breeds used in commercial production have occurred (e.g. use of Holstein-type cattle for genetic improvement of dairy herds) and a range of imported beef, cattle and sheep breeds are now widely reared (e.g. Simmental and Charolais beef cattle; Texel sheep). Intensive livestock and crop husbandry practices have also contributed to high yielding farming systems. Introduced conifer species, such as Sitka spruce, were used increasingly in forestry in the first decades after World War Two, but this use has not intensified in recent decades.
	Alien and non-native invasive species	More than 100 non-native plant and animal species have been identified as invasive species. Non-native plants are not common components of English rural vegetation as most occur in urban areas, but may become so with climate change. The majority of introduced species appear to cause no adverse impacts, while some cause widespread damage (e.g. Dutch Elm Disease). Many ornamental/exotic plant species have increasingly established wild populations and whilst many remain very local, others have spread to become abundant and problematic e.g. Australian swamp stone crop (<i>Crassula helmsii</i>).
	Outbreaks of native species	Some opportunist native species have persisted through changes to habitats and climate, and have capitalised on vacant niches. These include foxes and some bird, bat and invertebrate species in urban environments. Deer populations, especially roe deer (<i>Capreolus capreolus</i>), have increased dramatically since the removal of predators. Plants such as ragwort (<i>Senecio species</i>) have spread, especially along railway tracks.
	Extinctions and declines	Four hundred and twenty nine species have disappeared from England, mostly in the past 200 years (Natural England 2010b). The UK Biodiversity Action Plan and the England Biodiversity Strategy identified 943 species as being of conservation concern.

sustainability of agricultural production systems in the UK showed that land use and greenhouse gas emissions are the most significant factors determining sustainability (Glendining *et al.* 2009). It also suggested that agricultural systems are sustainable at rates close to current production levels and that extensification would result in the loss of non-food ecosystem services, so intensification would be preferable, although recent changes in the price of oil and the value of arable crops and livestock may affect this balance.

Indirectly, changes in policies have impacted agricultural land. For instance, the introduction, and later the cutback, of EU mandated set-aside land on farms affected farmland species. Removal of this requirement left each country to encourage policy uptake, as with Natural England's Environmental Stewardship programmes. Similarly, the EU CAP reform in 2013 could have a significant effect, not only on the English landscape, but also on biodiversity and ecosystem service delivery.

Atmospheric pollution has had a major effect on habitat condition and composition and decreased species richness. Critical loads are being exceeded for a number of chemicals, leading to acid deposition, eutrophication, ground level ozone and heavy metal pollution, although in some cases the situation is improving (RoTAP 2011).

Development, another major driver, is limited in part by legislation such as the Green Belt Policy, which regulates expansion of cities in order to control urban sprawl. However, development continues to happen, especially on greenfield sites, and will continue to do so due to increasing demand for housing. Between 2000 and 2003, 34% of all development happened outside of existing urban areas, on agricultural or other non-urban land (Natural England 2008). This profoundly affects the landscape, species dependent on the lost habitat, and the quality of services that can be expected from a built area (Natural England 2008). Positively, assessment of past mistakes, some developing

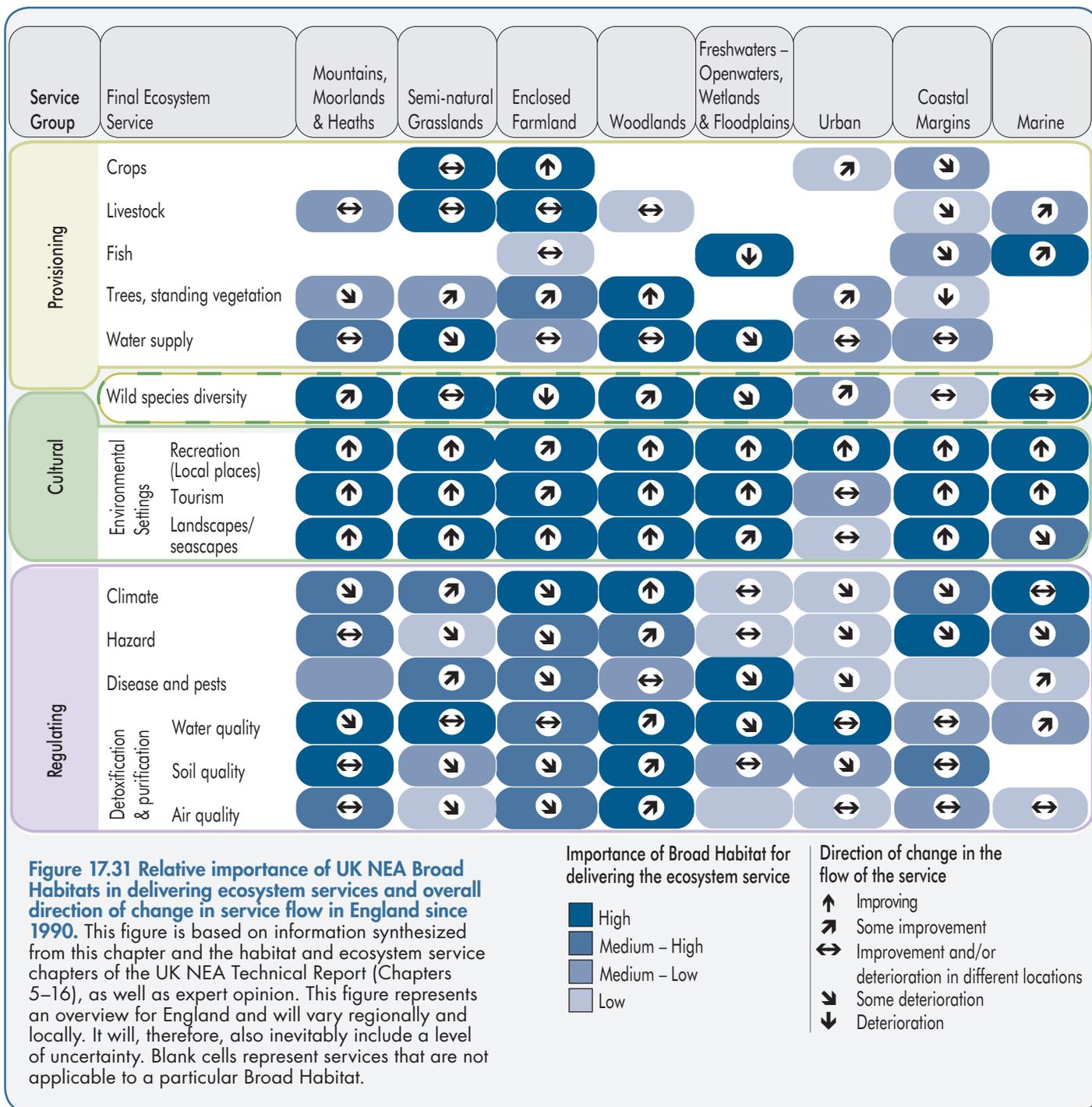
Table 17.17 Indirect drivers of ecosystem change in England.

Main driver	Specific driver	Description
Socio-political	Legislation, regulation	Key areas of legislation/regulation have been: town and country planning, pollution control, emissions regulation, protection of biodiversity, amenity and natural beauty.
	Financial support mechanisms	The 1947 Agriculture Act and 1973 EU Common Agriculture Policy (CAP) shaped agricultural production subsidies resulting in the transformation of most semi-natural systems into farmland. Recent CAP reform has decoupled production and financial support. Increasing farm payment has come through agri-environment schemes, which supported 65% of English farms in 2009. Thus financial support solely encouraging production is replaced by financial support that enhances biodiversity and promotes multi-functional forestry. A growing NGO movement has supplemented public investment in environmental management for conservation and other purposes.
Economic	Market forces	Markets for agricultural and horticultural produce have impacted most ecosystems, given the extent of agricultural land in England. Arable cultivation and dairy farming are currently the most profitable, while livestock and mixed farming are the least profitable. Niche markets include organic produce and natural products (e.g. reeds for roof thatching), which play a role in sustaining management of some ecosystems. The market collapse of charcoal and traditional forest products has resulted in the large-scale abandonment of broadleaved woodland management, however, the growth of biomass fuel markets may reverse this trend. Fish consumption has contributed to declining fish stock and the disturbance of marine habitats.
	Business size and globalisation	Primary products are supplied by a large number of small producers, while other parts of the supply chain are increasingly dominated by a small number of multi-national agricultural corporations that impose price and quality contrasts upon production.
Science and technology	Innovation / technological change	Mechanisation has enabled the intensification of farm production (greater efficiencies of ploughing, harvesting, etc.). The expansion in fertiliser and pesticide use further increases agricultural intensification. Precision farming has been introduced recently to improve resource use and moderate environmental impacts. Similar transformations of commercial forestry and commercial fishing have occurred.
	Biotechnology	Genetically Modified crops have been heavily regulated and their impact upon farming practices negligible. However, there have been major innovations in plant and animal breeding e.g. development of rape as an oil seed, short-straw wheat, and Holstein genetics in dairy cattle.
	Energy production	Fossil fuels and nuclear have been the dominant energy sources of the 20th Century. Policy changes to support renewable energy have led to increased wind power generation and the expansion of biofuel crops and short rotation coppice. Modest increases in woodfuel consumption has occurred, with some biodiversity benefits in neglected woodlands.
	Transport	Major increases in transport mechanisation have resulted in major road expansion, while increased global air and shipping freight may have increased rates of alien species introduction.
Cultural and behavioural	Consumption choices	Consumer choice of foodstuffs has increased sharply and currently represents a lower proportion of income. There has been more recent consumer interest in organic, local and other more sustainable consumption.
	Attitudes and the media	There has been a significant increase in media coverage of environmental issues in the past 50 years, increased membership of environmental NGOs (e.g. RSPB, Wildlife Trusts) and greater environmental awareness amongst the English populace.
	Knowledge individual & societal	The understanding of key issues, such as the health impacts of air pollution, biodiversity loss and environmental impacts of acid rain have driven significant changes of policy.
Demographic	Population and demographic change	England's population grew by 10.1 million from 1951 to 2008 giving rise to population densities that can reach 3.95 people per hectare. This is the highest in the UK and one of the highest in the world. There is, however, significant variation in population density which reaches 131 people per hectare in Kensington and Chelsea, but is only 0.2 people per hectare in Eden, Cumbria.
	Migration and ethnicity	Net migration from abroad has become a main contributor to population growth in England (Jefferies 2005). There has also been a significant internal migration of UK population towards southern England and movement of people out of metropolitan areas (Champion 2005). Ethnic diversity in England has increased significantly in the past 50 years (Jefferies 2005).

technologies and careful planning can offer opportunities to lessen our environmental impact. For example, the maintenance, or sometimes restoration, of brownfield sites can increase habitats for certain species. This can be especially important in invertebrate conservation, as at least 40 invertebrate species are confined to brownfield sites (Natural England 2008). Sustainable housing and transport will play a pivotal role in how we impact the environment, whilst changing agricultural practices to low-input (and possibly smaller-scale) operations will affect large areas of land and habitats.

17.7 Consequences of Change

The accounts of the Broad Habitats (Sections 17.4.1 to 17.4.8) have shown that each delivers a range of ecosystem services, but they vary in their importance for delivering specific services. They also vary in the recent trends in their ability to deliver ecosystem services (**Figure 17.31**). This figure provides an overall picture of the relative importance of each Broad Habitat for ecosystem service provision, but it was derived from available literature and



expert opinion and can conceal high intra-habitat and regional variations. It thus should be taken as indicative rather than definitive.

Amongst the provisioning services, Enclosed Farmland and Semi-natural Grasslands are of highest importance for crops and livestock and Woodlands for timber, whilst many of the semi-natural habitats are important for water supply. For the regulating services, Enclosed Farmland, Woodlands and Mountains, Moorlands and Heaths are of high or high-medium importance. This serves to underline the significance of these habitats, which is partly a consequence of their large areal extent, but also of their structure and functioning. The high importance of all Broad Habitats for cultural services reflects their value to human health and well-being through people's direct experience.

Our more limited knowledge of the ecological trends of Urban habitats makes assessment of change in their ecosystem service delivery difficult to assess. Similarly, our more limited knowledge of Marine habitats over time limits our ability to assess the change occurring in the ecosystem services they deliver.

Changes among ecosystem service delivery in the eight Broad Habitats over the last 20 years have shown that a significant proportion of service provision has declined (Figure 17.31). These adverse trends are likely to be even more noticeable over the longer timescale of the last 50 years, especially amongst regulating services. However the period since 1998 has been one in which England's countryside has remained relatively stable in ecological character by comparison with the last decades of the 20th

Century (Carey *et al.* 2008); although, as noted above, we know much less about recent change in the Marine and Urban environments. Further, there is now a range of mechanisms in place to variously restore biodiversity, Broad Habitat function and/or ecosystem services. Although this list is far from complete, these include improvements in the management of the protected area series, including approximately 7% of England which is notified as SSSI (95% of which is currently in favourable or unfavourable recovering condition); implementation of the EBS, which has ambitious objectives to increase the area of priority habitats (Defra 2006a); a major expansion of agri-environment schemes delivering a range of ecosystem services (Natural England 2009c); coastal realignment at 23 sites on the English coast, providing natural flood protection and a range of other services (Morris *et al.* 2008).

Despite these changes in service delivery, England's ecosystems provide considerable benefits to humans, both in terms of well-being as well as economically. In recent years, the economic value of ecosystem services has been demonstrated in a wide range of studies relevant to policy and other decisions (e.g. Shepherd *et al.* 2007; Willis *et al.* 2003; Harlow *et al.*; Chapter 22).

However, given the multiple drivers which affect the Broad Habitats, it is important that they are protected and managed sustainably in order to continue future service delivery (Section 17.8). This is particularly challenging, as some of the main drivers, notably air pollution and climate change, cannot be addressed by local ecosystem management alone and require action across all of society. The drivers will affect ecosystems and service delivery in two main ways in the future, firstly, through competition for space and, secondly, through changes in habitat and species condition. The projected population expansion and the associated demands for housing and infrastructure (particularly in southern England) and food provision are likely to lead to additional habitat loss, although there could be opportunities to minimise these losses through the development of brownfield sites and further use of biotechnology. Whilst regulation has reduced the emissions of many major pollutants and improved habitat condition, population pressure and climate change will continue to affect future pollution risks to the natural environment (Natural England 2008). Climate change will directly affect the distribution, condition and functioning of habitats, which will pose challenges for their conservation. It will also lead to sea level rise affecting marine and coastal habitats, the spread of pests and diseases and opportunities for cultural pursuits.

17.8 Sustainable Management

The drivers of change (Section 17.6) and the consequences of changes observed since the Second World War (Section 17.7) have shown the need for sustainable management if

ecosystems are to continue meeting the needs for human well-being. This was captured by the UK's Sustainable Development Commission, which had as one of its principles 'Living within environmental limits—respecting the limits of our planet's environment, resources and biodiversity—to improve our environment and ensure that the natural resources needed for life are unimpaired and remain so for future generations' (Defra 2005). In England, the Natural Environment White Paper, due in 2011, will outline the government's vision for the natural environment.

The Convention on Biological Diversity endorsed the application of the ecosystems approach at its fifth Conference of the Parties, as a strategy for the integrated management of land, water and living resources, and at the seventh Conference of Parties it gave priority to facilitating the implementation of this approach. The ecosystem approach is being promoted by Defra through its Ecosystems Approach Action Plan (Defra 2007a, 2010g) and is seen as involving a more holistic and integrated approach based on a consideration of whole ecosystems; it requires that the value of ecosystems and their services is reflected in policy and decision making across Government departments. In England, the Action Plan is also being taken forward by non-departmental public bodies such as Natural England, the Forestry Commission and the Environment Agency and they are undertaking case studies demonstrating the benefits of the approach (Everard 2009; Harlow *et al.* 2010). An evidence base is also being developed through such projects as Making Space for Water and Valuing Ecosystem Services in the East of England (Glaves *et al.* 2009), and several projects funded under the Asset Management Programme (AMP; Anderson 2010; Water UK 2009), which test and demonstrate the application of the ecosystems approach. In addition, tools for valuing ecosystem services have been developed and applied to support environmental management decisions. These have shown the importance of a healthy natural environment for current and future economic prosperity, as well as a range of societal benefits (e.g. Defra 2007c; Natural England 2009e; Chapter 22).

As discussed below, there are many potential trade-offs between ecosystem services. Arguably the most significant change in ecosystem services in the past 50 years has been the dramatic increase in the provisioning service of food production, which has resulted in a prolonged period of food security in England. For example there has been a 320% per hectare increase in wheat production (Section 17.5.3.1) that has had an adverse effect on regulatory services (e.g. climate regulation and hazard regulation) and cultural services (e.g. aesthetics) (Braat *et al.* 2008; de Groot *et al.* 2010).

Understanding the underlying economic process is critical to interpreting these changes and identifying solutions. Most provisioning services create goods (e.g. food and timber) that can be sold, which then enables producers to increase their supply by intensifying production systems, or overexploiting wild stocks. In contrast, most regulatory and cultural services are public benefits for which beneficiaries do not pay, so those who manage or exploit ecosystems are unrewarded. There is currently much interest in payment for ecosystem services (PES) schemes, which pay ecosystem owners and managers for the supply of non-market goods and benefits from ecosystem services, as a mechanism for

supporting a more balanced supply of ecosystem services (Defra 2010e). It is important to note that such approaches are difficult to apply to marine ecosystems where the property rights needed to operate such schemes do not apply, other than in some intertidal situations. Regulatory and voluntary regimes will continue to play a significant role in management of marine ecosystems.

The largest PES scheme in England is the government's agri-environment schemes under the Rural Development Programme for England that explicitly promotes conservation of genetic diversity of livestock, flood regulation and the protection of soil and water. It also plays a significant role in the protection of biodiversity, landscape and historic heritage. Other services such as pollination and climate regulation are incidental benefits of the schemes. In 2009, agri-environment scheme agreements covered over 6 million ha (66% of England's agricultural land) and provided payments of approximately £400 million a year to farmers (Natural England 2009c). Private investment in PES is also occurring, for example, water companies are investing in bog restoration and other forms of habitat management in several upland catchments that supply potable water, such as in the Forest of Bowland and the Peak District. The objective is to improve raw water quality and thereby reduce water treatment costs in the future, but the scheme may simultaneously improve water storage, carbon storage and biodiversity (Anderson 2010; Water UK 2009). Further water industry-funded catchment management schemes in the lowlands have focused upon reducing inputs of nutrients and pesticides from farming (Water UK 2009).

The current state of land use, as well as the needs of the future, were assessed by the Foresight Land Use Futures Project (FLUFP 2010). Among its objectives was an assessment of strategies for sustainable land use and methods to increase its value for people and the economy. It recognised the importance of public goods and services provided by the land and the amount of England's landscape that is held in private ownership. It also highlighted potential pressures on land in the South East, as well as water use in the South East and the East of England. To ensure the continued delivery of these services it suggested promoting the multi-functionality of land as an appropriate and potentially sustainable response, through an area or catchment-based approach to land use policy. An additional future consideration for landscape planners and policy makers is the range of potential impacts of climate change that will require a land use planning approach that integrates strategies for mitigation and adaptation to climate change.

17.8.1 Synergies and Trade-offs

The development of such a multifunctional approach to land use would require the recognition that any ecosystem delivers a variety goods and services and the setting of multiple objectives for its management. This requires an integrated understanding and management of ecosystems, including synergies and trade-offs between ecosystem services under different land uses and management regimes.

There are concerns about a perceived trade-off between the conservation of natural resources and economic growth (Natural England 2009e), with the former often regarded

as a luxury and the latter as a necessity (Dasgupta 2007). However, the evidence currently suggests that the two need not conflict and that natural, ecosystem-based solutions can be cost effective in addressing environmental issues, such as climate change adaptation, with potentially profound economic consequences (EFTEC 2009; TEEB 2009). For example, there are several documented cases of floodplain restoration providing benefits for both water regulation and biodiversity. Morris *et al.* (2004a) provide five case studies that demonstrate both the compatibility and conflict between flood defence, biodiversity and other ecosystem services, these studies include the Beckingham Marshes, River Trent, Long Eau Washlands and Lincolnshire and Harbertonford Flood Alleviation Scheme.

Similarly, the 23 English managed coastal re-alignment schemes (Morris *et al.* 2008), which relocated sea walls and restored intertidal habitats, provided synergies between increased natural flood protection and a range of other ecosystem services. One such example is the Wallasea Island Wild Coast, Europe's largest intertidal habitat creation project at over 700 ha (Morris *et al.* 2008, RSPB 2008). Its multiple objectives include creating new intertidal habitats to compensate for habitats and species losses elsewhere, reducing coastal flood damage risks, carbon storage, protection of potential nursery habitats for commercial fish stocks and an extensive area of accessible coastal land for recreation and the enjoyment of nature. A further interesting synergy is the use of material from Crossrail, the new rail route under London, for habitat creation. Negative effects on habitats and ecosystem services by the scheme were assessed as negligible or minor, since the project used materials excavated during construction for mitigation of negative impacts through habitat creation.

There are particular concerns about the synergies and trade-offs between ecosystem services when transformation occurs between habitats, particularly when changes in service provision is marked. For example, the conversion of floodplains to agricultural land or urban development would enhance the provision of food or space for housing and infrastructure respectively; but many of the water, soil and carbon regulating services provided by the floodplain would be severely diminished or lost. Such floodplain transformation has occurred in many parts of England (e.g. London, York and Oxford) and has created developed areas with increased flood risk. Nevertheless, there are plans, such as in the Thames Gateway, to restore some floodplain functioning as a means of sustainable development (Lavery & Donovan 2005). Flood risk management through changing land use practices also forms part of some agri-environment schemes, for example in the Belford catchment, Northumberland, where ecosystem management is thought to have played a role in mitigation of floods in September 2008 (Wilkinson *et al.* 2010).

Increasingly, research projects are examining cases where complex balances of synergies and trade-offs between services must be considered alongside scenarios to meet health and well-being requirements. In a project investigating peatlands on the Somerset Moors and Levels and on Thorne and Hatfield Moors, it was found that stakeholders saw the key synergies as being between cultural heritage and carbon storage, and between carbon storage, biodiversity and

recreation (Bonn *et al.* 2009). The key conflicts were identified as peat extraction versus carbon storage, and greenhouse gas emissions and cultural heritage versus peat extraction (Box 5.10, Section 5.4), although these may be context dependent. Other examples include the potential synergies between biodiversity and pollination services (Tscharntke *et al.* 2005). An assessment of trade-offs and synergies and the role for sustainable management for coastal margins habitats is given in **Box 17.3**.

There is an increasing awareness in government and land management organisations of the need for sustainable and integrated management of ecosystems and their services. This will require further refinement of our understanding of trade-offs and synergies between ecosystem services, some of which are likely to emerge from operationalising an ecosystem approach.

17.9 Knowledge Gaps

There is already a large amount known about ecosystems in England. However, significant gaps in our knowledge base remain, as described below. Addressing these gaps may help to provide guidelines for future research and information for policy making and management.

17.9.1 Status, Condition and Trends

Basic information on the extent of most Broad Habitats has been recorded since 1990 through the Countryside Survey (2009), although this only covers a number of sample sites in detail and is undertaken periodically. Fewer data sets are available prior to 1990, which makes the assessment of long-term trends more challenging. Whilst coastal margins and woodlands have been reasonably well recorded, other habitats are lacking in full information about extent or trends.

These include: Urban habitats, where currently there is no agreed definition of 'urban', nor are there comprehensive data on the extent of greenspace and Mountains, Moorlands and Heaths, which require better inventories and integrated monitoring of the extent and condition, especially the impacts of grazing on biodiversity. Information on condition is generally less well established.

Species monitoring, especially if carried out for a range of taxa, can be an important guide to habitat condition, particularly as most recording is done annually and covers a wide range of habitats (e.g. the BTO/JNCC/RSPB Breeding Bird Survey). Lower plants and organisms, however, are less well-recorded and may be particularly important in supporting ecosystem services.

17.9.2 Ecosystem Services

Quantifying the role of biodiversity, including uncharismatic and speciose groups of organisms such as invertebrates, lower plants and fungi, in ecosystem function and service provision, was one of 12 research priorities identified by Anton *et al.* (2010). The authors recognised that it is often species, or groups of species within habitats, that actually deliver the services. This aspect has not been considered in the UK NEA, partly due to our lack of knowledge on species as opposed to habitat delivery. Basic quantification of many of the ecosystem services is difficult, as it often requires extensive and long-term monitoring. For example, on arable land, water, wind and tillage erosion have accelerated over the 50 years; however, quantification of these processes at regional or national scale remains a challenge.

Given the multifunctional nature of ecosystems, greater understanding of the interactions between the habitats (and their component species) and ecosystem service delivery is necessary. This is particularly the case for some supporting services which underpin the delivery of the other services. If human needs are to be met, then assessing the current status of ecosystems in terms of their capacity to deliver services and identifying the most imperilled services will

Box 17.3 Evaluation of the likely synergies and trade-offs for Coastal Margin habitats.

There is a potential for clear synergies between different services, allowing the identification of 'win-win' combinations. Examples include environmentally friendly 'soft' engineering approaches to sea defence such as beach nourishment of shingle beaches. These have less impact and may help create conditions for shingle beach vegetation to develop. Potential conflicts include forestry on dunes which locally draws down the water table by around 50 cm (Clarke & Sanitwong 2010), with possible implications for the local hydrological regime and the associated dune slack flora and fauna.

In general, sustainable management should enhance or maintain the specific characteristics of coastal margin habitats in England, rather than replicating services provided better elsewhere. It should also take into account the uniqueness and non-replaceability of services. 'Win-win' combinations of services can be achieved by identifying complementary services within the context of sustainable management of these largely natural systems. Two main issues are relevant to the sustainable management of coastal margin habitats in England: sediment supply and managed realignment of coastal flood defences. Sediment supply is often interrupted by coastal protection works, and coastal sediment cells need to be considered to avoid causing sea defence issues downdrift, or possible negative consequences on protected areas. In the south and southeast, the trend is for nourishment schemes such as shingle bypassing (e.g. Shoreham harbour) and recycling (e.g. Dungeness). The Dungeness nuclear power stations require the transport of 67,000 cubic metres/134,000 tonnes of shingle annually 6.5 km from the east to the west to maintain the beach protecting them from the sea (Doody 2001; Chapter 11). Managed realignment, or roll-back, has primarily been applied to saltmarshes in England, but is increasingly being considered for other habitats such as dunes and shingle (e.g. Pye *et al.* 2007). With relatively minimal pre-treatment and/or management of the area, allowing tidal ingress through a simple, relatively small breach of the existing sea wall onto low-lying agricultural land will quickly produce inter-tidal mudflats which are colonised by salt marsh plants (French *et al.* 2000). There is growing evidence that restored salt marsh can perform many of the ecosystem services provided by natural systems including coastal defence and storage of pollutants. Where saltmarsh regenerates on former agricultural land, and where grazing is not introduced, there may be a transfer in services from provisioning services (e.g. farmed food and fibre) towards regulatory services (e.g. flood risk), supporting services (e.g. biodiversity) and cultural services (e.g. amenity). It can form one of the management options to maintain the extent of coastal margin habitats threatened by sea level rise and the services they provide. Artificial re-mobilisation of overstabilised or reclaimed habitats may rejuvenate natural processes, with the aim of restoring the dynamic processes which allow coastal margin habitats to self-adjust to changing environmental conditions, with long-term benefits for biodiversity (e.g. Garbutt *et al.* 2006).

provide guidance for management and policy making. This will involve determining the extent and condition of the particular habitat needed to maintain adequate levels of service provision as well as identifying limitations to the delivery of that service.

There is also a need to improve our understanding of how various drivers, such as climate change, are affecting ecosystem services (Haines-Young & Potschin 2008; Haines-Young & Potschin 2010) and to develop predictive tools to assess how the provision of ecosystem services might change in the future. These tools could be further used to explore the sensitivity of various ecosystem service provision drivers and to identify non-linear responses and thresholds in service delivery (Anton *et al.* 2010). The extent to which ecosystems exhibit distinct thresholds is uncertain, particularly in the context of England's natural environment, and so a gradual degradation of ecosystems and ecosystem services might be more probable than a sudden collapse.

17.9.3 Measurement and Monitoring

Much of the data used to establish and measure ecosystem services have been collected for entirely different purposes and further consideration should be given to data that are fit-for-purpose. Consistent, standardised data are needed for many services, as highlighted by terrestrial primary production where data collection is limited to local scales, and for freshwater and marine productivity where surrogates and models are used (17.5.1.4). Repeated consistent and thorough survey methodologies for each habitat would allow more accurate estimates of change in extent and condition over time and should, if possible, be designed to incorporate previous research data. Indicator taxa whose presence, abundance or density reveal different levels of service provision (or the lack of it) could be identified and used as assays for the state of systems as appropriate, either via bespoke field protocols or by making use of existing data sets or data collection. Additional research would be required to establish connections between species and services to ensure appropriate monitoring protocols.

Additional monitoring could be prioritised for those habitats or services which are under particular threat, so as to enhance our knowledge of changes under pressure and the existence of possible limits on their service delivery. It can also be useful in providing information on the effectiveness of new, sustainable management practices. If it is not possible to undertake such monitoring then consideration could be given to the use of indicators of habitat condition or service delivery as used for UK biodiversity, including three indicators on ecosystem integrity and ecosystem goods and services, relating to marine, terrestrial and freshwater ecosystems (Defra 2010f).

17.9.4 Valuation

Ecosystem services have often been regarded as 'free goods', particularly those for which there is no market. This includes some of the supporting and cultural services, such as decomposition and aspects of traditional conservation of biodiversity (Haslett *et al.* 2010). Defra and Natural England are currently assessing the value of the non-market benefits of environmental stewardship, but there is still a need

to refine methods to quantify the value of non-monetary services and broad habitats to improve decision making (Defra 2007b).

Whilst there are techniques to value some environmental impacts, a systematic and comprehensive method integrating both positive and negative impacts on the natural environment is lacking within the decision-making process (Defra 2007b). Often this has led to overexploitation of ecosystem services. Improved accounting of the value of natural capital and ecosystem services is needed, as well as ways of making ecosystem services more part of the formal economy (Natural England 2009e).

There is also a need to account for multiple services and resolving trade-offs between them. For example, resolving tensions between different cultural services, such as solitude and wildness experience versus increasing recreational use of the coast, and between societal and environmental services, particularly the role of biodiversity.

17.9.5 Management

A range of services are delivered by ecosystems that are poorly understood, despite their importance. These gaps in understanding impact upon management decisions and can affect policy making over the longer term. Amongst these knowledge gaps is the limited understanding of moor and heathland responses to various management options and grazing regimes in relation to greenhouse gas emissions. There are also concerns about eutrophication in land and water systems from agricultural sources and their influence on the composition and diversity of plant communities and soil biota, impacting ecosystem services via poorly understood mechanisms. Some of these concerns may be addressed by assessing past management decisions in the context of indicator data to improve future management. For instance, decreased fertiliser use and its relationship with improved local water quality might be examined using trends in native water-based flora and fauna. In coastal habitats, the management options required to respond to sea-level rise need more attention: in particular, how to apply rollback or managed realignment to Coastal Margin habitats, including Saltmarsh, and what habitat restoration measures are needed to make this feasible.

It should be acknowledged, however, that at no point will a complete picture be available. There will always be gaps in our knowledge, and the discussion above highlights some of the main gaps identified in previous sections. Nevertheless, progress is ongoing to address these gaps and to develop a robust evidence base demonstrating the effectiveness of integrating ecosystem management with ecosystem service delivery.

17.10 Conclusions

Whilst England's landscape is dominated by agricultural habitats, it is the mix of UK NEA Broad Habitats combined with the local climate, geology, soils and relief that provides

the character of the landscapes, and the delivery of the services is a function of both the nature of these habitats and human management practices. In terms of area, agricultural habitats, especially Enclosed Farmland, are important both for the delivery of production services and for the indirect effects which agricultural practices have on other habitats and their service delivery. The pressure on the agricultural habitats is driven by the increasing population of England and the demands made on the various provisioning services. These demands cannot be, or are not being, met by service provision within England and thus we are dependent on services from other countries and vice versa. England, for example, is the main contributor to UK crop production (17.4.3) and through increasing yields, has contributed more to greater self-sufficiency in food production in the UK. Nevertheless, England, like the rest of the UK, is dependent on non-UK ecosystem services (Chapter 21). In England, this is to meet the demand of its largely urban and growing population.

Some services, e.g. regulating and cultural, are provided locally or regionally, for example, through woodlands regulating water and air quality, whilst also providing greenspace for recreation and human well-being. Others can be local, such as recreation and tourism, but the demand may also be met from other parts of the UK as people seek particular activities or experiences and vice versa. For example, coasts are a popular holiday destination, as are certain other areas, such as the Lake District. This supply can also come from outside England, e.g. Snowdonia, the Cairngorms or the Fermanagh Lakelands. Similarly, carbon sequestration is local, but the benefits in contributing to emission targets for climate mitigation are at regional to national, if not global, scales. Thus it can be seen that service demand and supply cannot be considered entirely in the context of England alone, and whilst this chapter has assessed England's UK NEA Broad Habitats and their services, they need to be seen in this broader perspective.

The assessment of the status and trends of England's Broad Habitats has shown that Enclosed Farmland and Urban areas have increased significantly over the last 70 years, at the expense of the other Broad Habitats. The latter have not only decreased in area (excluding Marine), but also, all have declined in condition as they have been affected by changes to soil, air and water quality arising from farming practices and urban pollution. There has been recent improvement in their condition in many areas as a consequence of various agri-environment schemes, legislation and guidance (e.g. on air, water and soil) and policy shifts. Their condition is important for the delivery of a range of ecosystem services and this improvement in condition is reflected in **Figure 17.31**, although the situation in several of the habitats with regards to many of the regulating services still requires attention.

The recognition of the importance of ecosystem services, and the role of habitats and their condition on delivery, has led to research into more sustainable management, as well as a more holistic ecosystem approach. Both should help to ensure that ecosystems continue to deliver the service needs of humans and their well-being, and that the concerns about the synergies and trade-offs that may occur between

ecosystems and their services are addressed. In addition, investigation into the economics of ecosystem services has served to show the value of ecosystem services at national, as well as regional and local levels.

Whilst there is still much that we do not know about the exact nature of the relationship between the Broad Habitats and each of the ecosystem services, there is enough evidence to show that each habitat contributes, to varying degrees, to the delivery of a variety of services. This multifunctional delivery is dependent on the status and condition of the habitat and thus it is important that the habitats are maintained or enhanced through sustainable management. This is particularly the case for agricultural habitats, which dominate England's land cover and impact on the delivery of a number of services. With agriculture likely to become more important in the future, there will be a need for food production to be achieved with a lower environmental impact. In addition to this ecological appreciation of habitats, economic valuation has shown how many of the services they provide make a substantial contribution to national gross domestic product, as well as to local and regional economies. As drivers and pressures change, for example with forthcoming changes to EU agricultural policy and with climate change, it is important that England's habitats and services are regularly monitored, so that their capability to meet the demands of future generations can be assessed.

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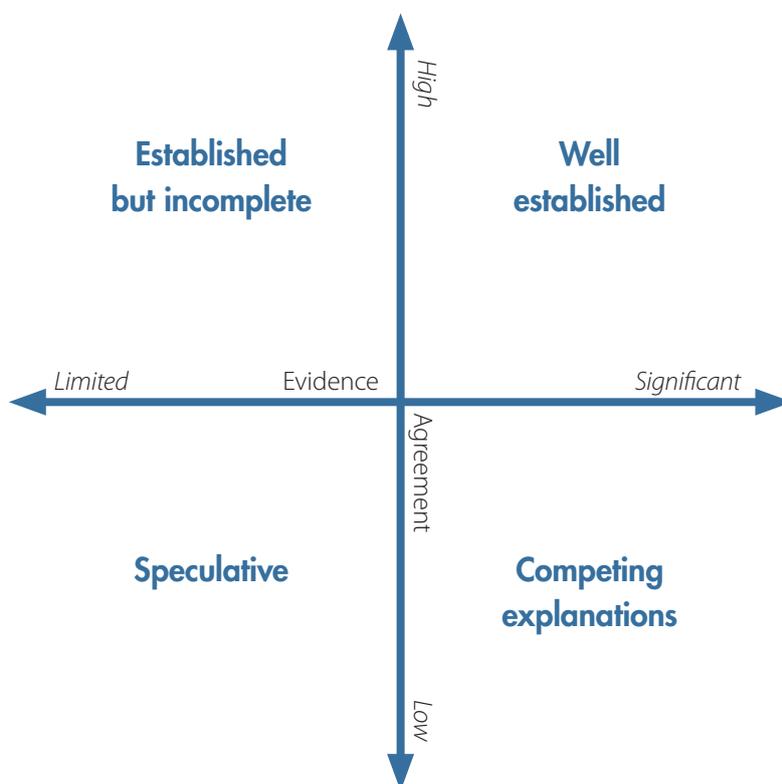
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Appendix 17.1 Approach Used to Assign Certainty Terms to Chapter Key Findings

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. <i>Well established:</i> | high agreement based on significant evidence |
| 2. <i>Established but incomplete evidence:</i> | high agreement based on limited evidence |
| 3. <i>Competing explanations:</i> | low agreement, albeit with significant evidence |
| 4. <i>Speculative:</i> | low agreement based on limited evidence |



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

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

