Chapter 20:
Status and Changes in the UK's Ecosystems and their Services to Society: Wales

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Key Findings

Biodiversity contributes to economic and social prosperity in Wales by underpinning valuable ecosystem services. The annual value of wildlife-based activity to the Welsh economy was estimated as £1.9 billion in 2007 (2.9% of Wales's national output and 3% of employment). These figures do not provide an assessment of the value of biodiversity in terms of its wider provision of ecosystem services to Welsh society. There have been significant changes to biodiversity in Wales over the past 70 years, with some species thriving or recovering from earlier losses, while others have contracted in numbers. Key seabird species have increased during the past 30 years; numbers of wild plants, butterflies of specialist habitats and farmland birds have declined. Honey bees showed a 23% decline in Wales between 1985 and 2005. In common with other countries in Europe, Wales failed to meet its international biodiversity targets in 2010. Fifty-four per cent of Biodiversity Action Plan species were assessed as being in 'unfavourable condition' in 2008, but with considerable variation between species groups. For example, 80% of marine mammals and birds were in favourable or recovering condition, while 80% of amphibians, butterflies and fish were recorded as being in unfavourable condition. In 2005, 59% of Biodiversity Action Plan habitats in Wales were in declining condition. Priority habitats classed as stable or improving increased from 30% in 2002 to 36% in 2008. A rapid review in 2006 judged conservation features at 47% of Welsh Sites of Special Scientific Interest (SSSIs) to be in favourable condition, with 53% in unfavourable condition.

Mountains, Moorlands and Heaths in Wales hold significant amounts of stored carbon, but many protected sites in this broad habitat type are in declining condition. Currently, approximately 60% of designated sites in upland habitats (Mountains, Moorlands and Heaths) are classed as being in unfavourable condition. Climate change, land management and atmospheric deposition of sulphur and nitrogen compounds have all affected the soil systems of Wales's mountain areas. Over 80% of soil carbon stores in Wales are associated with upland and grassland soils. There is a threat of a potential shift from carbon sink to carbon source in the uplands if these areas are not carefully managed for their carbon stores.

The alteration of the composition of lowland Semi-natural Grasslands was one the most rapid and widespread vegetation changes to have taken place in Wales during the 20th Century. Approximately 90% of former unimproved and semi-improved swards were transformed by agricultural management to Improved Grasslands.

About 37.4% of Wales is Enclosed Farmland, consisting of 34% Improved Grassland and 3.4% Arable and Horticultural land. Enclosed Farmland is valuable for provisioning and cultural services in Wales, with potential for greater contributions to supporting and regulating services. But it also imposes important disbenefits in terms of greenhouse gas emissions, diffuse water pollution and losses to biodiversity. There is also evidence that land drainage in Improved Grassland has increased flood risk. Livestock production in Wales is dominated by sheep and cattle farming, with Wales contributing 26% of the total numbers of sheep in the UK (8.2 million) and 11% of the UK total for cattle (1.1 million cows). These provisioning services are heavily supported by subsidy in Less Favoured Areas (80% of the agricultural land area of Wales). Wales imports considerably more food commodities in all categories than are exported, except in the case of animal feedstuffs. This is one indicator of the many ways in which the lifestyles of Welsh citizens rely upon and affect ecosystem services beyond the borders of Wales.

Woodland area in Wales has almost tripled since the early 1900s, and now covers 14% of the country's total land area. In addition, there is a significant tree resource outside Woodlands, in the form of individual trees (15 million live trees) and hedgerows. Forest resources contributed £429 million to the Welsh economy in 2007, and an estimated 8,900 jobs. Woodlands can deliver multiple ecosystem services and the drive for sustainable forest management over the last 25 years appears to have had a positive effect on the trends for many of these services. The Welsh Government is planning the creation of 100,000 ha of new woodland over the next 20 years which, if achieved, will create an additional sink of 1,600,000 tonnes of carbon dioxide equivalent annually by 2040. Despite their limited extent, semi-natural woodlands remain one of the most biodiverse habitats in Wales, with a rich association of rare and priority species. Approximately 5% of Woodlands are SSSIs. However, just 9% of these are considered to be in favourable condition and 25% are classed as being in unfavourable but recovering condition.

Welsh freshwater ecosystems still suffer from an industrial legacy, for example, point sources of metal pollution from mines, but there is evidence of improvement following remediation measures. Biological data suggest deterioration of some rivers from 'very good' to 'good' quality since 1995; reasons are unclear but may link to agricultural activity and phosphorus contamination. Nearly all the major river systems of Wales are regulated by headwater dams and reservoirs installed to provide water supply, flood control and energy generation. Nine ecologically distinct types of lake have been recorded in Wales, out of 11 types found in Britain. The Environment Agency has estimated that one in six properties in Wales (600,000 people in 357,000 properties) is at risk of flooding. The economic risk from flooding to properties and contents was £200 million per annum in 2008. UK climate impact projections suggest that average annual natural river flows could reduce by 10–15% in Wales by 2050, and natural summer river flows could reduce by 50% or more, with implications for flood hazard regulation and water supply.

Five per cent of Wales is classified as Urban habitat. During the past 40 years, activities have taken place to improve the quality of human well-being in the urban environment by expanding greenspace and tree planting, and increasing the numbers of local nature reserves close to urban centres. In 2010, 18 of the 22 local authorities in Wales were working on assessments of the extent and location of accessible natural greenspace in their urban areas.

Sand Dunes, Saltmarsh and Sea Cliffs are the most extensive coastal habitats in Wales and are important for a range of regulating services, including coastal erosion protection. Since 1900, there have been considerable losses of Sand Dune areas to agricultural land claim, forestry and development for housing and tourism. A further 23% of the Welsh coastline is eroding and 28% has some form of artificial sea defence works. In 2007, the sea defence services of Sand Dunes were calculated to be worth between £53 and £199 million in Wales. Seven in every eight hectares of European designated Natura 2000 sites in Wales (0.5 million ha) are Marine areas, reflecting their high importance for conservation. However, 60% of these sites have been classified as being in 'continued or accelerated decline'.

Wales is currently regarded as a net sink for carbon dioxide in the land use, land use change and forestry sector (UNFCC reporting). This is primarily due to the low incidence of land use change in Wales and the relatively young age structure of Welsh forests, rather than the overall stock of carbon held within Welsh soils. Soils represent a significant store of carbon, with 20–30% in the form of peat deposits which occupy 3% of the land area of Wales. Welsh soils hold nine times the amount of carbon that is stored in all vegetation (including forestry). The strength of the forest carbon sink increased from 1990 to 2004, but will start to decline in future as a result of the drop in planting rates over the last 20 years. The total amount of carbon stored in Welsh forests and their soils is equivalent to more than 10 times the annual emissions from industry and services.

Wales records some of the highest rainfall levels in the UK. There are large reserves of surface water in Wales that have long served as sources of supply for the UK more widely. Demands on these reserves from within and outside Wales are likely to increase in the future, under current climate change scenarios.

Provisioning services from agriculture contributed some £418 million or 1.1% to the Welsh economy in 2003. However, the agricultural sector accounts for more than 10% of total employment in Wales and contributes to a wide range of cultural ecosystem service benefits, including landscape values and tourism.

Wales is renowned for its attractive landscapes, with three National Parks and five Areas of Outstanding Natural Beauty covering 24% of the country's land surface. In Wales, 72% of the population has access to woodlands greater than 20 ha in extent within 4 km of their homes. Fifty-eight cultural landscape types are listed in the Register of Landscapes of Historic interest in Wales. However, during the mid-20th Century the distinctive character of the Welsh landscape suffered from intrusive developments related to energy, transport and tourism, and the poor design and location of forest plantations.

A 2001 study estimated that the environment contributed £8.8 billion of goods and services annually to the Welsh economy, 9% of Welsh GDP and one in six Welsh jobs, mainly in the leisure and tourism, agriculture and forestry, water abstraction, conservation and waste management sectors. It also found that the environment is relatively more important to the Welsh economy than it is to the other UK nations.

20.1 Introduction

20.1.1 Scope and Purpose

This chapter provides a snapshot of the major habitat types of Wales, with information about the ecosystem services that these habitats provide. It also discusses drivers of change in these habitats/services, and possible policy responses to achieve the optimum provision of ecosystem services in Wales.

Reference to other chapters of the UK National Ecosystem Assessment (NEA) will provide general and specific information on status and trends in regulating, provisioning, supporting and cultural ecosystem services at the UK level. This chapter aims to highlight aspects that are particular to, and distinctive about, the environment of Wales, through information on:

- condition, status and trends in the Broad Habitats of Wales, and their ecosystem services;
- valuation of the ecosystem services of Wales;
- drivers of change (locally and globally) in habitats and their ecosystem services;
- trade-offs and synergies in the ecosystem services provided by Wales's habitats;
- the relationship between biodiversity and ecosystem service provision in Wales;
- sustainable management options which may enhance ecosystem services provision;
- links between ecosystem services and human well-being; and
- knowledge gaps.

Original contributions to this chapter included more detailed and comprehensive information than could be accommodated within the space limitations for the published UK NEA Wales synthesis. This additional information is archived by the Wales Environment Research Hub (www.werh.org), but has not been subject to the same peer-review process as the condensed synthesis chapter presented here.

Table 20.1 Area and percentage cover of UK NEA Broad Habitat types in Wales. Source: Phase 1 Habitat Survey 2004 computed by I. Durance (Cardiff University).

UK NEA Broad Habitat	Total area (ha)	Percentage (%) of terrestrial area	Percentage (%) of total area
Mountains, Moorlands & Heaths	227,735	11	54.86
Semi-natural Grasslands	270,002	13	
Enclosed Farmland	1,066,998	52	
Woodlands	289,216	14	
Freshwaters – Openwaters, Wetlands & Floodplains	22,770	1	
Urban	94,894	5	
Coastal Margins	56,452	3	
Other	34,292	2	
Marine	1,594,175	-	45.14

20.1.2 Ecosystems in Wales

For the purposes of the UK NEA, eight 'Broad Habitat types' have been recognised, aggregated from the 25 broad habitats recognised in the UK Countryside Survey (Carey *et al.* 2008). The Countryside Survey Technical Report explains how habitats were identified in that study (Maskell *et al.* 2008). The UK NEA Broad Habitat classifications closely match the categories within the UK Land Cover Map 2007, and are also related to UK Biodiversity Action Plan (UK BAP) priority habitats. A table showing the relationships between these classifications is provided in Chapter 2.

The UK NEA Broad Habitat types of 1) Mountains, Moorlands and Heaths, 2) Semi-natural Grasslands, 3) Enclosed Farmland, 4) Woodlands, 5) Freshwaters – Openwaters, Wetlands and Floodplains, 6) Urban, 7) Coastal Margins, and 8) Marine, are mapped for Wales in **Figure 20.1**. Areal statistics for habitats are provided in **Table 20.1**.

20.2 Wales's Land and Sea

The predominantly ancient hard rock geology of Wales, combined with a northerly position in relation to peri-Arctic influences and a westerly situation facing the prevailing rain-bearing Atlantic airflow, has led to an erosion-sculpted landscape of hills/mountains and valleys. Due to the relatively strong relief, river catchments tend to be shorter and steeper than those in England, with rivers that often display 'spate' characteristics.

The climate of Wales is cool temperate, with a regime of cool summers and mild winters, but due to the topography, local climate is strongly influenced by aspect and altitudinal gradients in temperature and rainfall that lead to variation in microclimates.

The post-glacial, 'natural' vegetation of Wales comprised mainly broadleaved deciduous forests in the lowlands and valley sides, with tundra-like heathlands in the uplands. Now, mainly due to human management, the vegetation consists principally of a mosaic of improved grassland, woodland and some cropland in the lowlands, with 'semi-natural' grazing land and some heathland in the uplands.

Of the total amount of land in Wales, 60% is more than 150 m above sea level, and 27% is more than 300 m above sea level. Geology and climate have contributed to the generally low agricultural fertility of Wales's soils, and there are large expanses of substrate with high organic/carbon content, including major deposits of peat. Of the 2.1 million hectares of land in Wales, 1.6 million ha is classed as Less Favoured Area (LFA), of which 1.1 million ha is used for agriculture (69%).

With an area of 2,077,900 ha and a coastline of 2,740 km, no part of Wales is more than 75 km from the coast. The

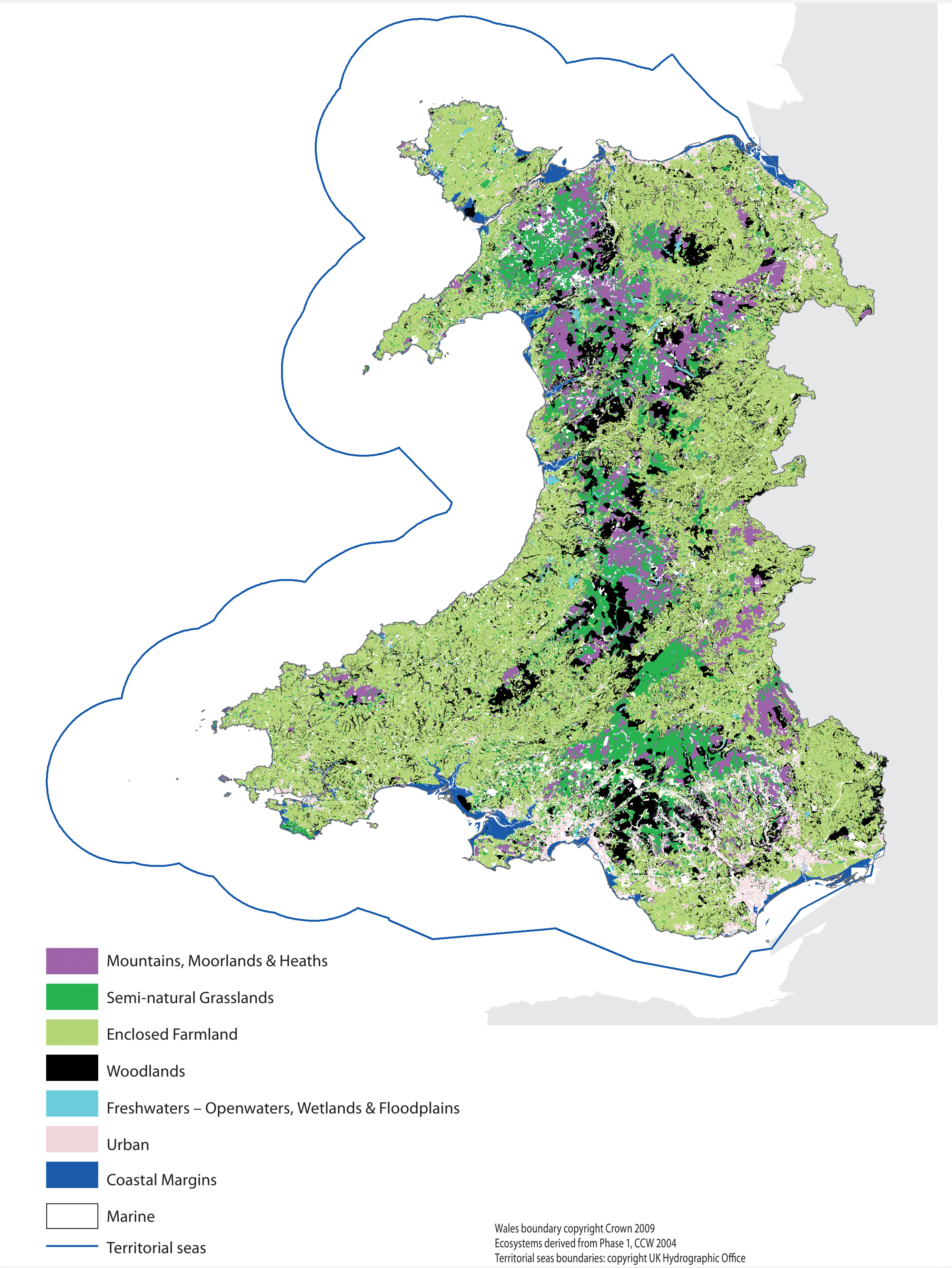


Figure 20.1 Distribution of the UK NEA Broad Habitat types. Source: Phase 1 Habitat data (CCW 2004).

coastal configuration of Wales has resulted in several different kinds of distinctive Marine habitats, on the Irish Sea coast, along the Severn Estuary and in the Menai Strait. Coastal scenery also includes impressive Sand Dune systems and spectacular Sea Cliffs.

There is a long history of human occupation and farming in Wales, with livestock rearing the prevailing land use over most of the rural landscape. Intensive pasture management is concentrated in valleys and lowlands, and many farms have associated blocks of unenclosed upland 'sheep-walk'. Croplands are much less prevalent and are largely limited to those lowland zones which have better quality agricultural soils. Semi-natural woodlands and other wildlife habitats are patchy and often degraded, and marine environments, too, have been heavily impacted by human activity.

Industrial development has been most evident in the South Wales Coalfield and north-eastern Wales, but is now only localised. Tourism is a vital component of the economy of Wales.

Key characteristics of Wales that provide the context for discussion of the ecosystem services are therefore:

- a population of 3 million people, mainly concentrated on the coastal plains;
- relatively small cities and towns;
- a unique 'valleys' environment of dense, often old housing, adjacent to semi-natural upland areas;
- large upland tracts often designated for landscape and biodiversity conservation, with high organic soil content and substantial water resources;
- relatively low quality soils for agricultural production;
- soils which have been susceptible to acidification and radioactive contamination, and which, through nutrient treatment, have also contributed to the eutrophication of freshwaters;
- 13–14% of land covered by forest/woodland;
- marine areas with significant biodiversity and potential for expansion of shell fisheries, renewable energy, tourism, etc., but which have been adversely affected by overharvesting in the past;
- a long history of extractive industries, e.g. coal, slate, stone, limestone, metals, which have left a legacy of derelict landscapes, contaminated land and water pollution;
- eight protected landscapes (National Parks and Areas of Outstanding Natural Beauty) in Wales, occupying 507,800 ha, i.e. 24.4% of Wales's terrestrial space; and
- rich cultural and historical/heritage resources.

20.3 Biodiversity in Wales

The landscape and biodiversity of Wales have been shaped by human activity for many centuries. As a result, Wales has a diverse cultural landscape, but human depredation and intensive land management have caused the loss of many animal and plant species. Examples include large mammals such as the brown bear, the wolf and the wildcat, which died out in Wales during the Norman period. Many other species continue to decline (Section 20.3.1) but there are also examples of recovery and successful reintroductions, e.g. the notable case of the red kite (*Milvus milvus*; **Figure 20.2**).

The geographical isolation of the UK and the long history of human activity means that Wales's terrestrial environment has relatively low numbers of native species in global terms. However, the diverse geology, westerly location and oceanic climate of Wales have led to certain groups of organisms showing higher than average abundance and diversity by European standards. There are rich communities of bryophytes (mosses and liverworts), lichens and fungi in Welsh woodlands and montane habitats. The upper reaches of Snowdonia are host to a distinctive arctic-alpine flora which includes species of saxifrage and the Snowdon lily (*Lloydia serotina*). There are several plant species in the lowland vascular flora that are not found elsewhere in Britain, e.g. spotted rock-rose (*Tuberaria guttata*) , Radnor lily (*Gagea bohemica*) and yellow Whitlowgrass (*Draba aizoides*) (Perring & Walters, 1990). In the aquatic environment, freshwater fish include economically and culturally valuable trout and salmon species, and the endemic gwyniad (*Coregonus pennantii*) of Lake Bala.

Wales is situated at the boundary of three oceanic/climatic zones (North-east Atlantic, Arctic Boreal, Lusitanian) and is thus richer in marine life than many other European sea-areas. In addition, Wales has a wider range of seabed habitats compared with eastern Britain (the North Sea), and the tidal range is greater than in much of the rest of Europe, leading to higher intertidal diversity. Seventy-five per cent of Welsh coastal waters are of European importance, including several internationally significant seabird colonies. The

Figure 20.2 Red kite at the Gigrin Farm Feeding Centre, Rhayader, Wales. *Photo © Amanda and Phil Ackerman, Bird Photos UK.*

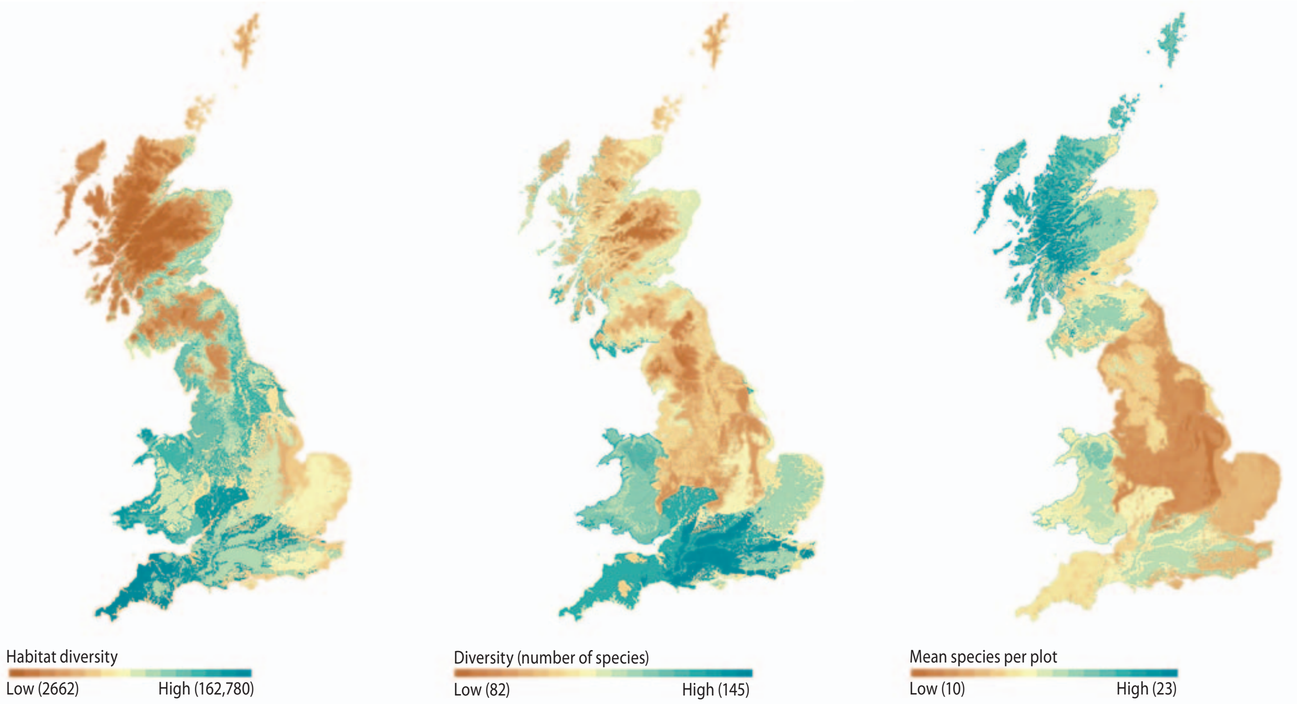


Figure 20.3 Terrestrial habitat complexity/diversity; total species richness per 1 km² and mean species richness per plot, for 1 km² sample plots from the Countryside Survey. Source: Smart *et al.* (2010) with the permission of the NERC Centre for Ecology and Hydrology.

Irish Sea and the south-western approaches are home to an important assemblage of marine animals, including sharks, seals, dolphins, porpoises, jellyfish, crabs and lobsters.

Within a UK setting, Wales has a medium to high terrestrial habitat complexity/diversity and overall species richness, according to the site sample data of the Countryside Survey (**Figure 20.3**). This compares with lower habitat diversity and numbers of species in Scotland and much of lowland England. The south and west of England has, in general, a higher habitat diversity and higher numbers of species compared with Wales.

20.3.1 Biodiversity Trends

The Countryside Survey (Smart *et al.* 2009) showed that plant species richness per sample plot had declined across Wales between 1990 and 2007 (**Figure 20.4**). In particular, there was a reduction in the richness of butterfly larval food plants in all landscape locations sampled, and this appears to be part of a longer-term trend, reflected in Great Britain more widely, that can be traced back to the first survey in 1978. A successional trend in vegetation character was noted, toward more shaded vegetation with fewer species of open ground and larger numbers of taller, more competitive species including trees and shrubs. No large step changes in ecological condition occurred over the 17-year period of the Survey in Wales.

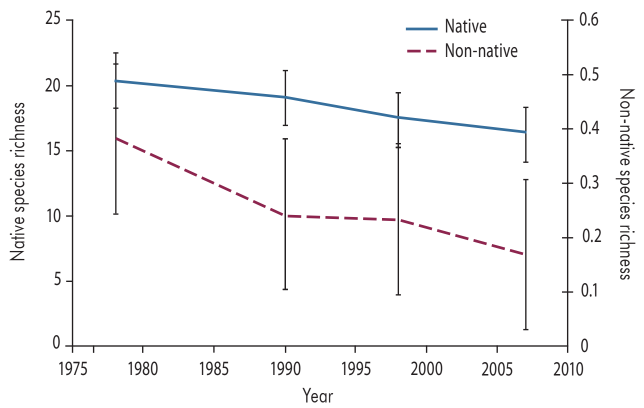


Figure 20.4 Native and non-native plant species richness of repeat survey plots in Wales. Source: Smart *et al.* (2009). Countryside Survey data owned by NERC – Centre for Ecology & Hydrology.

The Countryside Survey also assessed boundary and linear features in the landscape, i.e. hedgerows and walls. Woody linear features (managed hedges and lines of trees and shrubs) made up an estimated 51% of the total length of this landscape feature in Wales in 2007 (England 53%; Scotland 13%). Fences make up 35% of the total length of boundary features in Wales. Walls were evenly distributed between upland and lowland zones but were more likely to be in poor condition in the uplands. Managed hedgerows saw continuing reduction in length in Wales, reflecting the lower level of hedgerow management across Britain in general. Tree and shrub species richness in Welsh woody linear features was the highest in Britain at 4.2 species per 30 m length, compared with 2.2 in Scotland and 3.7 in England. Forty-four per cent of Welsh hedges were in good structural condition in 2007 according to UK Habitat Action Plan criteria (Smart *et al.* 2009).

In the marine environment, a study for the Countryside Council for Wales by the Marine Life Information Network (MarLIN; Jackson *et al.* 2010) has found varying degrees of habitat diversity (biotope richness) around the coasts of

Wales (**Figure 20.5**). Further studies are required to build up a better picture of species diversity within Welsh marine habitats than exists at present.

In order to assess progress towards UK Biodiversity Action Plan (BAP) targets, Wales has contributed to BAP reporting since 1999. Since 2005 this has largely been through use of the UK Biodiversity Action Reporting System (BARS). Reports were submitted in 1999, 2002, 2005 and 2008. In 1999 and 2002 Wales reported against the UK BAP habitats and species list, in 2005 and 2008 reporting in Wales was against the CRoW Act Section 74 list. Future reporting will be against the NERC Act Section 42 list. Trend data are used to measure progress towards targets and to ascertain whether the status of priority habitats and species is improving, declining or stable. The following section explores trend data from the 2008 BAP reporting round for Wales Section 74 priority habitats and species, and compares these results to the UK data for the same habitats and species.

In Wales, more than half of UK BAP habitats are classed as in 'declining' condition. However, this decline is slowing at many sites and 65% of BAP habitats in Wales can therefore be classed as improving, remaining stable or showing signs that decline is fluctuating or slowing (**Figure 20.6**). A comparison of Wales with the wider UK, for trends in priority species is provided in **Figure 20.7**.

Habitats within the Marine environment exhibit the greatest deterioration, with continued or accelerated decline across 60% of marine habitats compared to only 8% for terrestrial habitats and 33% for freshwater habitats. In non-marine habitats, a more positive picture emerges, with 80% of terrestrial habitats and 66% of freshwater habitats

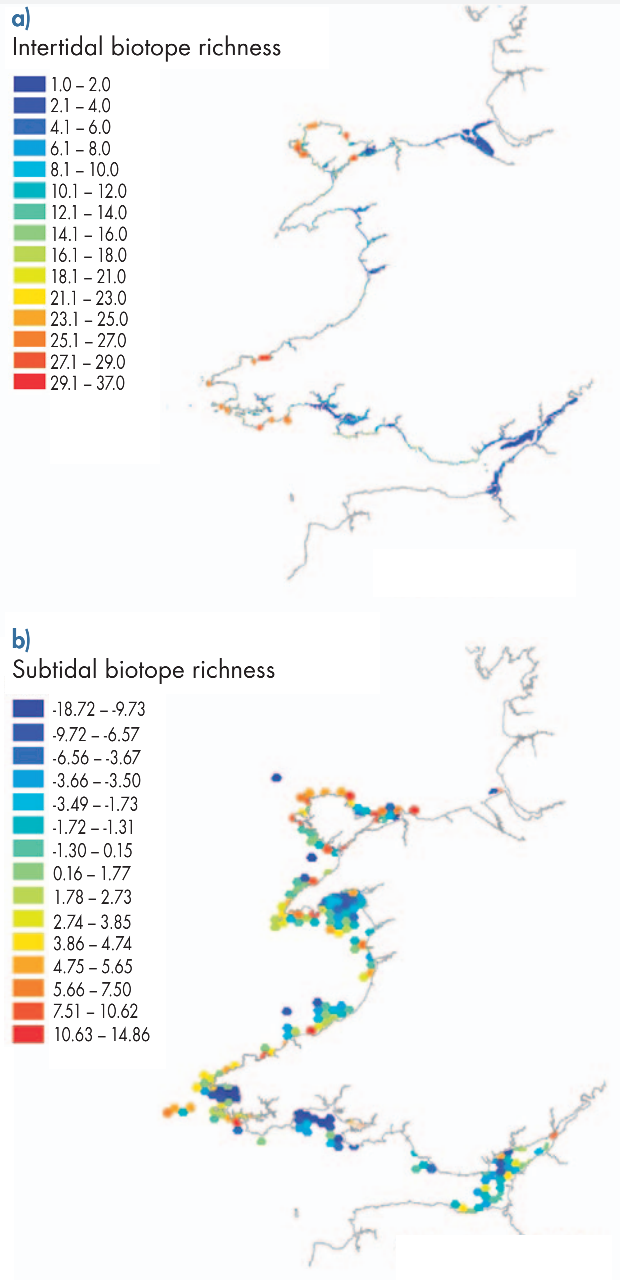


Figure 20.5 Habitat (biotope) diversity in marine habitats of Wales. a) intertidal zone; b) subtidal areas. Source: Jackson *et al.* (2010). Crown copyright all rights reserved, Countryside Council for Wales.

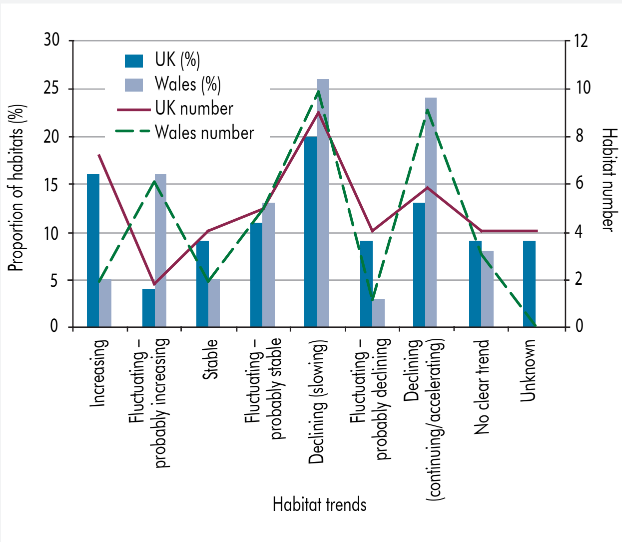


Figure 20.6 Trends for priority UK BAP habitats in the UK and in Wales. Source: Biodiversity Action Reporting System (BARS 2011).

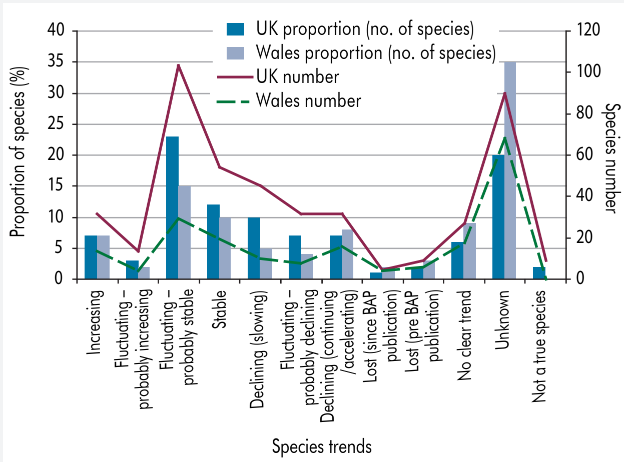


Figure 20.7 Trends for priority UK BAP species in the UK and in Wales. Source: Biodiversity Action Reporting System (BARS 2011).

showing stable or improving conditions, or slowing/fluctuating declines (BARS 2011).

In Wales, further analysis of the terrestrial habitat data shows that most progress is being made in Woodland, upland and Enclosed Farmland habitats, with 83% of Woodland habitats reported as improving. Of the terrestrial ecosystems, wetlands and coastal habitats show the greatest decline, with 25% of habitats declining at the same or an accelerated rate. For lowland grassland and heathland the decline appears to be slowing, but neither of these habitats is stable or increasing. Similarly, no coastal BAP habitats are recorded as stable or increasing (BARS 2011).

Due to the large number of species which have unknown trends in Wales, it is difficult to compare progress in Wales to progress at the UK level (see **Figure 20.7**). This could mask significant changes in species populations. These data highlight the need for more investment in surveys and monitoring to allow for reliable reporting on BAP and other species trends in Wales.

Figure 20.8 shows trends for Welsh BAP Section 74 species. The three species which are showing a continuing/accelerating decline are lapwing (*Vanellus vanellus*), curlew (*Numenius arquata*) and golden plover (*Pluvialis apricaria*).

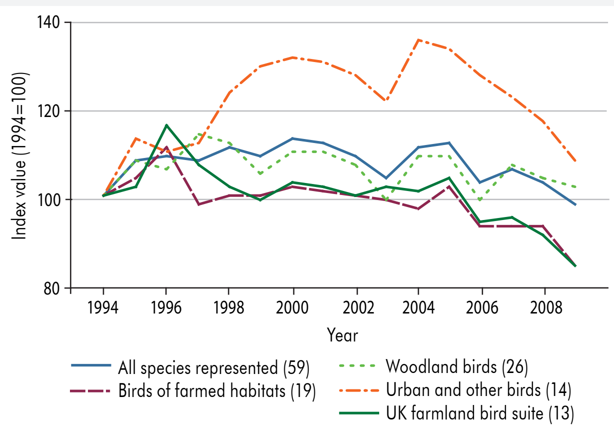


Figure 20.8 Short-term abundance of widespread breeding birds in Wales 1994–2009. Source: Welsh Assembly Government (2010e).

Table 20.2 shows Welsh BAP trend data by taxonomic grouping. Three taxonomic groups (fungi, mammals and marine species) have too few data to derive meaningful conclusions on trends.

Seven taxonomic groups (more than 50% of Section 74 species) show increasing, stable or fluctuating/slowing declines (lichens, mosses and liverworts, stoneworts, vascular plants, invertebrates, fish, amphibians and reptiles). The most notable negative trends are in the birds (34%) and invertebrates (19%). Three groups (with low numbers of reporting species) reported no negative trends, i.e. the stoneworts, fish and amphibians and reptiles. Within the remaining three non-animal groups (mosses and liverworts, lichens and vascular plants), less than 10% of the species are recorded as having a negative trend.

As is apparent from the UK BAP reporting exercise, some species and taxonomic groups have long-term monitoring data and comprehensive trend datasets, while many others are not regularly monitored at all. However, reporting on other groups and from other sources tends to confirm the general picture of species decline and habitat degradation in Wales up to the present day, but with signs of improvement and progress in particular species and habitats. The following indicators are a sample of better-recorded taxonomic groups in Wales.

Wales Environment Strategy Indicator 19b, the Wild Birds Population index, is based on the Breeding Birds Survey carried out by the British Trust for Ornithology and the Royal Society for the Protection of Birds. It shows no clear trend overall, with some groups having increased since 1994 (notably urban birds) while birds of farmed habitats have decreased (see **Figure 20.8**). Based on longer-term data from the Breeding Bird Atlas, 43% of bird species have experienced range decreases between 1968 and 1972 and between 1988 and 1991, with just 17% having increased.

Data produced from the Joint Nature Conservation Committee (JNCC) Seabird Monitoring Programme provide

Table 20.2 Wales BAP species trend data by taxonomic grouping (numbers of species). Source: Wales Biodiversity Partnership/Countryside Council for Wales.

Taxonomic grouping	Increasing	Stable	Declining Slowing/ Fluctuating	Declining Continuing/ Accelerating	Lost/Not Regular Breeder	Trend Unknown	No. of species in assessment
Lichens	0	6	0	0	1	5	12
Fungi	0	0	1	0	0	6	7
Mosses/Liverworts	1	7	0	1	0	3	12
Stoneworts	1	1	0	0	0	1	3
Vascular Plants	1	12	8	2	0	4	27
Fish (excluding marine)	0	1	0	0	0	1	2
Amphibians/Reptiles	2	0	1	0	0	0	3
Invertebrates	5	20	6	6	4	12	53
Birds	2	6	3	4	4	4	23
Mammals (excluding marine)	2	0	1	1	0	7	11
Marine species	1	1	0	4	0	14	20

an annual update on the progress of Welsh seabirds from a network of sites around the Welsh coast. Guillemot (*Urea aalge*), fulmar (*Fulmarus glacialis*) and kittiwake (*Rissa tridactyla*) are used to provide trend indices for Wales. The trend in the seabird population index is recorded as showing a clear improvement, although there is variation year-on-year within the different species populations. The JNCC survey suggests that the three species seem to be faring better in Wales than in the UK as a whole (JNCC 2010a).

The butterfly indicator for Wales has recently been developed by the Centre for Ecology and Hydrology (CEH) and the charity Butterfly Conservation, through the UK Butterfly Monitoring Scheme. Preliminary results indicate similar trends to those found for Scotland (SNH 2009), England and the UK as a whole (Defra 2009a). While generalist species appear to have remained more or less stable, habitat specialists have declined (**Figure 20.9**).

The mean proportion of records of non-native species in samples of birds, mammals, plants and marine life rose by 23% during the period 1990–2007 according to the CEH non-native species indicator. For all taxonomic groups recorded for this indicator, England was the country most affected by non-native species, Wales was intermediate and Scotland was least affected.

20.3.2 Designated Sites

Of the 21,000 km^2 land and freshwater surface area of Wales, about 30% is protected in special sites for wildlife, scenic beauty or geological value. Twenty-four per cent of terrestrial space (5,078 km^2) is included in the eight main protected landscapes of Wales. These are the three National Parks (Snowdonia, Pembrokeshire Coast and Brecon Beacons) and the five Areas of Outstanding Natural Beauty (Gower, Wye Valley, Clwydian Range, Ynys Mon and Llyn Peninsula).

The most important areas for biodiversity in Wales have been mapped by the Countryside Council for Wales (**Figure 20.10**) This work does not include marine Section 42 habitats, some new terrestrial Section 42 habitats, or widespread habitat features such as hedgerows, ponds and veteran trees. Work is ongoing to compare these with spatial mapping of other ecosystem services in Wales, as part of the new Natural Environment Framework initiative (Section 20.10).

In 2006, the Countryside Council for Wales carried out a 'rapid review' of condition in Welsh Sites of Special Scientific Interest (SSSIs). Forty-eight per cent of conservation features at these sites were assessed to a high level of confidence, with 47% of these judged to be in favourable condition and 53% in unfavourable condition.

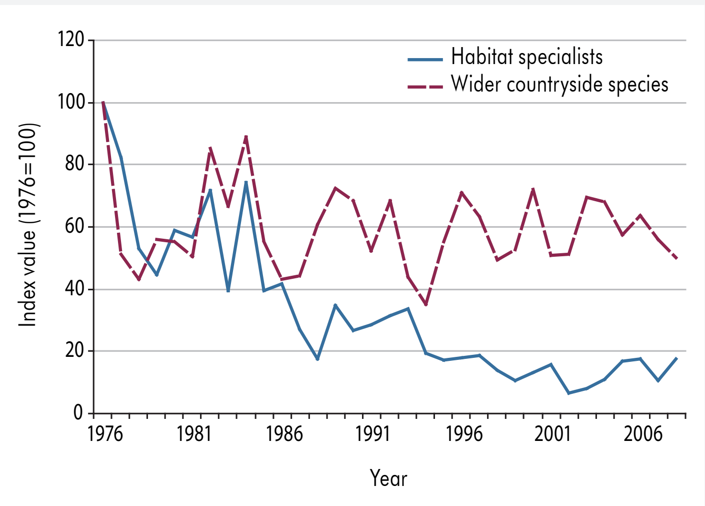


Figure 20.9 Butterfly indicator for Wales. Source: Centre for Ecology & Hydrology & Butterfly Conservation (unpublished data).

20.3.3 Drivers of Biodiversity Change

In Wales, habitat fragmentation and biodiversity loss have been caused mainly by changing management and use of land and sea. These changes have been driven largely by development pressures and subsidy regimes that were established to meet the challenges of changing population structures, increasing consumption, technological progress and economic development.

The direct drivers of biodiversity change (and loss) in Wales are similar to those listed for the UK as a whole (Chapter 3) and these include:

- land-use change (particularly agricultural extensification/intensification and softwood afforestation in Wales);
- pollution;
- exploitation of marine ecosystems, both target species and non-target species;
- climate change; and
- invasive species.

These drivers have led to a loss of connectivity between habitats, and therefore reduced viability of biological communities. These issues are further addressed in Section 20.9 of this chapter, on drivers and consequences of change in habitats and ecosystem services.

Threats for 25 terrestrial habitats were identified for the 2008 BAP reporting round (**Figure 20.11**). These responses also highlight agriculture, climate change, pollution and invasive non-native species as major drivers of biodiversity change in Wales.

20.3.4 Biodiversity Commitments in Wales

In 2001, the EU set itself the target of halting the decline of biodiversity in Europe by 2010 and restoring habitats and natural systems. In April 2002, the Parties to the Convention on Biological Diversity (CBD) committed themselves to achieve, by 2010, a significant reduction in the rate of biodiversity loss at the global, regional and national levels as a contribution to poverty alleviation and to the benefit of all life on Earth. The Welsh Government committed itself to both the EU and global targets, which have been incorporated into national schemes and strategies. In particular, the Environment Strategy for Wales, Outcome 21, aimed for 95% of sites of international importance in Wales to be in favourable condition by 2010. Wales has also adopted the more ambitious target of reversing biodiversity declines by 2026 (Outcome 19 of the Wales Environment Strategy, WAG 2006a).

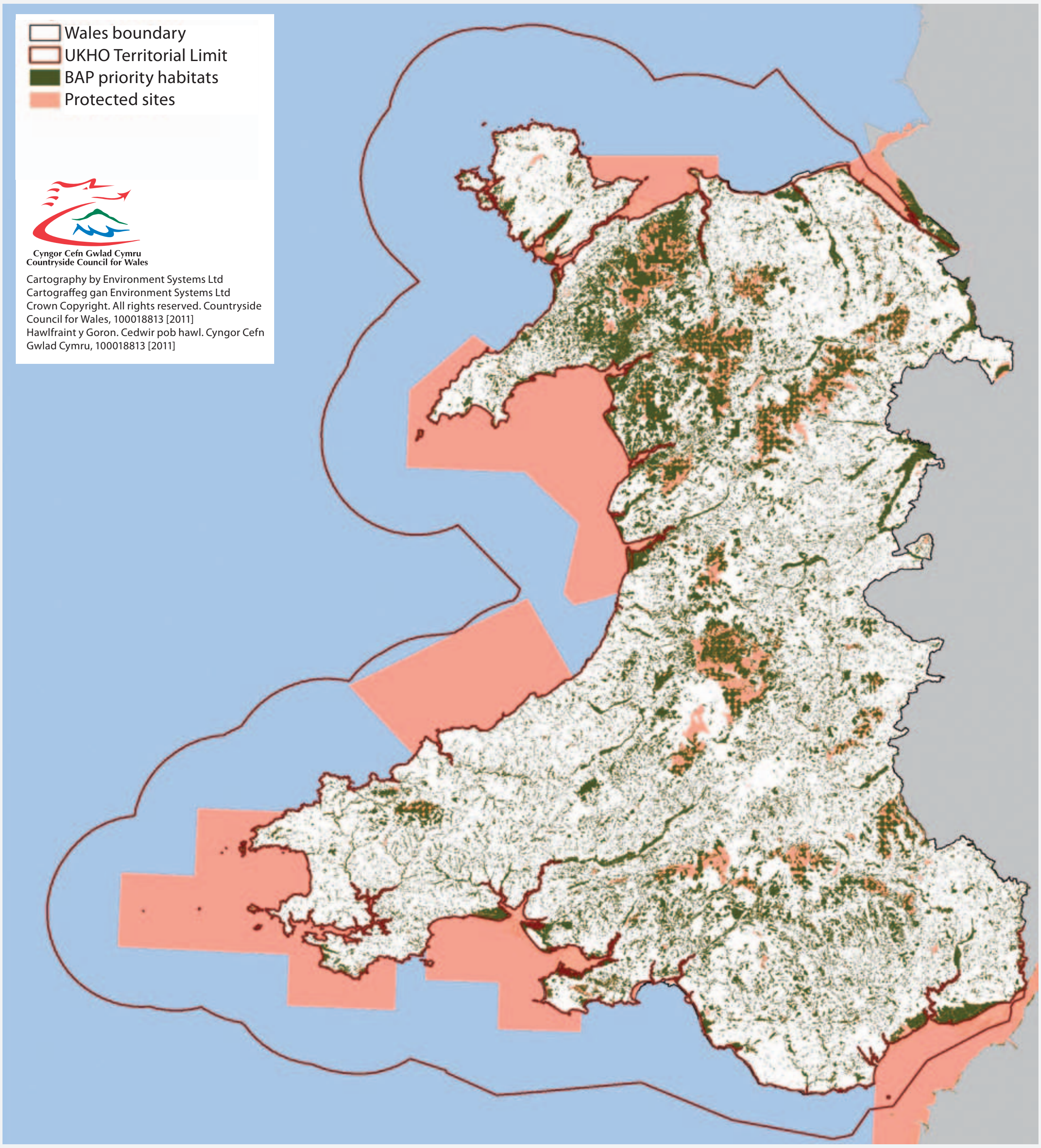


Figure 20.10 Areas of importance for biodiversity in Wales. Protected sites include Sites of Special Scientific Interest, Special Areas of Conservation and Special Protection Areas. Source: Countryside Council for Wales (2010).

In common with other countries and regions of Europe, the Welsh Government has acknowledged its failure to meet the 2010 biodiversity targets and has initiated a programme of responses to address this (see material on the new Wales Natural Environment Framework in Section 20.12). In 2010 the National Assembly for Wales Sustainability Committee also held an inquiry into why Wales had missed its 2010 target to halt the loss of biodiversity. The Committee's report lists 19 recommendations for addressing biodiversity loss in Wales, including driving the ecosystem approach into policy and across all government departments in Wales, focusing more on biodiversity in the wider landscape rather than dependence on protected sites alone, and involving the private sector in biodiversity management through the use of incentives and payments for ecosystem services (National Assembly for Wales Sustainability Committee Inquiry into Biodiversity Loss in Wales, January 2011).

20.3.5 Developing Biodiversity Indicators for Wales

Current 'State of the Environment' assessments are presented biannually in Wales, and they represent the first attempt to systematically monitor Welsh biodiversity within a broader environmental framework. Progress towards

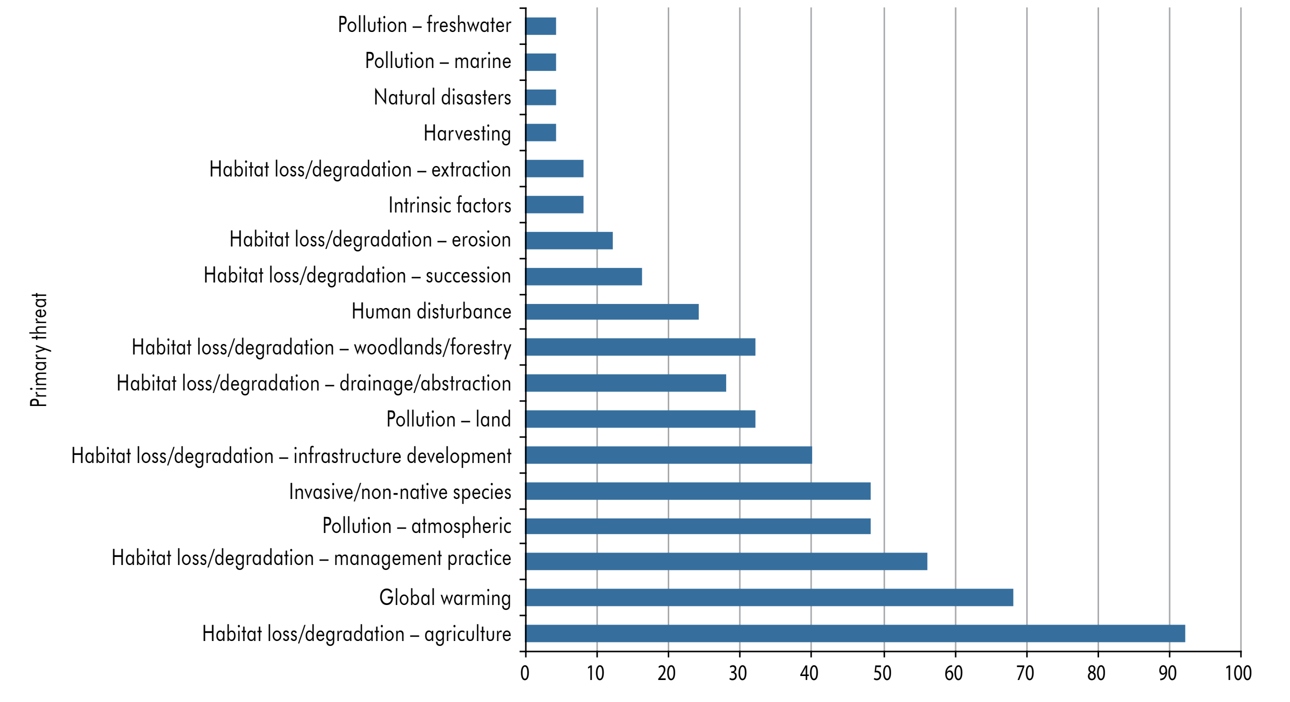


Figure 20.11 Threats to biodiversity in Wales. Source: WBP 2008.

these outcomes is measured using a suite of indicators, but at present, many of the indicators required to make a proper assessment of progress are yet to be defined (Statistical Directorate 2009).

The longer time frame adopted by Wales for its own biodiversity targets, and the fact that it has been late in developing biodiversity indicators, allows it the luxury of developing indicators specifically designed for the task. There is a wealth of biodiversity data collected in Wales, often as part of other UK-wide schemes, but much of this data are not yet presented in the form of Wales-specific measures. It has therefore been proposed to incorporate much of this data into a broad-based suite of indicators that will encapsulate biodiversity status and trends in subsequent State of the Environment assessments (Hockley *et al.* 2009).

Current work sponsored by the Welsh Government aims to synthesise the necessary data from many sources, covering most broad taxonomic groups, habitat types, and aspects of biodiversity (including abundance, range and diversity), to produce a small number (approximately 2–4) of headline indicators, which will sit atop a hierarchy of sub-indicators, synthesis reports and raw data. At the time of writing the indicators are being reviewed and refined to allow for the incorporation of new information, as and when it becomes available.

20.4 Condition, Status and Trends in Broad Habitats

Habitat specialists from the Countryside Council for Wales and Forestry Commission Wales have contributed the following sections on the Broad Habitat types of Wales. For more detailed information on Welsh terrestrial habitats, the reader is referred to the recent publication: *Habitats of Wales: a comprehensive field survey 1979–1997* (Blackstock *et al.* 2010).

20.4.1 Mountains, Moorlands and Heaths

Mountains, Moorlands and Heaths represent some of the least developed land in Wales. They include upland grasslands, heathlands, woodlands and bogs, and lowland heathlands. Lowland heath occurs mainly in two distinct zones: within the coastal belt and at the upper limit of agricultural enclosure.

The Welsh uplands and lowland heaths are important in a European context due to their oceanicity, which affects the status and composition of many plant communities. Some oceanic communities are well represented, making the UK one of the most important world locations for habitats such as heaths and blanket bogs.

Wales does not have the largest stands of moor and heathland, and some areas are in poor condition, but those that remain intact have a heightened importance due to their southerly and westerly location and differing climatic conditions from those experienced further north. This southerly location has also resulted in the Welsh uplands supporting habitats such as montane heath, and arctic-alpine species at their southern limit in the UK. Characteristics typical of the oceanic conditions include the dominance of western gorse in the lowlands, the widespread abundance of purple moor-grass in humid and dry heaths, and the oceanic bryophyte assemblages found in some forms of upland heath.

20.4.1.1 Status, conditions and trends

Two trends are apparent in upland flowering plants and ferns. Rare arctic-alpines such as Snowdon lily and alpine saxifrage

(*Saxifraga nivalis*) remain in a steady state, but many more widespread upland species are significantly threatened. The *New Atlas of the British and Irish Flora* (Preston *et al*. 2002) shows a consistent pattern of range contraction amongst several species which were formerly characteristic of upland Wales, such as mountain pansy (*Viola lutea*) and lesser butterfly orchid (*Platanthera bifolia*).

These factors have produced a suite of Welsh habitats of conservation importance, as listed in the European Habitats Directive. The Countryside Council for Wales Habitat Survey, carried out between 1979 and 1997, remains the best available information source on the characteristics of Mountains, Moorlands and Heaths in Wales (Blackstock *et al.* 2010).

Important ecosystem services provided by the uplands and lowland heathlands of Wales include carbon sequestration in peatland soils, catchment water services including water quantity and quality regulation (important for areas beyond the borders of Wales due to water transfers), nutrient buffering, food and fibre from agriculture and forestry, renewable energy and many cultural services including tourism assets that are highly significant for the Welsh economy (Section 20.5).

Some 127,300 ha (approximately 30%) of the Welsh uplands and lowland heathlands have been designated as SSSIs, of which about 92,149 hectares have also been designated as European Special Areas of Conservation (SACs) or Special Protection Areas (SPAs). The Environment Strategy Action Plan for Wales (WAG 2008a) set a target of ensuring that 95% of international sites were in favourable condition by 2010, with 95% of all SSSIs in favourable condition by 2015 and all sites in favourable condition by 2026. Currently, approximately 60% of upland habitats in Wales are in unfavourable condition, with blanket bog and heath failing at a high percentage of sites. This provides a challenge not only for reaching government targets, but also for the retention of fully functioning habitats and the ecosystem services they provide in the long term, particularly when the potential future effects of climate change are taken into account.

Upland habitats need to be in the best possible condition if they are to be buffered against climate change impacts which are likely to arise in future. Many upland habitats in Wales are near the edge of their range and so could be adversely affected by climate change unless they are robust enough to cope with and adapt to at least some of the effects. This particularly applies to the more montane habitats, of which we have a small but important subset in the UK.

Despite concerns about the effects of climate change, direct land management is still a far more potent force in the uplands at present, particularly sheep grazing which, in addition to its own impact in reducing vegetation cover and replacing heaths, woodland and mires with grassland, also exacerbates other impacts such as pollution and climate change.

Regarding the mitigation of future effects of climate change, the primary concern within Welsh uplands is to secure the existing carbon resource that is locked up within organic and organo-mineral soils. Welsh soils represent a significant store of carbon, currently estimated at 410 million tonnes, of which approximately one-third (121 million tonnes) is in the form of peat (ECOSSE 2007), despite the fact that peat deposits occupy only 3% of the surface area of Wales.

20.4.1.2 Drivers of change

The hotter, drier summers expected with climate change present high risks to organic soils, particularly given the stark warning offered by Holden *et al.* (2006) that many upland peatlands in Wales may already be close to the tipping point between carbon sink and carbon source. Should these soils dry out, peat resources will be oxidised, dissolved organic carbon losses to receiving rivers will increase and carbon dioxide emissions will accelerate. Anticipated increases in winter rainfall will bring other problems, notably increased peat erosion and increased rainwater runoff, leading to downstream flooding.

Modelling of changes in the climatic envelope suitable for peatbogs is underway, but it seems likely that extensive areas of the Welsh uplands will remain suitable for carbon storage and ongoing sequestration in the medium term at least. Management of our finite and comparatively modest peat resource (in proportional land cover terms) is one area where low cost restoration work could make significant contributions in terms of adaptation to climate change. For example, some 36% (25,100 ha) of the Welsh peatland resource is composed of modified bogs within the uplands. Much of this resource is capable of being restored to a condition suitable for long-term protection of the underlying carbon store, whilst a significant subset of this area could also be restored to active peat growth and thus further carbon sequestration. Such restoration would also need to be accompanied by measures designed to ensure that existing high quality areas of bog are well managed and where possible actively growing, and are thus sufficiently buffered against the effects of climate change to continue to function as carbon sinks rather than as sources.

Heathlands occur on organic and organo-mineral soils and therefore play a vital role in carbon storage, particularly in the uplands and in lowland wet and humid heaths. Carbon is also stored above ground in the heather biomass with estimates varying from 200 g C/m^2 to 1,325 g C/m^2 (Farage *et al.* 2009). Both lowland and upland heath are managed by regular burning, which can result in a net loss of carbon. However, careful burning practices over long burning rotations (15–20 years) can reduce the losses of carbon attributed to burning to less than 10% of the total losses of carbon from the system (Farage *et al.* 2009).

Compared to active peatland, the level of organic matter accumulation in grassland soils is likely to be small at the level of the individual land unit. But, given the extent of acid- and *Molinia*- dominated marshy grasslands in the uplands, these may still contribute significant carbon storage potential in aggregate. By contrast, fertiliser applications, compaction (leading to increased rainwater runoff), drainage and even the poaching of wet ground associated with stock feeding sites and gates may all lead to emissions of carbon and other greenhouse gases, which exceed the capacity of vegetation-soil combinations to absorb and store carbon and may even cause them to act as sinks.

Woodlands absorb and store carbon dioxide, but carbon balances in woodland are complicated by interactions with soil and the ultimate fate of the timber crop. Conifers planted on peatlands (within Wales there are some 12,000 ha of such plantations) cause the soil to dry out, oxidising the peat and releasing carbon dioxide. Recent research has shown that whilst in the short-term the clearance of plantations on peat soils increases the level of greenhouse gas emissions, over several decades the subsequent carbon sequestration within newly restored bogs will offset losses within acceptable timescales (Colls 2006).

Native broadleaved woodland cover in the Welsh uplands is very low, with many woodlands used for shelter for grazing animals, and consequently regeneration is absent or very limited. Natural tree lines are practically non-existent and most woodlands have sharp boundaries protected by fencing.

Evidence is now beginning to emerge of a change in grazing regimes on a number of upland SSSIs/SACs. Prior to the 2003 Common Agricultural Policy (CAP) reforms, the most commonly reported problem on such sites was that of overgrazing. Whilst this is still very much an issue on large parts of many upland SSSIs, some landholders are now reducing or even removing stock from all or part of their holdings. This is a development which has the potential to help both land managers and government achieve best use of the Welsh uplands, but which could also have detrimental effects if abandonment, rather than active management, takes place.

Trends in the uplands have led to a failure to achieve early BAP and government biodiversity targets, so there is a need to develop large-scale initiatives to target particular areas for appropriate conservation management, to restore upland woodland and scrub and the natural altitudinal succession of vegetation, extend priority habitats and restore degraded stands. The new Natural Environment Framework for Wales will help address these issues by putting the ecosystem approach at the centre of government action on development and land management in Wales.

In lowland heathlands the trend has been towards neglect and abandonment, as small and fragmented sites became more difficult and less economic to manage by grazing and burning. Other drivers include increasing recreational pressure on the coastal belt, which results in farmers withdrawing grazing from these sites to avoid conflict between livestock and people (PCNP 2003). In the long-term, lowland heathland like other semi-natural habitats will remain threatened as long as it exists in small, isolated and scattered patches. Emphasis needs to be given to the re-creation of lowland heathland and associated semi-natural habitats to provide more extensive units of ecologically functional semi-natural vegetation.

20.4.2 Semi-natural Grasslands

Over most of the rural land surface of Wales, sheep and other livestock rearing is the major land use and much of the vegetation is grassy. In the lowlands, improved rye-grass (*Lolium perenne*)/white clover (*Trifolium repens*) grasslands and silage crops prevail, and during the 20th Century these extensively replaced semi-natural swards that were formerly used for grazing and hay crops. The much diminished Semi-natural Grasslands are rich in species, including many that are only poorly represented in other habitats and do not ascend into the uplands. Fragmentation of species-rich grasslands and other habitats has led to isolation and concern that there will be local extinction of component taxa in surviving fragments over time (Kuussaari *et al*. 2009).

In the sheep-walk country of the open moorlands, above the upper level of enclosure, Semi-natural Grasslands cover considerable areas of the major hills and mountains. These grasslands are mostly developed over shallow acid soils and are likely to have increased in extent, at the expense of Dwarf Shrub Heath and other habitats, as sheep numbers increased during the last century.

Sources of data presented in this short account on the extent and composition of Welsh grassland include two major field surveys undertaken by the Countryside Council for Wales. These are the Habitat Survey of Wales and the associated Lowland Grassland Survey of Wales. The surveys were largely undertaken during the period 1979–2004, and provide data on the distribution and abundance of Welsh habitats and lowland grassland plant communities; full accounts have recently been published (Blackstock *et al*. 2010; Stevens *et al*. 2010).

20.4.2.1 Status, conditions and trends

The relative amounts of unimproved, semi-improved and improved dry grasslands in Wales are summarised in **Table 20.3**. In the lowlands, the floristic composition of semi-improved swards on dry soils is somewhat intermediate between the rarer species-rich unimproved grasslands and the lush, green Improved Grasslands that now cover approximately half of the land surface of Wales. This is reflected in community composition. The highly productive improved grasslands are heavily dominated by bred strains of rye grass and white clover; semi-improved swards have more species but mostly belong to one community; unimproved swards have a range of communities on differing soil types, with many more species, up to 64 per 4 m^2 in calcareous pastures, up to 61 per 4 m^2 in Neutral Grassland, up to 55 per 4 m^2 in acidic grasslands and up to 59 per 4 m^2 in marshy grasslands. Examples of specialist plant species, more or less confined to the unimproved or Semi-natural Grasslands in the lowlands and often becoming scarce over many parts of their range, are shown in **Table 20.3**; such grasslands also host a wide variety of grassland fungi, invertebrates and other taxonomic groups. In many cases such species now occur in somewhat isolated stands; the distribution of crested dogstail/knapweed (*Cynosurus-Centaurea*) neutral pastures and meadows, for instance, in Wales is plotted in **Figure 20.12**, which reveals the thin scatter and patchy distribution of remnant fragments.

Also included in **Table 20.4** are wet or marshy grasslands that are mainly found on shallow peats, peaty gleys and related soil types; these are a distinctive component of the Welsh land cover in a European context (Blackstock *et al*. 1998). Forty per cent of the UK's 'rhos' habitat (unimproved, damp heathland pasture) is found in Wales.

In the uplands, by contrast, there are large stands of semi-natural dry grasslands composed of relatively few communities. Major dominant species include common bent (*Agrostis capillaris*), sheep's fescue (*Festuca ovina*), purple moor-grass and mat grass (*Nardus stricta*). There are fewer uncommon grassland species than in the lowlands, but such swards are used by a range of bird species, including uncommon species such as chough (*Pyrrhocorax pyrrhocorax*) and the well-known carrion-feeders buzzard (*Buteo buteo*), red kite (*Milvus milvus*) and raven (*Corvus corax*).

Important in the Welsh context is the ffridd (or coedcae) zone. This zone does not belong to any one broad habitat type, but instead refers to a mix of vegetation communities found on the often uncultivated valley sides; bridging the uplands and lowlands of Wales. The Brecon Beacons National Park Authority website states, "Its primary characteristic is a collection of various habitats (a diverse mixture of grass and heathland with bracken, scrub (often hawthorn and gorse) or rock exposures and it may also include flushes, mires, streams and standing water)" (BBNPA, 2011) In most instances, ffridd cannot be effectively farmed due to steepness or the rocky condition of the ground. The ffridd zone is noted for its dynamic nature due to a long history of changing cycles of management. Because of its situation at the boundary of lowland and upland habitats, the future management of ffridd may have important implications for biodiversity and the delivery of regulating services in Wales.

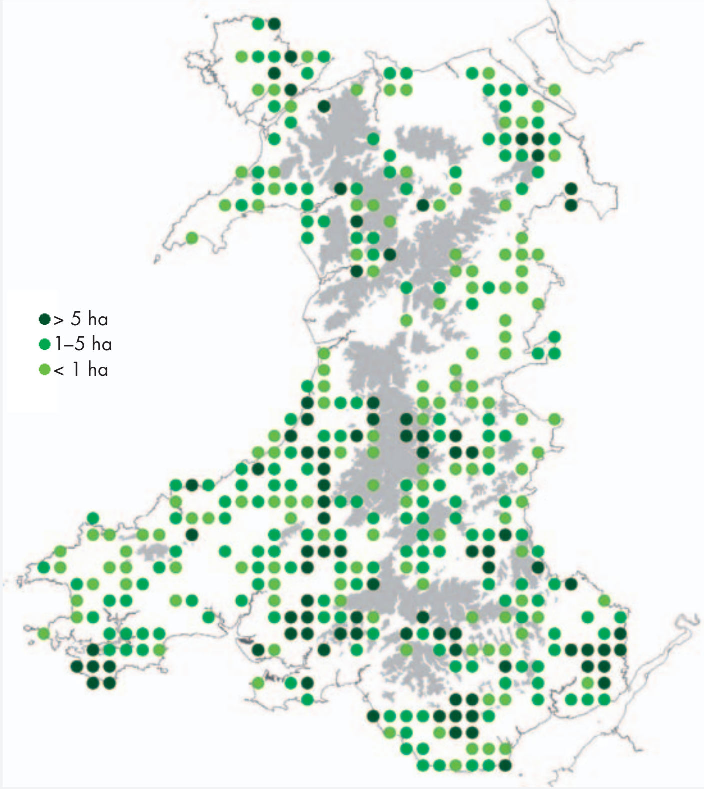


Figure 20.12 Distribution of crested dogstail (*Cynosurus cristatus*)/knapweed (*Centaurea nigra*) (MG5) grassland in Wales. Source: Stevens *et al.* (2010).

20.4.2.2 Drivers of change

Sheep and, to a lesser extent, beef rearing are the major forms of farming in Wales, with dairying and crop production now more localised. Many farms in the upland heartlands have land extending from the valley bottoms into the uplands, with the mountain flock overwintering in the lowlands or off-farm, although sheep are also on the hills during winter in some parts of Wales. Semi-natural Grasslands formerly played a fundamental role along this altitudinal gradient, providing summer grazing and hay crops in lowland enclosures; nowadays these have been very widely replaced by productive rye-grass grasslands that provide grazing and silage for winter food, and a much enhanced level of meat production. It is now common to find that remnant examples of Semi-natural Grasslands have become neglected and overgrown. While these grasslands still prevail in the uplands, this change in grassland composition in the lowlands has come at the cost of heavy fertiliser application and land drainage works in many locations.

Soil conditions in lowland grasslands have shown changes in the soil microbial community that have implications for nutrient management and carbon storage. Soils associated with low nutrient input semi-natural dry grassland have a relatively high fungal to bacterial biomass ratio compared to Improved Grassland (e.g. Bardgett & McAlister 1999), with fungi-rich soils appearing to retain

Table 20.3 Extent and community diversity of grasslands in Wales. Source: Blackstock *et al.* (2010).

	Extent (ha)	Number of component communities
Lowlands		
Improved	1,012,700	2
Semi-improved	53,400	3
Unimproved dry	22,100	4 (acid), 3 (neutral), 6 (calcareous)
Marshy	35,300	7
Uplands		
Improved	14,000	2
Semi-improved	5,400	2
Unimproved dry	108,700	5 (acid), 2 (calcareous)
Marshy	29,200	3

Table 20.4 Examples of plant species strongly associated with semi-natural lowland grasslands in Wales. Source: Stevens *et al.* (2010).

Acid grasslands	Neutral grasslands
Radnor Lily (*Gagea bohemica*) Upright Clover (*Trifolium strictum*) Wood Bitter-vetch (*Vicia orobusv*	Dyer's Greenweed (*Genista tinctoria*) Green-winged Orchid (*Orchis morio*) Greater Butterfly Orchid (*Platanthera chlorantha*) Great Burnet (*Sanguisorba officinalis*)
Calcareous grasslands	**Marshy grasslands**
Soft-leaved Sedge (*Carex montana*) Dwarf Mouse-ear (*Cerastium pumilum*) Hoary Rock-rose (*Helianthemum oelandicum*) Spiked Speedwell (*Veronica spicata*)	Whorled Caraway (*Carum verticillatum*) Meadow Thistle (*Cirsium dissectum*) Blunt-flowered rush (*Juncus subnodulosus*) Wavy St John's-wort (*Hypericum undulatum*)

nitrogen more effectively (e.g. de Vries *et al*. 2006; Gordon *et al*. 2008). Soil carbon pools may also be increased in grasslands with legumes such as birdsfoot trefoil (*Lotus corniculatus*) and white clover (e.g. de Deyn *et al*. 2009), and grassland management has potential to enhance carbon sequestration in agricultural landscapes (Smith *et al*. 2008); marshy grasslands on peaty soils are likely to be particularly significant in this respect.

The ecosystem services provided by Semi-natural Grasslands include carbon and nutrient storage, and regulation of water quantity and quality through mediation of drainage regimes. These aspects are dealt with in more detail in Section 20.5.2.

Alteration of the composition of lowland grasslands is one the most rapid and widespread vegetation changes that has taken place in Wales during the 20th Century. Grasslands of different types were mapped across Wales over several years up to 1934/1935 by staff of the Plant Breeding Station at Aberystwyth (Davies 1936). Although the classification employed differs from that of the recent surveys, a comparative assessment by Stevens *et al*. (2010) indicates that some 90% of former unimproved and semi-improved swards have been transformed by agricultural management to Improved Grasslands. Such changes in grassland habitats are likely to have profound implications for the specialist biodiversity associated with Welsh lowland grasslands. The rate of loss of Semi-natural Grasslands in lowland Wales has been dampened by protection in conservation sites and agri-environment schemes, but such measures were too late to curtail the major post-war transformation.

Changes in the extent of upland Semi-natural Grassland have not been assessed, but the cover is likely to have increased during the last century, especially at the expense of Dwarf Shrub Heath. An inventory of heath on upland moorland in 1990–1991 (Bardgett *et al*. 1995) found a considerable amount of degraded heath which was attributed in part to overgrazing by sheep. This is corroborated by the findings of the Habitat Survey of Wales, which recorded a high proportion of heathland in grass-heath mosaics (Blackstock *et al*. 2010).

Modification of the composition of Welsh grasslands has taken place during a period of substantial increases in the number of sheep in Wales from about 4 to 11 million between 1950 and 1990 (Fuller & Gough 1999). More recently there has been a decline, and sheep numbers recorded in 2007 totalled almost 9 million (WAG 2009a).

Further widespread impacts on the composition of Welsh Semi-natural Grasslands are also likely to have come about through atmospheric deposition, particularly of nitrogen and sulphur, and associated acidification and eutrophication. Changes in community composition have been found with nitrogen manipulation experiments (Cunha *et al*. 2002), and there is evidence of a decline in acidic grassland species diversity associated with nitrogen deposition in Britain more generally (Stevens *et al*. 2004).

20.4.3 Enclosed Farmland

Agriculture is the predominant land use over much of the land surface of Wales, and it plays a major role in the management of natural resources and the provision of ecosystem services, particularly the provisioning services that result from agricultural production.

Including commons, agricultural land occupied some 1.64 million ha or 79% of Wales in 2008. Of this, permanent grassland and arable crops accounted for 1.163 million ha or nearly 71% of the total agricultural area (WAG 2009a). Not all of this can be regarded as Enclosed Farmland, however, since whilst much permanent grassland has been improved, a large proportion remains in a semi-natural state (Smart *et al*. 2009). According to the methods used, there remains scope for considerable variation in the estimated area of Enclosed Farmland. For example, Improved Grassland was estimated by the Countryside Survey of 2007 as covering 731,000 ha or 34% of Wales, a much higher proportion than any other country in the UK apart from Northern Ireland (Smart *et al*. 2009). By contrast, the Habitat Survey of Wales (HSW) which was completed in 1997, records the total area of improved grassland (virtually all of which, by its very nature, must be enclosed) as being 1,026,700 ha (Habitat Survey of Wales, 2008). These variations are likely to arise from the use of different definitions of improved grassland, rather than any fundamental change in the extent of this habitat between the mid-1990s and 2007.

According to the Countryside Survey (Smart *et al*. 2009), Enclosed Farmland can be defined as comprising Improved Grassland, Arable land and Horticultural crops. In 2007, the total area of Enclosed Farmland was estimated at 804,000 ha or some 40% of Wales (Smart *et al*. 2009). In comparison to the other terrestrial habitats, Enclosed Farmland varies enormously from one part of Wales to another. For example, there are considerable differences between parts of Pembrokeshire and the Brecon Beacons in terms of recreation activity, nitrogen dioxide emissions and hedgerow morphology. Enclosed Farmland has more or less intrinsic value for many ecosystem services by virtue of its scale and proximity to other habitats. In much of the Welsh uplands there is a more intimate interaction between Enclosed Farmland and the semi-natural habitats that surround it, whilst in the lowlands, the interactions are primarily with rivers, streams and woods.

Wales's National Parks and Areas of Outstanding Natural Beauty are famed for their mountainous scenery, coastal views and extensive woodlands, but all of these features interconnect with a matrix of Enclosed Farmland where field boundaries, streams, woodlands, farm buildings and a wide range of historic features contribute substantially to the overall quality of the landscape. In addition, many of the more spectacular elements of protected landscapes can only be accessed by using the roads, tracks or public footpaths that are part of the Enclosed Farmland mosaic.

Within Wales, Improved Grassland predominates in the lowlands and the upland fringes, whilst semi-natural rough grazings and woodlands occupy most of the uplands (WAS 2008). Arable land is largely confined to the lowlands and occupies less than 10% (162,000 ha) of the total agricultural area (Habitat Survey of Wales 2008). Pembrokeshire, Gower, South Glamorgan, Eastern Powys and Eastern Clwyd have significant areas of intensive arable cultivation, with smaller areas present in Ceredigion, the Lleyn Peninsula and Anglesey. A relatively small amount of arable land is occupied by cereals, potatoes and horticulture (42,898 ha) representing less than 3% of the agricultural area. Part of the arable area is devoted to oilseeds (2,820 ha) and livestock feeds such as maize (18,632 ha) or forage crops, but the majority is occupied by improved grasslands of less than 5 years old (95,034; Habitat Survey of Wales 2008). Many of these grasslands will continue to be reseeded on a regular basis and will have been defined as improved grassland during the Habitat Survey of Wales (Blackstock *et al.* 2010).

The optimal zones for agricultural production are related to climatic and soil conditions. High altitudes, acid soils and impeded drainage have prevented arable cropping and grassland intensification over large parts of Wales. The LFA designation identifies those areas where farming is most difficult, with the Severely Disadvantaged Area (SDA) closely aligned with the most mountainous and upland areas. The current LFA (which includes both the SDA and the Disadvantaged Area or DA) covers approximately 80% of the total agricultural area of Wales.

Soil conditions suitable for cultivation and sufficiently fertile to support arable crops are described as falling within Agricultural Land Classes Grade 1–3 (**Figure 20.13**). In these areas, crops are a frequent component of the landscape. Grasslands that are regularly reseeded (i.e. less than 5 years old) are relatively more frequent across Grades 1–4.

20.4.3.1 Status, conditions and trends

According to the annual Welsh Agricultural Census, the total area of agricultural land has decreased since 1994, with a reduction of 45–50,000 ha occurring in 1999 (Smart *et al.* 2009). Within this total agricultural area, the relative proportions of the different types of farmland have also changed (Smart *et al.* 2009):

- Permanent grassland increased steadily from 55% in 1994 to 62% in 2008.
- Rough grazing decreased steadily from 29% in 1994 to 23% in 2008.
- Temporary grassland decreased steadily from 9% in 1994 to 5% in 2008.
- Total tillage has mostly remained stable at around 4%, but a significant increase of 4,300 ha (66%) was detected in the upland zone between 1998 and 2007.

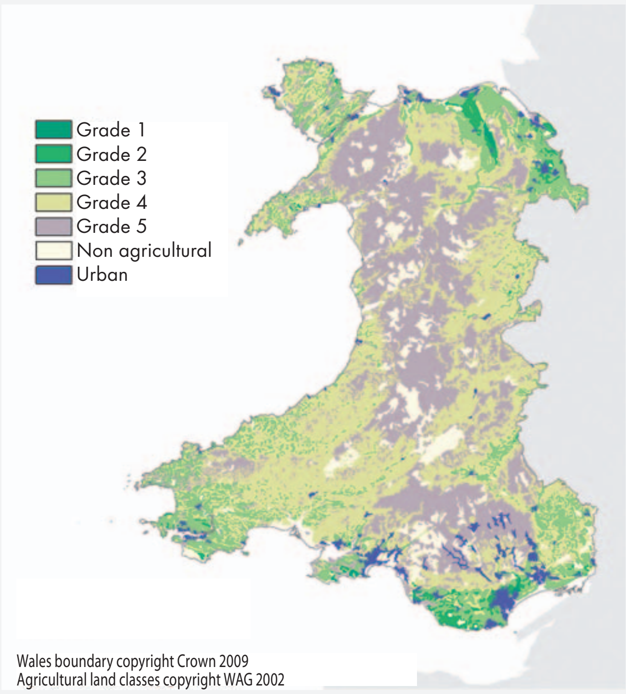


Figure 20.13 Agricultural land classes across Wales. Grades reflect geology, climate and soil, and range from 1=excellent to 5=poor. Source: GI Services Branch, Welsh Assembly Government, Aberystwyth. Crown Copyright 2002.

Livestock rearing is a major component of agriculture throughout rural Wales. Whilst rough grazings play a major role, in particular within the sheep sector, the bulk of Welsh agricultural production takes place on enclosed land. This not only accounts for 70% of the agricultural area, but is also considerably more productive. Agriculturally improved grasslands characterised by various strains of rye-grass and white clover now predominate. During the course of the 20th Century, these highly productive crops have largely replaced the once much more characteristic semi-natural pastures and hay meadows. In particular, much of the land formerly used for hay cropping is now devoted to the production of silage. This is used for stock feed over the winter period along with concentrates and occasional forage crops.

20.4.3.2 Drivers of change

Data on the long-term trends (1867–2002) in agricultural land use and livestock numbers are presented in Section 20.5.3 on provisioning services. Towards the end of the last century, arable crops covered about 300,000 ha or 20% of the agricultural area, with cereals accounting for over half of this and the remainder consisting of roots, brassicas, peas and beans (Ashby & Evans 1944). Crops were grown for domestic consumption as well as for feeding livestock such as horses. Towards the end of the 19th Century, however, it became possible to import livestock feed. This allowed a movement away from mixed farms and towards greater specialisation. In general, the importance of crops declined and the area of land under grass increased. By the late 1930s the area of crops had reduced markedly. Despite a brief surge as more land was ploughed during the Second World War (WWII), the switch from arable to grassland accelerated from 1947 onwards, especially as horses were replaced by tractors. Crops now account for only 3% of the agricultural land area according to the Habitat Survey of Wales (Blackstock *et al.* 2010).

Information on hedgerows and walls, which are important ecological and cultural features of farmland in Wales, is provided in the sub-section on biodiversity trends in Section 20.3.

There are some 68,000 ha of farm woodlands, both conifer and broadleaved, comprising some 4% of the total area of agricultural holdings in Wales (WAS 2008). Recent woodland and agricultural schemes have helped to increase the area of Woodland (**Figure 20.14**) which has been fenced to control access by livestock, but extensive areas of semi-natural broadleaved woodland remain heavily grazed, in particular by sheep. Whilst this can bring benefits to birds such as

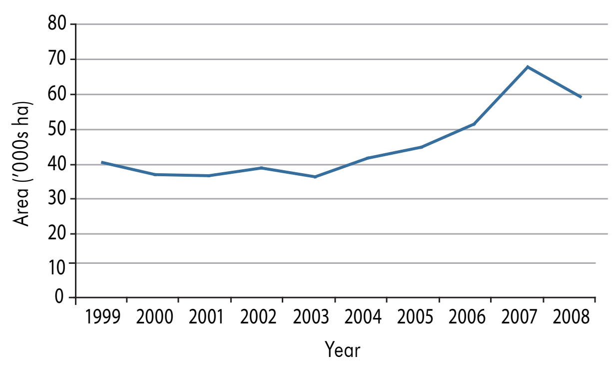


Figure 20.14 Trends in area of Welsh farm woodlands. Source: Forestry Commission (2009a).

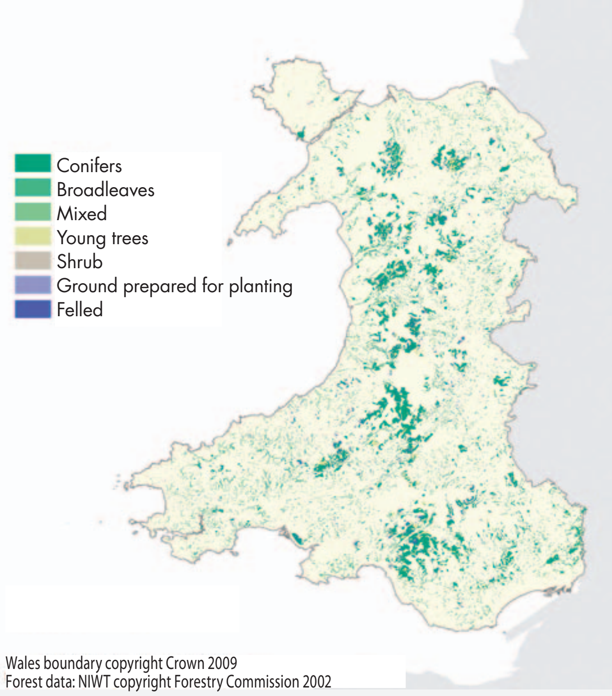


Figure 20.15 Distribution of forested land in Wales, derived from National Inventory of Woodland and Trees (NIWT) (areas of tree cover with a crown density of, or likely to achieve, at least 20%, a minimum width of 50 metres and a minimum area of 2 ha). Source: Forestry Commission (2003).

the pied flycatcher (*Ficedula hypoleuca*) which are more common in heavily grazed oak woodlands, uncontrolled levels of grazing seem likely to inhibit regeneration of trees and shrubs, representing a long-term threat to the continued survival of these habitats. However, in 2007, the Countryside Survey reported on changes in a number of sample plots between 1971 and 2001 and found that the basal area of trees and shrubs had increased, numbers of tree seedlings had decreased and the abundance of open habitats and signs of recent management had all decreased. These changes were also accompanied by a decrease in the number of species of ground flora and a shift toward more shade-tolerant understorey plants (Countryside Survey 2007). As a result, current advice on woodland management focuses on trying to ensure the right level of grazing is used, rather than attempting to exclude livestock altogether.

20.4.4 Woodlands

"Trees…Nothing can compete with these larger-than-life organisms for signalling the changes in the natural world." (Deakin 2007).

Woodlands cover approximately 14% of the land area of Wales (**Figure 20.15**). They provide an important range of ecosystem services and associated goods and benefits such as timber, soil protection, amenity and biodiversity. The climate of Wales has a strong maritime influence that, over time, has led to the development of a number of distinctive cool temperate native forest types, which are a subset of those found in continental Europe (Barbatti *et al.* 2007). There is considerable variation in composition in response to climatic gradients and soil type. Distinctive Atlantic woodlands dominated by oak, also known as upland oak woodlands, are widespread throughout Wales, currently accounting for about half of the semi-natural woodland cover. Other native woodland types in Wales include upland mixed ash woodlands, which represent 25% of the semi-natural woodlands, wet woodlands of alder, willow and birch, lowland beech and yew confined to South Wales, and on the heavier soils, lowland mixed broadleaved woodland of oak, ash and elm. Climatic constraints have influenced the development of woodland management in Wales, permitting a wide range of potential temperate species to be considered for use, and imposing other constraints such as wind, rather than fire, as a dominant abiotic disturbance factor (Quine & Gardiner 2006).

Biodiversity is one of the main benefits from forests that people (70–80% of respondents) recognise (Forestry Commission 2009b) and has been included as part of estimates of the non-timber values associated with woodland. The environmental benefits of woodlands in Wales have been valued at £34 million (Read *et al.* 2009). There have been some attempts to assess the value of the services provided by woodlands and forests. One of the most comprehensive was by Willis *et al.* in 2002. The assessment of annual and capitalised social and environmental benefits are summarised in **Table 20.5**.

Table 20.5 Annual and capitalised social and environmental benefits of forests in Wales (£ millions, 2002 prices). Source: Read *et al.* (2009).

Environmental benefit	Annual value	Capitalised value
Recreation	13.84	395.40
Landscape	7.25	207.14
Biodiversity	4.00	28.57
Carbon sequestration	9.19*	262.57
Air pollution absorption	0.04*	1.13
Total	**34.32**	**894.81**

* An approximation, since carbon sequestration, and probability of death and illness due to air pollution, varies over time (Read *et al.* 2009).

20.4.4.1 Status, conditions and trends

The area of woodland in Wales began to increase following the First World War when, in 1919, the Forestry Commission was formed. The Forestry Commission began acquiring land and planting it mainly with conifers, to build up a strategic reserve of timber so that Britain would no longer have to rely on imports in times of war. The first trees to be planted by the Forestry Commission in Wales were in Llantrisant in 1921. The Second World War (1939–1945) put further pressure on our woodlands, despite all the planting in the previous years. Concern over losses and degradation of ancient and native woodland in the decades after WWII led to the development of policies for the protection of key sites (e.g. National Nature Reserves (NNRs), first designated in 1951, and SSSIs, first designated in 1981), and latterly for the protection, management and expansion of priority woodland habitats (Kirby 2003; Latham *et al.* 2005; UKBAP 2006; section 2). The latest estimate (Finch *et al.* 2008) is that there are currently 109,556 ha of native woodland in Wales (5.2% of Wales's land surface) comprising 81,000 ha semi-natural woodland and 29,000 ha of planted native woodland. This is 38% of the total woodland cover in Wales.

Different regimes of woodland management have evolved, reflecting woodland type, markets, and labour availability and affordability. In the latter part of the 20th Century, there was an almost complete cessation of traditional coppice management systems in native woodlands (Buckley 1992). Commercial plantations were, and in many cases still are, managed on an even-aged basis, with large-scale felling of stands at economic maturity to maximise timber production. In recent decades there has been a major shift in forestry policy and practice with the adoption of the principle of Sustainable Forest Management (SFM) for multiple benefits (Mason 2007). Woodlands are increasingly managed as a resource for people (recreation, amenity, well-being) and wildlife as well as timber and other wood products.

Woodlands in Wales vary in nature and character, with a very uneven spatial distribution of the principal woodland types. All Welsh woodland has been modified by management to some extent. According to the FRA (Global Forest Resource Assessment) 2005 definitions, there are no areas of primary woodland left in Wales. The majority of woodland area is classed as productive plantation with the next largest category, modified natural, representing 28.7% of the woodland area. Each of these categories delivers a somewhat different set of ecosystem services. In Wales only 1.6 % of land surface (and 12% of woodland) is ancient and semi-natural, and thus of the highest value for nature conservation (**Table 20.6**). However, native woodland (6% of land surface and 45% of woodland) is one of the most species-rich habitats in Wales, and non-native woods also have some biodiversity value. About 210 (39%) of the Section 42 species of principal importance for conservation of biological diversity in Wales either rely on woodland habitats, or could potentially be affected by silvicultural operations.

The major concentrations of Coniferous Woodland are located on the poorer soils in upland Wales. These woodlands are generally not close to major towns except for in the Valleys of South Wales where large areas of woodland are found close to sizeable centres of population. The vast majority of Wales's ancient semi-natural woodland and native woodlands are small and fragmented, often unmanaged, and generally set within an intensively managed agricultural landscape. There are some significant areas of ancient semi-natural woodland in South East Wales, particularly in the Wye Valley. Forty-four per cent of woodland over 2 hectares in extent is owned by or leased to the Forestry Commission, and responsibility for the management of the remaining 56% of woodland is in other ownership (NIWT 2002).

A significant amount of the tree resource in Wales is outside woodlands, in the form of individual trees and hedgerows (approximately 15.33 million live trees and 64 thousand dead trees in Wales; NIWT 2002). No data are available on trends in the area of urban woodland or numbers of urban trees in Wales.

The UK NEA Broad Habitat 'Woodlands' is based on the UK BAP broad habitat definitions, as also used by the UK-wide Countryside Survey (Countryside Survey 2007) with slight variation. Two woodland component habitats are recognised: Coniferous Woodland and Broadleaved Mixed and Yew Woodland. Within these categories, further priority habitats are recognised, with five of these being found in Wales. In addition about a quarter of the UK BAP priority species are associated with woodland or tree habitats to varying degrees. The NERC Act 2006, Section 42 List, includes 152 species which are associated with woodlands in Wales.

Tree cover of one sort or another is considered to have dominated the landscape in Wales in the pre-Neolithic period, although there are disputes as to how much of this

Table 20.6 Extent of woodland in Wales ('000s hectares). Source: Forestry Commission (2009a) with data on ancient woodland derived from Pryor & Peterken (2001) and the National Inventory of Woodlands and Trees, Forestry Commission (2003).

	Conifer		Broadleaf		Total Woodland
Woodland Type	Area ('000 ha)	Proportion (%) of total woodland	Area ('000 ha)	Proportion (%) of total woodland	Area ('000 ha)
PAWS* 1997	17	6	11	4	
ASNW* 1997	-	-	34	12	
Total in 2009	**156**	**55**	**128**	**45**	**284**

* Ancient woodland is woodland that has been in continuous existence since 1600; ASNW (ancient semi-natural woodland) is both ancient and semi-natural; PAWS (plantation on an ancient woodland site) is ancient but not semi-natural – and may be covered with broadleaf or conifer species.

was closed high forest and how much was a more open wooded system (Vera 2000; Rackham 2003; Hodder *et al.* 2005, 2009). The post-glacial history of native woodland in Wales (as in the rest of the UK) is largely one of loss, degradation and fragmentation (Rackham 1986; Watts *et al.* 2005). It is thought that a significant proportion of the country's woodland biodiversity was conserved through the retention of ancient broadleaved woodland (accounting for approximately 1% of the land area).

Forest cover in Wales declined through the Middle Ages, reaching an all-time low of 4.2% around the beginning the 20th Century. Since that period woodland area in Wales has almost tripled and currently amounts to 284,000 ha, representing approximately 14% of the total land area (Forestry Commission 2009a). This compares with a global woodland cover average of 30% and the EU average of 37% (FAO Forest Resource Assessment). The increase in woodland cover in Wales parallels a similar trend in Europe (World Resources Institute 2003). Notable woodland planting by private estate owners in Wales began in the late 17th and 18th Centuries, but substantial re-afforestation efforts began in the 20th Century (Smout 2002; Linnard 2000). Successive governments attempted to address the shortage of timber (compounded by wartime fellings) by encouraging the creation of large plantations of non-native conifer species. There was considerable criticism of planting on upland habitats (Avery 1989) and on existing ancient woodland sites (NCC 1984; Humphrey & Nixon 1999) due to loss of valued habitats, and pace of change in upland areas. This, and other changes, such as those relating to government taxation policy, has led to a dramatic decrease in the last 20 years of new planting of conifers, although they continue to be used extensively in replanting (restocking).

By contrast, over this period there has been an increase in the area of native woodland and use of broadleaved tree species through planting or natural regeneration. On river and stream banks, a clear on-going successional trend is observed, consistent with a marked increase in cover of trees and shrubs, and continuing reductions in species richness, especially of butterfly larval food plants (Countryside Survey 2007).

The restoration in tree cover has resulted particularly from the afforestation of marginal grazing land in the uplands—the main driver for expansion being timber production—and this underpins the current dominance of conifers, which comprise 55% of woodlands in Wales. However, the amount of broadleaved woodland has also increased, so that by 2009 broadleaf cover stood at 45% (see **Table 20.6**). This reflects changes in forestry policy since the mid-1980s which have sought to increase the range of services that woodlands can provide (including biodiversity, regulating services and cultural services). In this period the overall rate of increase in woodland cover slowed (the increase in the 5 years to 2006 being only 15% of that in the 5 years to 1976). There was a shift towards expansion of broadleaved/native woodland rather than coniferous woodland (Forestry Commission 2003), and usually in smaller blocks (**Table 20.7**).

Table 20.7 New woodland creation ('000s hectares) in Wales; five year totals over an 18 year period ending March 31st. Source: Forestry Commission (2009a).

Woodland type	1976	1981	1986	1991	1996	2001	2006	2009
	'000 hectares							
Conifer	12.9	6.8	5.6	3.0	0.5	0.7	0.0	0.0
Broadleaved	0.1	0.2	0.3	1.1	2.0	2.1	1.9	0.7
Total	**12.9**	**6.9**	**5.9**	**4.1**	**2.5**	**2.7**	**1.9**	**0.7**

One of the key aims of Woodlands for Wales, the Welsh Government's strategy for woodlands and trees (WAG 2009b), is to increase the diversity of woodlands. Ancient and semi-natural/native woodlands, a particular concern from a biodiversity perspective (Peterken 1977), have declined due to losses to agriculture and to a lesser extent to development; and in addition, there was widespread planting of conifer species on ancient woodland sites between 1900 and the 1980s (at least 17,000 ha; Spencer & Kirby, 1992; Roberts *et al.* 1992). This was followed by a concerted effort to restore these woodland areas to native species (approximately 5,000 ha between 2000 and 2010; Forestry Commission 1985; Defra/Forestry Commission 2005; ODPM 2005; Goldberg *et al.* 2007). Individual sites do, however, still come under threat.

Despite recent reductions in pollutant emissions, nitrogen deposition and ozone levels are still above 'critical loads' for habitats such as Atlantic oak woodlands with sensitive ground flora and epiphytic lichens. It is well established that wild herbivores, including deer, have increased in Wales over at least the past 30 years, with impacts on tree regeneration, woodland structure, species diversity and timber quality. Woodland ageing has led to increased shading and loss of structural diversity and may have contributed to the decline of some woodland birds. Increased shading is also caused by lack of management. Where woodlands cover a sufficiently large area there will be a range of woodland types and age structure with associated variation of flora and fauna which will be able to move between and into gaps, sustaining complex ecosystem dynamics and resulting in greater biodiversity. However, most Welsh woodlands are small and may consist of stands of one or just a few tree species. In these, the process of stand development can have the effect of displacing ground flora to the edge of the woodland, and with little scope for moving to adjacent suitable habitat, some species may be lost to the site either temporarily or permanently.

Historic management patterns of thinning, small-scale felling and coppicing have in the past mitigated the shading effect by removing a proportion of canopy trees, accelerating the environmental partitioning process and producing a more diverse stand structure. In small woodlands where such management has ceased or never commenced, woodland ecosystems have lost many important functions and remain sub-scale and less diverse than their full potential would allow. Deforestation of other woodland types does takes place to restore open habitats that were afforested during the 20th Century. For instance, Forestry Commission Wales is working to restore deep peat habitats on the Government Woodland Estate and to date, 900 ha of conifers have been removed to achieve this. There is less information on changes in the numbers and extent of small clumps and individual trees (Forestry Commission 2003). These include a high proportion of veteran trees, for which the UK has a particular responsibility/reputation in Europe (Woodland Trust 2009). These declined in the post-war period (e.g. Peterken & Allison 1989) as a consequence of agricultural intensification.

In broadleaved woodlands, evidence from the Countryside Survey (2007) and Kirby *et al.*(1998) suggests that three key changes have taken place over the last 20 years. 1) Increasing shadiness, reductions in open space and increases in deadwood: primarily due to the ageing of woodlands planted in the 20th Century, but also following limited silvicultural interventions in broadleaved woods over the last 60 years. This has led to increases in shade-tolerant plants including bramble, with concurrent reductions in the species richness of ground flora (particularly butterfly food species). 2) Increasing density of the 0.5–4 m shrub layer. Amar *et al* (2010) suggest that over the last century Welsh woodlands have typically experienced increased levels of grazing by stock, followed in the last 20 years by a reduction in grazing pressures as government policy has encouraged stock exclusion. The increasing shrub layer may further shade out the ground flora and lichens on lower trunks of trees as well as competing with the veteran trees (Read 2000). 3) An increasing 'generation gap' whereby sites with mature or veteran trees frequently lack younger generations to replace them.

For at least the last 30 years, grey squirrel and deer populations have increased in Wales (Ward 2005) and now constitute a major limitation on natural regeneration (Fuller & Gill 2001). The apparently increasing threats (Broadmeadow *et al.* 2009) to mature trees from disease (Dutch Elm Disease, alder dieback, ash dieback, various syndromes affecting oak, new strains of *Phytophthora* affecting a broad range of trees, etc.) makes a lack of replacement trees even more acute.

The condition of Coniferous Woodlands has also changed. There is increased diversity of structure with the maturing of coniferous forests, plus the impacts of deliberate restructuring of plantations through smaller felling coupes and gradual transformation of forests in Wales from clear felling to continuous cover (Mason 2007). Over the last decade, efforts to identify areas to be left as stream corridors, and to remove dense conifer shading and open out stream sides, are likely to have significantly increased invertebrate abundance and numbers of trout where water quality is suitable.

A landscape connectivity indicator has recently been developed (Watts & Handley 2010) to reflect the constraints that different landscapes may place on the dispersal of species from one patch of habitat to another. This has been applied to Countryside Survey 2007 data for the purposes of biodiversity reporting. Preliminary results indicate a decline in Wales in the functional connectivity of woodlands within the landscape. The declines appear to be largely due to the increasing hostility to species dispersal of landuse types that separate woodland patches, for example by the intensification of agricultural practice. Efforts are underway to encourage native woodland planting in key network zones via the Better Woodlands for Wales grant scheme. The trends identified are likely to continue to be significant in the short to medium term. The future may pose a different set of threats to woodland condition.

20.4.4.2 Drivers of change

Over the last century, the key drivers of change in Welsh woodlands have been:

a) Government policy: The last century saw a major shift from a policy of large-scale woodland planting (early 1900s to 1980s) generally, with timber production as a single objective, to a focus on multipurpose forestry and little increase in woodland cover (1980s to present) where forest design and management have aimed to provide a balance of ecosystem services. In particular, there have been significant increases in the provision of recreation facilities, a restructuring of wooded riparian zones, a large-scale redesign of woodland shapes in the landscape, and a recent reduction in the reliance on clear felling.
b) Endogenous ageing of woodlands: The ageing of conifer and broadleaved woodlands planted in the 20th Century has led to significant changes in ecosystem delivery through a combination of active management and natural processes.
c) Reduction in use of home-grown hardwood fibre: There has also been ageing of the broadleaved woodland resource due to reductions in silvicultural intervention (e.g. for firewood, tan bark, pit props and charcoal making).

To a lesser extent, invasive species, pests and diseases, pollution and rising energy prices have also been drivers of change.

In future, the key drivers of change are likely to be:

a) Implementation of the Welsh Government's Woodlands for Wales Strategy. This 50-year strategy, published in 2001 and revised in 2009, recognises the role of woodlands and trees in delivering social, economic and environmental benefits. It promotes the design and management of woodlands to provide a wide and balanced range of ecosystem services. Government and market incentives for planting to deliver more benefits such as carbon sequestration (or to a lesser extent, flood risk mitigation). These could lead to a major increase in planting rates, and also affect the way that existing woodlands are managed.
b) Projections about the probable impacts of climate change. These are likely to drive change in silvicultural practice in order to increase the resilience of the woodland resource. Efforts are already underway to diversify woodland structures and to alter the variety of tree species planted. A changing climate is likely to increase the number of outbreaks of pests and diseases (e.g. *Phytophthora* species), and the levels of windthrow and drought.
c) Rising energy prices. These are likely to further encourage planting and management of broadleaved woodland for woodfuel, and may also impact on the way conifer plantations are created and managed.

Detailed discussion of drivers is provided in the UK-level chapter on Woodlands (Chapter 8). It includes coverage of climate change, land use change, economic forces, woodland fragmentation and loss, pollution (e.g. nitrogen deposition and ozone levels), biotic pressures due to herbivores, pests and invasive species, and the ageing of the woodland stock in Wales.

20.4.5 Freshwaters – Openwaters, Wetlands and Floodplains

Wales has some of the most dynamic fluvial systems in Britain. An average annual total of 3,000 mm of rainfall falls on Snowdonia, the wettest part of the country. The geological foundation of the region is mainly hard rock with limited underground water storage capacity. Generally, rainfall is quickly channelled into rivers, which are very responsive to changes in weather. In addition, lakes and wetlands act as surface reservoirs supplementing river flows. Over 20 major river systems drain the total surface area of Wales (2,077,000 ha).

Welsh rivers have a distinctive westward- or eastward-flowing biogeography (distribution of plants and animals). Westward rivers are dominated by salmonid species, while eastward rivers often have a more diverse assemblage, including several coarse fish species. Plant communities dominated by bryophytes and a range of vascular plants tolerant of fast flows and base-rich conditions are found in the south-east, e.g. Wye and Usk. River plant assemblages in the westward-flowing rivers have a diverse bryophyte flora adapted to the shaded, base-poor conditions. There is also a distinctive plant community adapted to acid, low-nutrient conditions in the headwaters.

20.4.5.1 Status, conditions and trends

Change in freshwater habitat. An Environment Agency dataset has shown that Wales has some of the best quality river habitat in England/Wales. River invertebrate distribution reflects the 'River Continuum Concept' (Vannote *et al.* 1980), responding to physical and chemical factors and varying across riffle-pool (shallow-deep) sequences. There is no distinctly Welsh river invertebrate fauna, but many species are of conservation importance and some are on the brink of extinction within the region, e.g. freshwater pearl mussel (*Margaritifera margaritifera*). In headwaters, invertebrate community composition is strongly influenced by calcium and pH composition.

Lakes located along rivers reflect the environmental gradient from upland acid waters to lowland, often more nutrient-rich conditions. Geographic location has a major influence on lake biology in Wales, with the most obvious distinction occurring between lowland and upland environmental conditions. The upland, natural lakes of glacial origin usually have nutrient-poor, acid, clear, or peat-stained waters. Their stony and exposed shorelines are a challenging environment favouring stress-tolerant, low-growing rosette vegetation (plants with a rosette of leaves held flat to the ground). Invertebrate communities are dominated by insect taxa—mayflies, stoneflies, some beetles—with simple food webs based on algal growths and fine detritus.

Lowland lake systems have a higher degree of niche diversity, with a variety of submerged and floating plant forms and greater range of physiological tolerance. Abundant and diverse assemblages of invertebrates are found, including leeches, snails, crustaceans and insects, with the more complex food web based on well-developed plant beds.

The biodiversity of Welsh lakes is comparable to that found in England and Scotland, but the range of lake types is high for a small region, with nine out of 11 of the UK's ecological lake types recorded in Wales according to the JNCC lake classification (Duigan *et al.* 2007).

Welsh fens are important by virtue of their extent, diversity and quality, and they present a microcosm of the range of variation found within British fens. There is an estimated 6,200 ha of fen habitat occurring in Wales, encompassing approximately 2,700 ha of basin, valley and floodplain mire and 2,100 ha of flush vegetation in the lowlands, together with approximately 1,400 ha of swamp (figures from the Lowland Habitats Survey of Wales 1987–1997 and the RSPB Inventory of Welsh Reedbeds 1993, 1995).

There is an estimated 460 ha of Welsh reedbed, amounting to approximately 10% of the total UK cover of this habitat (some 5,000 ha), and the notable concentrations in some Welsh local BAP areas represent an important western UK stronghold. Wales supports a total of 1,700 ha of lowland blanket bog, of which 1,200 ha is modified bog, which reflects the extent to which this habitat has undergone modification. Grazing marshes and floodplain grasslands are widespread in lowland Britain, covering an estimated total area of 300,000 ha; however, only a small proportion of this is semi-natural grassland. A total of 54,600 ha of grassland habitat types have been recorded within coastal levels and floodplain landscapes in Wales, within a Countryside Council for Wales inventory of Welsh grazing marsh and floodplain sites. There is a continuously changing assemblage of birds moving into and around Wales and a substantial proportion are dependent on freshwater and wetland habitats. For example, the red-breasted merganser (*Mergus serrator*) and goosander (*Mergus merganser*) have successfully colonised, osprey (*Pandion haliaetus*) have returned and nested near the River Glaslyn since 2004, while some species have noticeably shifted their distribution away from the coast.

The otter (*Lutra lutra*) is one of the largest predators found in fresh waters and wetlands in Wales. Historic population declines have been attributed to the use of toxic pesticides but recovery remains slow, with numbers and the distribution range of otters below previous levels (Environment Agency, 2004). Rivers are especially important to a diversity of bat species, as feeding/roosting areas and flyway connections. Mink introduction has been linked with water vole decline. However, Welsh rivers have also served as isolated refuges for imperilled species, such as the polecat (*Mustela putorius*).

The Welsh fish fauna has a preponderance of diadromous types (species that migrate between the sea and fresh water). The populations of salmon, shad and lampreys (*Lampetra planeri*) are of particular conservation importance in a European context. Welsh rivers have 32 resident fish species, including eight non-natives. Brown trout are common in upland lakes, and Welsh lakes also support the most southern populations of Arctic charr (*Salvelinus alpines*) and gwyniad in Britain.

Freshwater ecosystems in Wales are undergoing serious environmental degradation from a variety of human pressures including pollution, sedimentation, extractive fisheries, invasive/non-native species introduction and water regulation. The majority of freshwater features within designated sites in Wales are in unfavourable or declining condition according to European survey criteria (**Figure 20.16**). The Countryside Survey (2007) found that species richness within sampled watercourses (primarily headwaters) did not change between 1998 and 2007 and the physical characteristics of watercourses improved.

Condition of rivers. Upland Welsh freshwater ecosystems are very vulnerable to acid deposition due to a combination of local acid sensitivity (base-poor rocks and soils), large volumes of rainfall containing sulphur and nitrogen oxides, and local land use practices. In particular, over 20% of the highest altitude catchments in Wales (over 200 m) are afforested by exotic conifers that increase local sulphur and nitrogen deposition, thereby increasing the contribution of acids and metals. Over half of Wales's stream length—around 12,000 km—was impacted by acidification making this the single largest pollution problem (Firth *et al.* 1995; Stevens *et al.* 1997). Ecosystem structure and function in acidified streams has been altered, including reductions in salmonid and dipper populations (Ormerod & Jüttner 2009).

Condition of lakes. It is estimated that there are almost 570 lakes (over 1 ha) in Wales and 47,000 smaller ponds and wetland pools (2007) increased from 40,000 in 1998. However, only 5% of ponds were classified as being in 'good' condition at the time of the Countryside Survey in 2007 (**Figure 20.17**). The majority of Welsh lakes are of glacial origin and located in the mountains of north and mid-Wales. Several shallow lake ecosystems in Wales have switched from clear-water, plant-dominated ecosystems to phytoplankton-dominated lakes, or are exhibiting symptoms of a trend in this direction (e.g. Langorse Lake; Anglesey Lakes; Bosherston). Records of toxic blue-green algal blooms are increasing (e.g. Llyn Padarn, 2009; Llyn Tegid , since 1995).

Condition of reservoirs. Nearly all the major river systems in Wales are regulated by headwater dams and reservoirs installed for water supply, flood control and energy generation, which have caused hydromorphological modification of lakes and river courses (**Figure 20.18**). Reservoir development became an Anglo-Welsh political issue in the 1960s, with the displacement of the Welsh-speaking Capel Celyn community to create Lyn Celyn

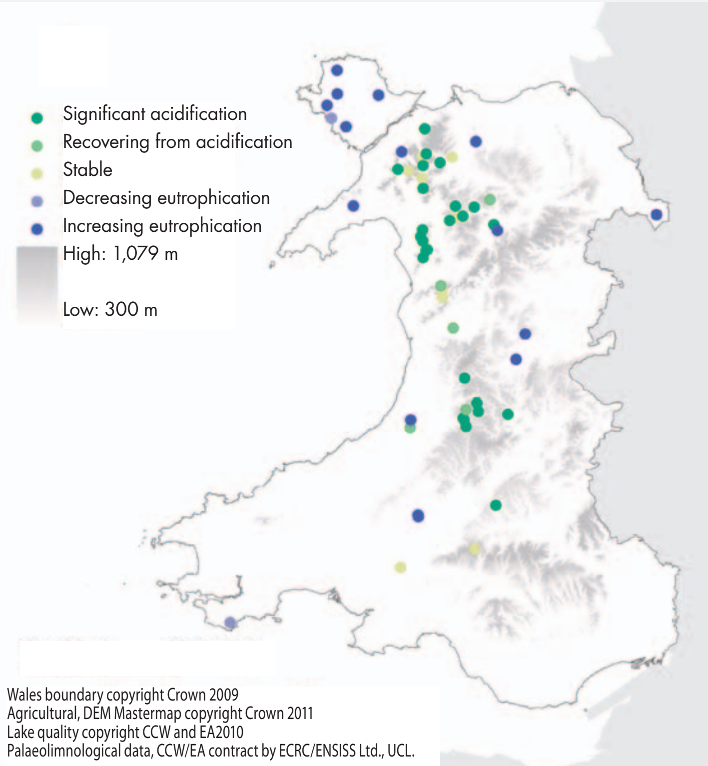


Figure 20.17 Condition of Welsh lakes within Sites of Special Scientific Interest, derived from 24 surveyed lakes. Source: CCW 2010.

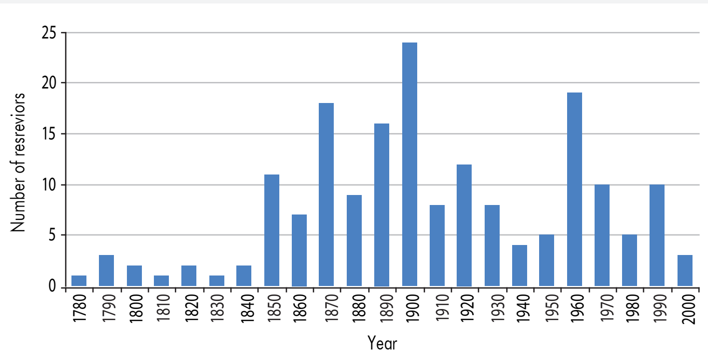


Figure 20.18 The number of reservoirs constructed per decade in Wales from 1780 to 2010. Source: based on Environment Agency data (statistics derived by the Countryside Council for Wales).

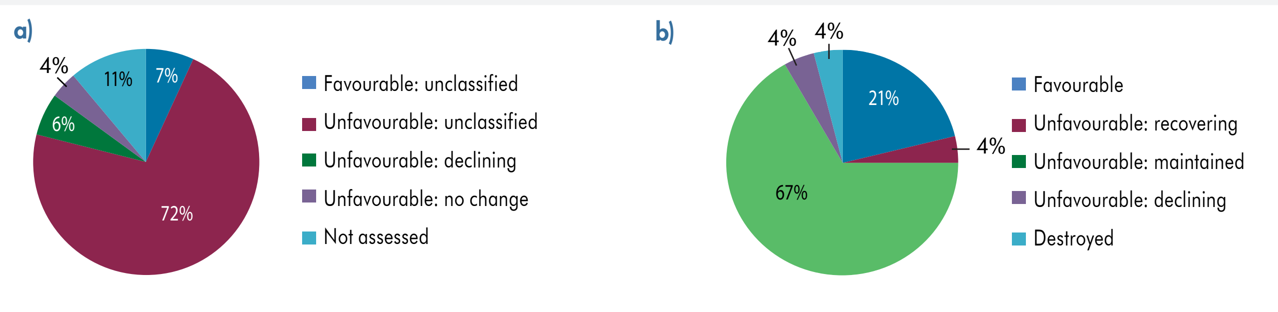


Figure 20.16 Condition of a) riverine species, and b) riverine habitats in Special Areas of Conservation in Wales. Source: Countryside Council for Wales, unpublished data.

(1965) as a water supply for Liverpool, and resistance to impoundments in the Clywedog valley in the 1970s. Two hundred-and-three reservoirs are now listed in the public register of reservoirs in Wales, but 11 of them are less than 1 ha in extent. One hundred and ninety-two reservoirs greater than 1 ha in area represent 33.86% of Welsh lakes. In 2010, over 799,709,824 m^3 of fresh water was contained within Welsh reservoirs. There may be further demands for reservoir construction as climate change increasingly impacts water availability and security in England and Wales. As Wales develops the ecosystem approach to governance as embodied in its new Natural Environment Framework, questions are certain to arise regarding the trade-off between maintenance of natural freshwater ecosystems and human demands on the environment where riverine, lake and reservoir resources are concerned.

Condition of floodplains. Some of the most valuable and productive agricultural land in Wales is strongly associated with floodplains. As a result, floodplain habitat is scarce, with 60% contained within just 10 river systems. Welsh river floodplain habitat is seriously degraded and fragmented, largely due to agricultural intensification and flood defence structures (Jones *et al.* 2009). Agricultural grassland is the most extensive land cover within Welsh floodplains, with neutral and marshy grassland as the most common component of semi-natural habitat. Secondary woodland, swamp, fen, bog and standing water also occur, with a wide diversity of floristic communities dependent on low-intensity farming in floodplains. Flood defence structures protect and isolate neighbouring areas from inundation, especially in urban environments. For example, almost the entire length of the River Taff is channelised with reinforcement and embankments for flood control (Dobson *et al.* 2009). This, coupled with conversion to improved grassland, upland forestry, general agricultural intensification, non-native species and urbanisation has degraded floodplain habitat across Wales.

More than 75% of Welsh-designated conservation sites (SSSIs /SACs/SPAs) contain water-dependent features. The Countryside Council for Wales is responsible for ensuring protection of these designated interests on six major river systems and over 140 lakes. Approximately 320 wetland SSSIs depend upon groundwaters, and 35 sites depend upon critical water level management. Between 50 and 75% of the land area of Wales is within the catchments of these rivers, lakes and wetlands.

Water and aquatic habitats form a key naturally occurring habitat network, and some river stretches have also been recognised for their fluvial geomorphological features, as part of the Geological Conservation Review. These sites (approximately 20) serve as illustrations of the evolution of the Welsh landscape, its cover landforms, processes, channel features, channel change and examples of human impact.

20.4.5.2 Drivers of change

A direct policy driver of change in Welsh freshwater ecosystems is, and will continue to be, the European Water Framework Directive (WFD). Through River Basin Management Plans working at the catchment level, the WFD is emphasising a more holistic approach to freshwater management that takes account of the wide range of ecosystem services that Welsh freshwater habitats provide.

Climate change is set to have a major influence on Welsh freshwater ecosystems, and changing patterns in water quantity and temperature are already discernible in Wales. In Llyn Brianne streams for example, winter temperatures have increased over the last 25 years by 1.4–1.7°C, causing changes in invertebrate populations (Durance & Ormerod 2007). Declines in Wye salmon and trout populations are also being linked to hotter, drier summers (Clews *et al.* 2010); Ormerod & Jüttner 2009). Welsh streams are adapted to large-scale 'gradual' climatic phenomena such as the North Atlantic Oscillation (Bradley & Ormerod 2001; Briers *et al.* 2004; Ness *et al.* 2004), so native species with less capacity for internal temperature control tend to dominate assemblages. They are therefore more vulnerable to climate change impacts that are likely to result in more sudden changes in local stream environments (Ormerod & Jüttner 2009).

Upland waters in the UK and Wales that were damaged by acid rain are beginning to recover. Between 1984 and 1995, average pH across streams in the Welsh Acid Waters Survey increased on average by 0.2 pH, while sulphate concentrations fell by around 16% (Stevens *et al.* 1997). Biological recovery is lagging behind chemical trends (because some streams remain chronically acid, while others are still affected by acid episodes), with acid-sensitive species still occurring only sporadically in recovering streams, and representing only a fraction of the species previously lost (Bradley & Ormerod 2002; Ormerod & Durance 2009). The true extent of acidification in Wales is under-recorded by routine Environment Agency monitoring and there are potential adverse consequences for key conservation sites, e.g. the River Wye (Ormerod & Jüttner 2009; Lewis *et al.* 2007).

Nutrients from diffuse and point sources and other forms of pollution are responsible for a decline in the health of freshwater ecosystems across Wales. Pollution may take the form of a short-term event/incident or may be a persistent influence over a longer period of time. Phosphorus and nitrate values are limiting the number of rivers which can be considered to be in 'good' condition. Significant slippage of rivers (700–800 km) from 'very good' to 'good' biological quality has taken place in Wales from around 1995 onward. The reasons are unclear but may be linked to diffuse pollution from agricultural sources (Ormerod & Jüttner 2009). Phosphate measurements indicate decreasing levels, but nitrate levels are remaining constant (Ormerod & Jüttner 2009). Agricultural runoff has been identified as a particular problem in mid-Wales and sheep dip impacts are of concern, particularly in west Wales. In 2000–01, sheep dip residues were found at 86–92% of Welsh survey sites, with cypermethrin responsible for most water quality failures. Reduced invertebrate abundance has been linked to sheep dip impacts in the upper Teifi (Rutt 2004, Environment Agency Technical Memo unpublished) and Johnes *et al.* (2007) have shown how agricultural developments and increased livestock densities across Wales have probably more than doubled phosphate loadings and trebled nitrate loadings to river catchments.

Industrial contamination. Welsh freshwater ecosystems are still suffering from an industrial legacy but there is evidence of improvement following remediation interventions, with over 50 metal mine locations having remediation strategies in place (Environment Agency 2002). The Afon Goch ('Red River'), which drains the currently inactive copper mine on Parys Mountain, Anglesey, has been described as one of the most acid- and metal-contaminated streams in the UK (Boult *et al.* 1994). Abandoned coal mines release acid, sulphate-rich water, often with negative effects on biota (Ormerod & Jüttner 2009). The most recent Welsh review identified 90 mine discharges and 60 km of Welsh rivers suffering clear biological impacts at around 70% of the sites sampled. The Afon Pelenna wetlands were constructed (1995–1999) to remediate an acid-mine discharge, and the abundances of invertebrates, trout and river birds have recovered, despite occasional episodes of pollution (Wiseman *et al.* 2004). There has also been ecological recovery in the Welsh Valley Rivers, with salmon returning to the Ebbw, the Rhymney, the Taff and the Rhondda.

20.4.6 Urban

The urban feature type of the Ordnance Survey Strategic dataset (1:250,000 scale) shows that 117,373.6 ha or 5.64% of Wales may be classified as Urban. However the Land Cover Map (LCM 2000) classifies only 4.1% of Wales as urban habitat. Depending on methods for mapping areas, the estimate tends to range between approximately 3–6% urban cover. Although a relatively small total area, the urban centres are mainly concentrated in the south Wales valleys and coastal strip and along the north Wales coast. Stevens *et al.* (2002) concluded that there were no national level statistics on annual loss of land to development in Wales and no consistent, nationwide schemes for gathering the necessary data. They noted that while planning policy tended to protect better quality agricultural land, protection of land with less agricultural value, but possibly greater ecological importance, was inadequate and therefore at greater risk of loss.

20.4.6.1 Status, conditions and trends

The definition for an urban space in Wales is where the population size is over 3,000 (Countryside Agency 2004). The extent of non-built land in urban Wales is unclear and the breakdown of that land by type is also unknown. The Countryside Council for Wales LANDMAP system can only provide data on land use in non-built parts of urban areas outside Cardiff and Swansea—our largest cities. Similarly, the Countryside Survey excludes all 1 km squares which are found to be more than 75% built-up, effectively excluding major urban areas from that survey.

However, the Countryside Survey showed that the extent of the Built-up Areas and Gardens habitat type was estimated to have increased by 14,700 ha between 1998 and 2007. This increase was evenly spread between the uplands and lowlands. In survey squares, half of the increase was new buildings and the remainder included gravel workings, caravan parks, gardens and extensions to the boundaries of farmyards and outbuildings. Eighty-six per cent of the mapped increase replaced Improved or Neutral Grassland or boundary and linear features (Smart *et al.* 2009).

In Welsh planning policy guidance (WAG 2009c), open space is classified as follows:

"Parks and gardens; natural and semi-natural urban greenspaces; green corridors; outdoor sports facilities; amenity greenspace; provision for children and young people; allotments, community gardens and urban farms; cemeteries and churchyards; accessible areas of countryside in the urban fringe; civic spaces and water". However, habitats in Urban areas also include building surfaces (walls, roofs, etc.) and the newly defined UK BAP priority habitat: open mosaic habitats on previously developed land (OMHoPDL). The criteria and definitions for OMHoPDL are available in the recently updated UK BAP Priority Habitats Description report (Maddock 2008). Gwent Wildlife Trust used an experimental survey methodology and an earlier version of the habitat definition to discover 640 potential OMHoPDL sites within Gwent, covering an area of 1909.35 ha. Of these, 115 (946.14 ha) were considered to have high or medium/high potential to meet the priority habitat criteria. They were able to extrapolate a 'best guess' estimate of 13,128 ha for the extent of this habitat in Wales (Gwent Ecology 2010).

In 2010, 18 of the 22 local authorities in Wales were working on complete assessments of the extent and location of accessible natural greenspace in their urban areas (**Table 20.8**). Because these assessments provide information to assist in improving public health they do not classify greenspace by habitat type. However, a desk-based analysis conducted across the five local authorities in the Heads of the Valleys area indicated that of the 104,800 ha total area assessed, 37,900 ha were classed as greenspace, but on average only 55% of people in the area lived within a 400 m walk of greenspace judged to be accessible and natural (exeGesIS 2007, unpublished data).

Many authorities are planning for networks of greenspace in their Local Plans, and Wales has recently introduced its first formal green belt on 2,536 ha of land between Cardiff and Newport**.**

Gardens are an important component of Urban areas and the Biodiversity in Urban Gardens (BUGS II) project assessed the extent and characteristics of gardens in five cities across the UK. The research revealed that of the 9,080 ha within the urban boundary of Cardiff, 2,100 ha or 16.2% could be defined as private gardens (Loram 2007).

The extent of urban woodlands in Wales, as a percentage of the total Urban area, is 13.1% (LCM 2000), the highest in the UK. In 2009, 76% of the Welsh population were assessed as having access to woodlands over 20 ha within 4 km of their home (Woodland Trust 2010).

Many Local Nature Reserves (LNRs) are in or adjacent to urban areas (CCW 2003). The Countryside Council for Wales keeps records of the area of all LNRs upon which it is consulted—**Figure 20.19**. Despite the overall area being inflated by one large rural LNR (Traeth Llafan, Gwynedd, declared an LNR in 1979), there has been a steady increase in the extent of LNRs in Wales. Whilst this does not reflect a change in habitat type within or around urban areas in Wales, it does show increasing protection for habitats considered to be of educational or conservation importance.

Table 20.8 Accessible Natural Greenspace Standards by local authorities in Wales from 2007 to 2010. Source: WAG (2010a).

Local Authority	Extent (ha) of accessible natural greenspace per 1,000 population	Proportion (%) of the population			
		Living within 300 m walk of any accessible natural greenspace	Living within 2 km of 20 ha site	Living within 5 km of 100 ha site	Living within 10 km of 500 ha site
Isle of Anglesey	-	-	-	–	–
Gwynedd	-	-	-	–	–
Conwy	-	-	-	–	–
Denbighshire	188	34	89	79	43
Flintshire	-	-	-	-	-
Wrexham	68	56	90	87	96
Powys	-	-	-	-	-
Ceredigion	-	-	-	-	-
Pembrokeshire	-	-	-	-	-
Carmarthenshire	109	24	24	32	38
Swansea	-	-	-	-	-
Neath Port Talbot	4	60	-	-	-
Bridgend	58	67	48	91	98
Vale of Glamorgan	-	-	-	-	-
Rhondda Cynon Taff	52	27	83	100	94
Merthyr Tydfil	95	57	98	100	100
Caerphilly	52	51	98	100	99
Blaenau Gwent	84	65	100	100	100
Torfaen	64	76	76	97	99
Monmouthshire	95	76	93	93	100
Newport	74	75	95	97	100
Cardiff	11	68	100	100	100

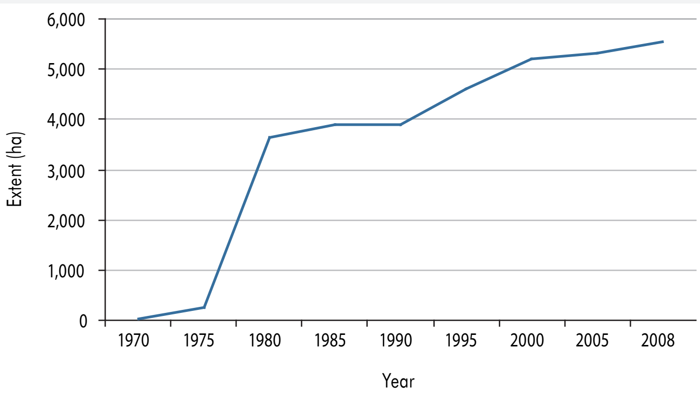


Figure 20.19 Change in extent of Local Nature Reserves in Wales. Source: Countryside Council for Wales, unpublished data.

Several bird species are strongly associated with human settlements, including the house sparrow (*Passer domesticus*), swift (*Apus apus*), starling (*Sturnus vulgaris*) and collared dove (*Streptopelia decaocto*). The British Trust for Ornithology Breeding Bird Survey (British Trust for Ornithology, pers. comm.) shows the following percentage population change for these species in Wales between 1995 and 2007:

- House sparrow: 71% increase
- Collared dove: 51% increase
- Swift: 43% decline
- Starling: 51% decline.

However, these results are not exclusively from urban Wales as there are only 16 survey tetrads in villages, towns and cities, so further monitoring work is required to develop a clear picture of these species in the urban setting in Wales. The UK BAP has associated the lapwing with OMHoPDL because of its tendency to nest on larger areas of post-industrial wasteland. The great crested newt (*Triturus cristatus*) is particularly associated with ponds in urban areas, and the large pond at Stryd Las in north Wales is a notable breeding site which has been given SSSI status for the protection of this species.

The UK BAP also associates Species Action Plans for the following animals with OMHoPDL: slow worm (*Anguis fragilis*), common lizard (*Lacerta vivipara*), adder (*Vipera berus*), grass snake (*Natrix natrix*), and common toad

(*Bufo bufo*). Open mosaic habitats on previously developed land provide open areas in which reptiles may bask for thermoregulation and rubble piles which may serve as hibernacula. Fish-free ponds and water bodies in which amphibians may breed may also be available. Some plant species are also highly associated with human settlements where walls mimic natural cliff habitats. The Dalmatian bellflower (*Campanula portenschlagiana*) is now red listed in its original habitat in the Balkans but thrives on urban walls in the UK as a garden escape—with Llanelli as a notable location in Wales. Because of the year-round damp climate in western Wales, the wall flora of human settlements is particularly diverse compared to the rest of Europe (Gilbert 1996).

Soil contamination is an additional threat posed by industrial development, urbanisation and mineral extraction, which can particularly affect biological processes of soil formation. Wales has a long history of mining and heavy industry, resulting in a significant legacy of soil contamination. For example, there are 1,300 mine sites where discharges to water are known to occur (EAW 2002). Although abandoned mines are generally perceived to pose an environmental risk, there are several sites designated as SSSIs because of the unique ecosystems that have developed on them.

A baseline desk study assessment of contaminated and derelict land in Wales was undertaken in 1988 (EAU 1988). It indicated that there were 752 potentially contaminated sites covering 3,721 ha of contaminated land and 10,900 ha (0.5% of the land area of Wales) of derelict land. The Welsh Office Environmental Advisory Unit (EAU) report (1988) and the review by Stevens *et al.* (2002) both acknowledged the limitations of the assessment, due to the relative rapidity of urban and industrial land-use change (e.g. factory closures, redevelopment) and the dynamic nature of the legislation at the time due to the introduction of the Pollution Prevention and Control Act 1999 and the 1990 Environmental Protection Act. Subsequently, 122 sites were designated in Wales under Part 2A of the Environmental Protection Act (1990) between 2001 and the end of March 2007 (Environment Agency 2009). Of these, four had been fully remediated by the end of March 2007. However, Part 2A excludes many wastes and some receptors and so may not represent the full extent of contaminated soils in Wales.

Soils in the built environment can provide the same range of services as in any other environment (Wood *et al.* 2005), but soil can also be degraded and destroyed by construction of buildings and infrastructure. If the population of Wales continues to grow and there is a focus of economic activity in the built environment, pressure on soil from urbanisation will increase. However, the scope for future urban development in Wales is constrained by the topography of the country and the infrastructure. Future development may, therefore, put more pressure on soils in the coastal margins, estuaries and river floodplains of Wales. These are likely to be vulnerable to impacts from climate change such as sea level rise and more frequent storm surges (Farrar & Vaze 2000), so that a complex picture emerges for future scenarios of urban development in Wales and for the threat to soil formation.

20.4.6.2 Drivers of change

Air quality declines and sealing of surfaces due to increased vehicle ownership, and loss of greenspace due to the selling-off of parks, gardens and allotments in the UK in general, are likely to have been mirrored in urban areas of Wales. Large gardens are increasingly sold as development plots for housing and front gardens are converted to parking space, which usually involves paving or otherwise sealing the ground surface. Loram (2007) has estimated that front gardens represent 26% of the total garden area for an average city. Applying this to the total garden area of Cardiff, then 5.46 km^2 of the urban area of that city is front garden (Loram et al. 2007). If this were all to be paved over for parking then the amount of permeable surface available for the absorption of rainfall would fall by around 6%.

20.4.7 Coastal Margins

The Coastal Margins comprise five component habitats in Wales; the sixth, Machair, is found only in Scotland and Ireland. Sand Dunes, Saltmarsh and Sea Cliffs are the most extensive, and each covers around 12% of the UK resource (**Table 20.9**). Sand Dunes are found all along the coasts of Wales. Sites such as Newborough, Kenfig and Merthyr Mawr are among the largest in the UK. These west coast sites are particularly important for their invertebrate biodiversity (Howe *et al.* 2010), and for their dune slacks, holding 68% of the UK resource of rare early successional (sd13 and sd14) dune slack communities (JNCC data).

20.4.7.1 Condition, status and trends

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, primarily along the North Wales coast, and due to forestry in north, mid- and south Wales. Losses are probably comparable to the UK figure of 30% loss since 1900 (Delbaere 1998). Habitat quality has also declined, with most dunes becoming overstabilised since 1945 (Rhind *et al.* 2001, 2008), Morfa Dyffryn being the notable exception.

Saltmarsh is also found all around Wales, with the largest extents in the Dee estuary in North Wales and the Severn estuary in South Wales. Estuarine saltmarsh occurs mostly on sandy substrate in macrotidal estuaries. The area in

Table 20.9 Area of Coastal Margins UK NEA component habitats in Wales, and as proportion of UK total. Trends in habitat condition (SACs/SSSIs): = stable, ↓ weak decline, ↓↓ strong decline, ↔ trend equivocal, ? trend unknown. Source: Table 11.2, Chapter 11 of the UK NEA.

Coastal Margins component habitats	Area (ha)	% of UK total	Trend
Sand Dunes	8,101	11.3	↓
Saltmarsh	5,800	12.7	?
Shingle	109	1.9	↓
Sea Cliffs	522*	12.9	↓
Coastal Lagoons	37	0.7	=

* Cliffs are measured as length (km).

Wales has been reduced landward by land claim for industry and agriculture, but in the larger estuaries such as the Dee, habitat has extended seaward due to vegetative colonisation of mudflats. The net change in area since 1945 is uncertain.

Some Coastal Lagoons have probably been lost in Wales historically, as was the case in England in the mid-20th Century, but there is little documentary evidence. Hard flood defence structures may hinder the development and evolution of coastal lagoons and lead to further losses, especially when compounded with climate change effects. The Countryside Council for Wales has developed new monitoring tools and baselines that are contributing to the management of Welsh lagoonal habitats (Stringell *et al.* in press), the reporting of Conservation Status, and potentially reporting for the European Water Framework Directive also.

Hard rock Sea cliffs occur predominantly in South West Wales and the Lleyn Peninsula, while soft rock cliffs have a slightly wider distribution around the Welsh coast. 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. Welsh Shingle comprises less than 2% of the UK resource but locally important examples occur, e.g. Dinas Dinlle in north Wales and Freshwater West in Pembrokeshire. There are 13 Coastal Lagoons in Wales, less than 1% of the UK total lagoon area. These are predominantly small sea inlets and artificial sluiced pools. Changes in area since 1945 and predicted changes to 2060 are unknown. However, of the terrestrial ecosystems, wetlands and coastal habitats show the greatest decline, with 25% of habitats declining at the same or accelerated rate (Wales Biodiversity Partnership 2008, unpublished data).

20.4.7.2 Drivers of change

Major drivers of change in the Welsh Coastal Margin habitats include changing tourism patterns and interests, land use demands, as discussed above, climate change, nitrogen deposition and sea-level rise. Background levels of nitrogen deposition on the Welsh coast are currently around 10 kg nitrogen per hectare per year (Jones *et al.* 2005, 2008) but have doubled since 1945. This increase is likely to have reduced plant species diversity and, with climate change, has altered soil processes in coastal habitats (Jones *et al.* 2008). Climate change is likely to have major impacts on dune slacks, by reducing water tables (Clarke & Sanitwong 2010). Isostatic adjustment (coastal lifting or depression since the ice-age) is more or less balanced in Wales, but sea-level rise will have impacts on Welsh coastal margin habitats, with a sea-level rise of 26.3 cm predicted for Cardiff by 2060 under a medium emissions scenario (Lowe *et al.* 2009), and steepening of beach profiles observed in Wales (Saye & Pye 2007). Seaward habitat losses will cause coastal squeeze where habitats are unable to migrate inland.

20.4.8 Marine

The coastline of Wales borders the Irish Sea and the Celtic Sea. Its length has been estimated at 2,120 km (2,740 km including the islands of Holyhead and Anglesey; Frost 2010). Marine designated sites in Wales total more than half a million hectares. Seven in every eight hectares of Welsh Natura 2000 sites are in the marine environment, reflecting the high conservation importance afforded to marine habitats in Wales.

20.4.8.1 Status, conditions and trends

The condition of the Marine areas of Wales is the subject of a recent report (UKMMAS 2010; **Figure 20.20**). Typically, there are good data for coastal areas but generally less data for offshore habitats. The last synoptic assessment of European marine Special Areas of Conservation (SACs) in Wales was in 2007 and showed that about half the features of these SACs were in unfavourable condition and that their future prospects (in status assessments) were, in general, not likely to improve in the short term.

The majority of factors contributing to environmental degradation in Welsh waters have recently been re-emphasised by the Charting Progress 2 (UKMMAS 2010) process. The major factors identified as affecting marine habitats in Wales are: fisheries, coastal development, non-native species introductions and climate change.

Condition of Intertidal Rock. The spatially most widespread pressure in Intertidal Rock habitats is that of shore collecting of winkles and other shellfish from moderately wave-exposed shores and collecting of bait from beneath boulders. These activities result in disturbance of the substratum and the associated biological communities, as well as removal of the target species, but in relatively small numbers at the majority of intertidal habitats. The Countryside Council for Wales is currently monitoring the effects of this kind of pressure in the boulder shores of the Menai Straits.

Estuarine rock habitat is consistently under threat from coastal development and riverine inputs, causing habitat loss and damage, local changes in water movement (hydrology) and increased siltation. The introduction of additional non-native species and continual spread of established non-

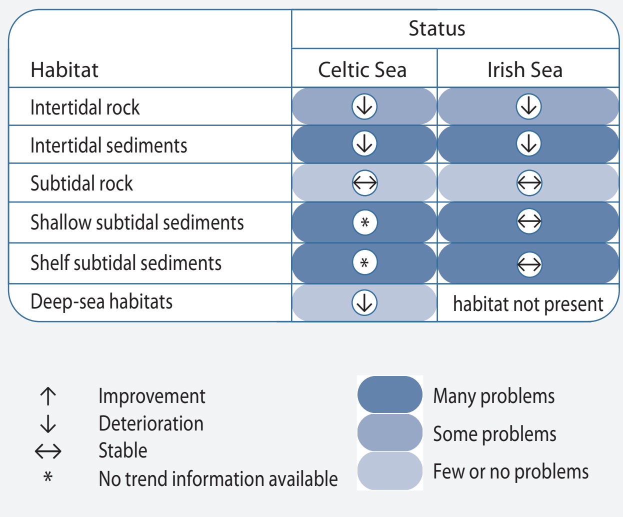


Figure 20.20 The health and biodiversity of Welsh Marine habitats. Source: adapted from UKMMAS (2010).

native species, particularly in conjunction with the effects of climate change, present a long-term threat to Welsh estuarine rocky habitats that is currently most evident in the south-western regions of the UK. The invasive non-native wireweed (*Sargassum muticum*) was first found in Pembrokeshire in 1998 and has since been tracked by the Countryside Council for Wales Phase 1 Intertidal survey, monitoring work and incidental recording as it spread to Cardigan Bay, the Llyn, the Menai Strait and the west coast of Anglesey (Brazier *et al.* 2007). It is now widespread in Wales and of particular concern because it can outcompete local species, including red and brown seaweeds.

In intertidal rocky habitats throughout Wales the impact of climate change is evident with regard to species succession. The northward progression in Wales of the toothed topshell (*Osilinus lineatus*) illustrates how some marine species are quick to take advantage of warmer sea surface and air temperatures, whilst other species show little or no shift in distribution, presumably due to the different driving forces and influences on the species (Mieszkowska *et al*. 2006; Mieszkowska 2010).

Condition of Intertidal Sediment. The key pressure responsible for changes to Intertidal Sediment, relative to former natural conditions across Wales, is habitat loss, predominantly resulting from historical land claim, with concomitant hydrological changes. This pressure has particularly affected intertidal sediment habitats in estuaries. Coastal squeeze of intertidal sediment habitats due to rising sea levels and the presence of immobile coastal defence structures is likely to continue to cause habitat loss. This may result in certain habitat types (particularly saltmarsh communities) becoming increasingly scarce. Other pressures, while not resulting in very widespread change across *all* the communities that comprise Intertidal Sediment, are considered to impact significant proportions of individual habitats within Wales.

Contamination by hazardous substances is likely to have impacted the species composition of some upper estuary sediments in Wales. For example, Milford Haven and some parts of other estuaries may be impacted by organic and nutrient enrichment. The invasive species common cord-grass (*Spartina anglica*) has colonised areas of upper mudflat and pioneer Saltmarsh communities within the Wales and the wider Irish Sea regions, in some cases leading to replacement of these communities by dense, monotypic swards, and thereby modifying the habitat.

Where bait digging, particularly among sheltered muddy gravels, and the collection of cockles occur with sufficient intensity in or adjacent to sensitive communities, composition of these environments has been altered. For example, a Countryside Council for Wales-commissioned study in Milford Haven has found over 30,000 bait dug holes in sheltered muddy gravel and mudflat habitats. This activity is widespread and intensive in the waterway. Some areas get little, or in some cases, no chance to recover. This work will inform a bait digging management scheme.

It is also worth noting that unexplained mass mortalities of cockles (currently under investigation by the Environment Agency) have occurred in the Burry Inlet in the last few years. Countryside Council for Wales evidence shows that the inlet is no longer able to support the number of wading birds for which the Special Protection Area was notified in 4 out of the last 5 years (Sanderson *et al.* 2010).

The distribution of some Intertidal Sediment habitats, particularly of saltmarshes, intertidal mudflats, intertidal seagrass beds and annual vegetation of driftlines on shingle, has been reduced compared to their historic distribution due to various impacts, including land reclamation, coastal development and disease (UK BAP 2006; JNCC 2010).

Condition of Subtidal Rock. Subtidal rocky habitats harbour rich benthic communities that have altered little over the years at the scale of regional seas. Most rocky habitats have largely avoided significant physical damage as their complex topography can damage many types of mobile fishing gear and these fisheries tend to avoid such habitats where possible. Current trends in static gear effort measured at Skomer Marine Nature Reserve may make a reassessment necessary of the potential for damage from static gear, such as lobster pots, at specific sites. Fishing effort has increased by 400% in this area since 2001, with a trend away from single pots towards strings that affect a greater area of seabed and are more prone to dragging during recovery.

Biogenic reefs such as those built by horse mussels (*Modiolus modiolus*) are easily damaged by physical disturbance, and some reefs within the regional sea have been permanently lost (although this is not known to be the case yet in Wales). Examples of illegal heavy fishing activities have been recorded adjacent to horse mussel reefs by Countryside Council for Wales monitoring (Robinson 2007), highlighting the need for adequate enforcement. Nevertheless, the Countryside Council for Wales's annual monitoring work has shown that the ancient horse mussel reef in Pen Llyn, the largest such biodiversity hotspot left in the Irish Sea, has been maintained since the designation of the SAC and the inception of the 'Modiolus Box' closed area (Lindenbaum *et al.* 2008).

The invasive carpet seasquirt (*Didemnum vexillum*) has caused substantial harm to biodiversity and economic damage around the world. It was discovered on pontoons and ropes in the marina in Holyhead harbour in 2008 (the only location in the UK at the time), and the Welsh Government funded a Countryside Council for Wales eradication attempt in the marina, which was successful. Unfortunately, the gap between identifying the invader and starting the eradication (13 months) appears to have allowed it to spread to other areas in the harbour (still to be confirmed). This highlights the need for appropriate rapid responses when dealing with invasive non-native species.

There is very little information on the effects of contaminants or increases in nutrient concentrations or siltation on reef habitats, but damage on the open coast, at least, is believed to be small. Although available evidence suggests that the damaging effects of invasive non-native species in Wales are very limited, this is probably the greatest threat to subtidal reefs in the future.

Condition of Shallow Subtidal Sediment. Many of the activities in shallow subtidal sediments can cause damage in small, localised areas (e.g. aggregate extraction). Damage or change in the structure and function of the habitat due to fishing activities is potentially the most damaging and widespread activity in the Regional Seas around Wales. However, the degree of impact will depend on the type of gear used, intensity and the sensitivity of the community. Intensive beam trawling and scallop dredging have significant effects on both the structure and function of many habitats. The Countryside Council for Wales has recorded cases where illegal fishing has impacted Shallow Subtidal Sediment habitats in SACs in 3 of the last 4 years. One case in Tremadog Bay has impacted 77 ha of muddy gravel habitat that was formerly rich in invertebrate species.

Maerl is one of the most sensitive of the sub-habitats in the component habitat of Shallow Subtidal Sediments. Wales has only one maerl bed, which is located in Milford Haven. This bed is approximately 1.5 km^2, of which only 0.5 km^2 still contains live maerl. Baseline monitoring has been established. Spatial mapping of the sea bed enabled the establishment of a statutory exclusion zone in 2009 for shellfish dredging.

Seagrass beds are also affected by localised pressures such as anchor chain damage, siltation and nutrient enrichment. Unpublished Countryside Council for Wales surveys using volunteer divers show impacts from moorings and anchors on a seagrass bed in Pen Llyn a'r Sarnau SAC. This evidence is being used to seek less damaging alternatives. At Skomer Marine Nature Reserve, successive surveys have shown improvements in the spread and abundance of seagrass since management of anchoring was introduced in the form of buoyed 'no anchoring' areas and the provision of visitor moorings adjacent to, but outside the seagrass bed. Improved water clarity may also have contributed to this, however.

Indicator 22c of the Wales Environment Strategy is the number of fisheries, assessed annually by the International Council for the Exploration of the Sea (ICES) and the Sea Fisheries Committees, to be in safe biological condition, based on stock assessments, fish catches and catch per unit effort. It helps to assess which species are within 'safe biological limits' or suffering reduced reproductive capacity, and to decide upon fishing quotas (total allowable catch). **Table 20.10** shows the current status of selected fish stocks based on these analyses.

Marine Management Organisation and UK Sea Fisheries annual statistics give landings into Welsh ports, but not necessarily of catches which have been sourced from Welsh waters. More information on Welsh fisheries is provided in this chapter's section on provisioning services.

Table 20.10 State of selected Welsh commercial marine fish species in the Celtic Sea and the Irish Sea. Source: Irwin & Thomas (2010).

Species	Total Allowable Catch (TAC) Advisory 2010 (% increase/decrease on 2009 TAC)	Stock Assessment
Celtic Sea		
Cod	*	Status unknown for 2009 but in 2008 stocks were viewed as at risk of suffering reduced reproductive capacity
Plaice	*	Stocks at risk of suffering reduced reproductive capacity
Sole	Decrease – 15%	Stocks at full reproductive capacity and being harvested sustainably
Haddock	*	Status unknown
Irish Sea		
Cod	Decrease – 25%	Status unknown for 2009 but in 2008 stocks were viewed as suffering reduced reproductive capacity
Plaice	Increase – 12%	Stocks at full reproductive capacity and being harvested sustainably
Sole	Decrease – 20%	Stocks suffering reduced reproductive capacity
Haddock	*	Status unknown

* No data available, management plan under construction.

20.5 Ecosystem Services

Ecosystem services are the outputs of ecosystems from which people derive benefits, including goods and services. The UK NEA follows the categorisation of ecosystem services adopted in the Millennium Ecosystem Assessment, namely: Supporting Services (primary ecological functions) and Final Ecosystem Services (Regulating, Provisioning and Cultural services; Section 2.2). These services are discussed here in relation to their role and importance in Wales.

20.5.1 Supporting Services

Supporting services include the underlying ecological processes of soil formation, nutrient cycling, the water cycle, primary production, decomposition, etc. These fundamental supporting services tend to be generic across the UK and the reader is therefore referred to the main UK NEA chapter on supporting services for further information. Some aspects of supporting services that are relevant to Wales are summarised below.

Not all the factors and influences on soil formation discussed by Bardgett *et al.* (this volume) have equal importance within the Welsh geographical context, and therefore, particular attention is given here to soil formation as a supporting service. Considerable studies on soils, of relevance for Wales and the wider UK, have also been carried out by the Government's CEH research station based in Bangor, North Wales.

20.5.1.1 Soil formation

The soil is a multifunctional resource without which land is infertile, barren and unable to support vegetation. The soils of Wales are the foundation of the land-based economy and have a strong influence on the Welsh landscape (**Figure 20.21**). The diversity of the vegetation and the quality and flows of Welsh rivers reflect the range of climate and soil conditions found in Wales. The sustainability of these services, along with

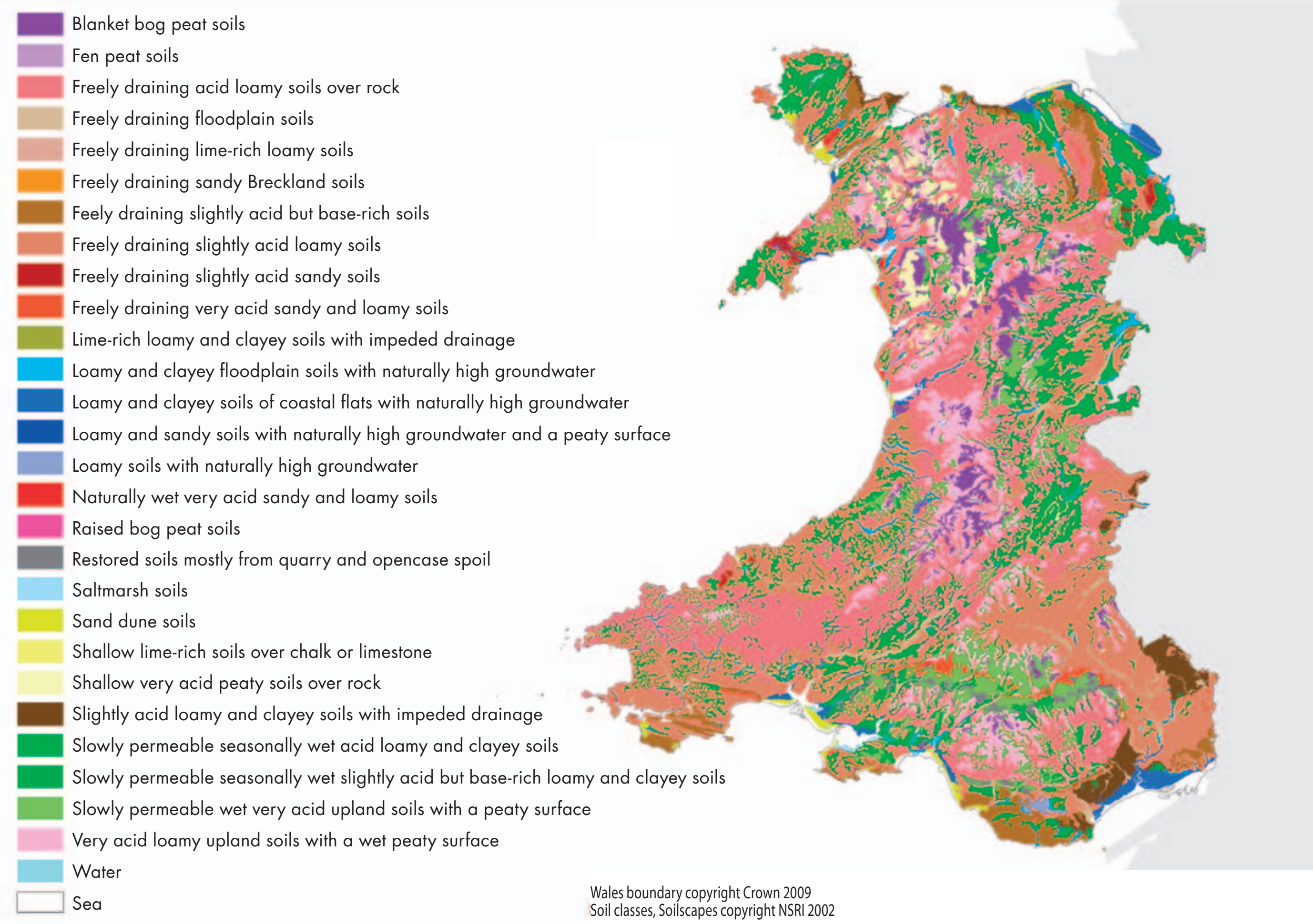


Figure 20.21 National Soil Map of Wales. Soilscapes classification from the National Soil Inventory 1998. Source and copyright: NSRI (2009).

the capacity to retain or lose carbon, depends significantly on soil management (Stevens *et al.* 2002).

Soil-forming processes are discussed in the UK context by Bardgett *et al.* (this volume) and are not repeated here. However, there are several key factors that have specifically influenced, and continue to affect, soil formation in Wales. These include the following:

- Almost complete glaciation of the landscape, ending around 12,000 years ago. This left a fresh land surface for soil development; soils in Wales are therefore relatively young by world standards.
- A moist, cool climate; low thermal energy results in low weathering rates but high rainfall leads to high leaching rates.
- Hard, mostly acid bedrock and superficial deposits resulting in a particular suite of acid, base-depleted loamy soils (**Table 20.11**).
- High relief and steep slopes which control soil formation through their effects on hydrology and climate.
- Predominantly low intensity land management including extensive agriculture dominated by grazing, forestry and significant areas of protected (conservation) land.

The coastal fringes of Wales tend to be the exceptions to these general principles. Here the land is at lower altitude and

Table 20.11 The major soil groups of Wales. Source: data from Rudeforth *et al.* (1984); Stevens *et al.* (2002).

Major soil group	Extent in Wales (% cover)	Description
Terrestrial raw soils	<0.1	Very young soils with only a superficial organo-mineral layer
Raw gley soils	0.2	Unripened young soils of saltmarshes
Lithomorphic soils	2.2	Shallow soils without a weathered subsoil
Pelosols	0.1	Clayey 'cracking' soils
Brown soils	30.2	Loamy, permeable soils with weathered subsoil
Podzolic soils	32.3	Acid soils with brightly coloured iron-enriched subsoil
Surface-water gley soils	24.7	Loamy and clayey seasonally waterlogged soils with impermeable subsoil
Ground-water gley soils	3.4	Soils associated with high seasonal groundwater
Man-made soils	0.4	Restored soils of disturbed ground
Peat soils	3.4	Soils in deep peat
Unclassified land (urban)	3.0	

therefore warmer, drier and often underlain by more base-rich parent materials, making the soils more productive.

Soils in Wales have a long history of influence by humans, both indirectly through management of native vegetation and more directly through agricultural practice. With significant changes in climate throughout the period of human settlement it is not always possible to isolate the effects of man's influence (Stevens *et al.* 2002). However, clearance of much upland deciduous woodland in Wales during the Neolithic period led to the development of heathland vegetation, accompanied by a transition from brown earth soil formation processes to podzol conditions, due to changes in microclimate and nutrient cycling (Rudeforth *et al.* 1984). Organic matter accumulated on wetter sites leads to peat formation. Agricultural management in the lowlands and, to a lesser extent, in the uplands, has led to significant changes in soil hydrology, fertility, acidity and structure. Factors influencing soil formation in Wales are given in **Table 20.12**.

Accumulation of soil organic matter. The cool, wet climate of Wales encourages the formation of organic-rich soils including peats and organo-mineral soils such as humic gleys, humic rankers, podzols, stagnohumic gleys and stagno-podzol soil groups (ECOSSE 2007). Collectively, they account for over 20% of the land surface and are an important repository for carbon. Recent estimates suggest that for Wales, peats account for 121.3 Mt C and organo-mineral soils a further 74.5 Mt C to the base of the soil profile (ECOSSE 2007). Using the most recent Countryside Survey data (Emmett *et al.* 2010), the amount of soil carbon stored across all broad habitat types in Wales to a depth of 15 cm has been estimated at 159 Mt C. It is important to note when comparing these figures that the Countryside Survey estimate is for 0–15 cm depth and includes data from a wide spectrum of soils, including those with relatively low organic matter content (less than 8% loss on ignition), whilst the estimating carbon in organic soils, sequestration and emissions (ECOSSE) estimate is restricted to organic-rich soils, but extends to the base of the soil column.

The rate at which the soil carbon store is changing in Wales is the subject of considerable debate, with apparently contradictory results from two major UK surveys: the National Soil Inventory (Bellamy *et al.* 2005) and the Countryside Survey 2007 (Emmett *et al.* 2010). Work is ongoing to understand and resolve these differences.

Soil mineral weathering. During the 1970s and 1980s there was a focus of research interest in Wales to determine chemical weathering rates for the Lower Palaeozoic sedimentary rocks that make up the bulk of the Cambrian Mountain chain (see, for example, Adams *et al.* 1971; Day *et al.* 1980; Hornung *et al.* 1987; Reynolds *et al.* 1987). A variety of techniques was employed, leading to estimated rates of surface lowering for Lower Palaeozoic greywackes in Wales of between 2 and 5 mm per 1,000 years, equivalent to 0.06 to 0.14 tonnes per hectare per year of bedrock under steady state conditions.

In the mid-1980s and 1990s, there was renewed interest in the weathering release of base cations for these systems because of its importance in the neutralisation of acid rain and for setting critical loads to protect ecosystems from acidification (Langan *et al.* 1996). Empirically derived weathering rates have been assigned to the major soil associations in Wales as part of the national critical load mapping exercise (Hornung *et al.* 1995; Figure 1 empirical critical loads map for Wales), but these values are largely based on expert judgement underpinned by relatively few experimentally determined quantitative data. Concerns have also arisen about the acidifying effects of plantation conifer forests established on large areas of base-poor, acid sensitive soils and associated depletion of soil calcium reserves by repeated forestry cycles (Reynolds & Stevens 1998).

Table 20.12 Key factors affecting soil formation as a supporting service in Wales. + Positive, - Negative. Source: Stevens *et al.* (2002); EAU (1988).

Factor	Influence on soil formation service	Importance in Welsh context: Geographical	Importance in Welsh context: Functional	State of knowledge on status and change
Accumulation of soil organic matter	+	Relatively large spatial coverage of organic-rich soils with significant carbon store	Regulation of carbon fluxes	Several estimates of stock; conflicting data on change
Soil mineral weathering	+	Large area of 'acid' geology and soils with low weathering rates	Neutralisation of acidity; sustainability of forestry and agriculture	Limited quantitative data from site specific studies; extensive empirical data
Erosion	–	High relief, steep slopes and high rainfall	Loss of productivity, siltation of water courses and reservoirs	Some data on extent of erosion, particularly for uplands, few data on erosion rates
Structural degradation (compaction)	–	Large areas of extensive grazing on seasonally wet vulnerable soils	Increased flood risk; loss of productivity	Few quantitative data (Stevens *et al.* 2002), some semi-quantitative surveys of soil structural condition
Urbanisation (soil sealing) and contamination	–	Urban and industrial centres are focused in south Wales and northern coastal fringe; extensive historical legacy from mineral exploitation throughout much of Wales	High risk of degradation or total loss of soil resource; risk to ecological and human health	Baseline of 1988 data (EAU 1988); need for audit of current status following changes in legislation

There is currently renewed interest in quantifying soil formation processes and loss rates in the context of the 'critical zone' concept defined as the soil-plant system from 'bedrock to tree top' (Richter & Mobley 2009). The Plynlimon catchments in mid-Wales are now part of an international network of critical zone observatories (CZEN 2011) and a pan-European project (SoilTrEC 2010), which is intended to provide platforms for collaborative research into processes and rates of soil formation and loss across gradients of climate, geology and land management.

Urbanisation and removal of soil overburden during mineral extraction have major impacts on soil formation (Section 20.4.6). Loss of soil to urbanisation eliminates many of its functions, although significant areas may remain in an amenity role within parks, gardens and verges, etc., where soil can perform an important hydrological function for infiltration of runoff. The importance of soil management is well recognised in the planning process for mineral extraction in Wales (NAW 2000), with an emphasis on progressive restoration to eliminate the need for soil storage.

20.5.1.2 Nutrient cycling

The nutrient status of soils and waters underpins the delivery of regulating and provisioning services in particular. Trace elements are no more or less important in Wales than in the rest of the UK, although there are pockets of trace minerals in rocks and soils that influence farm animal nutrition in parts of Wales, and sources of contamination related to metalliferous mining that also effect local water quality in some areas (see section on regulating services). Major nutrients such as nitrogen and phosphorus show some differences in Wales compared to other areas of the UK.

Nitrogen levels tend to be greater in soils of high organic content in woodlands and wetlands than in agricultural soils. There is also a spatial trend in relation to climate and land use, with a greater amount of nitrogen being found in the soils of the uplands and the more westerly parts of Britain, including Wales (Emmet *et al.* 2010).

Statistics for the past 20 years published by the Environment Agency (2008; Chapter 13, Figure 13.7b) suggest a decline in phosphate concentrations in the higher rainfall, livestock-rearing areas of western Britain.

Much of Wales is more acidic than England due to the higher rainfall and its leaching effects, and the presence of more organic soils in the uplands and the west. In common with the rest of the UK, however, soil acidity has decreased in Wales as a result of emissions controls that have curbed air pollution in the past 40 years. These trends appear to be related particularly to the decline in sulphate deposition that occurred over this period, which in most cases was accompanied by increases in rainfall pH (Morecroft *et al.* 2009; Chapter 13, Figure 13.10a).

20.5.1.3 The water cycle

The hydrological cycle encompasses rainfall, water storage in soil, groundwater, lakes, etc., evaporation and transpiration from water surfaces, soil and plant leaves, and river flows to the ocean. With its westerly Atlantic location, Wales shows some of the highest rainfall values recorded in the UK. This rainfall varies widely, with the highest average annual totals recorded in the central upland region from Snowdonia in the north to the Brecon Beacons in the south. Snowdonia is the wettest area, with average annual totals exceeding 3,000 mm, comparable to those in the English Lake District or the western Highlands of Scotland. In contrast, places along the coast and closer to the border with England are drier, receiving less than 1,000 mm per year (UK Met Office; Chapter 17, Figure 17.2).

The cooler and cloudier conditions in Wales, compared to the rest of southern Britain, lead to lower levels of evaporation and transpiration and more humid conditions. Coupled with less fertile soils, this favours pastoral agriculture over arable tillage. The more humid conditions also favour crops that are less susceptible to blight and other fungal infections than those commonly planted in eastern Britain.

There are large reserves of surface water in Wales that have long served as sources of supply for the UK more widely. Demands on these reserves from within and outside Wales are likely to increase in the future, under current scenarios for climate change in north-western Europe.

The relatively high rainfall and steep and varied topography of Wales leads to rivers that are more variable in runoff than those in England. This 'flashiness' has increased in some watercourses in Wales over the past century, for example the River Wye (**Figure 20.22**). The long-term catchment experiment at Plynlimon on the headwaters of the River Severn has provided a record of rainfall and runoff over the past 40 years in Wales for Britain's largest river (Chapter 13, Figure 13.14).

20.5.1.4 Primary production

Plant photosynthesis and primary production processes in the terrestrial habitats of Wales mirror those of other cool temperate zones where agricultural land use has predominated for millennia, and so the information contained in the main UK chapter regarding primary production supporting services applies in general to Wales also (Chapter 13).

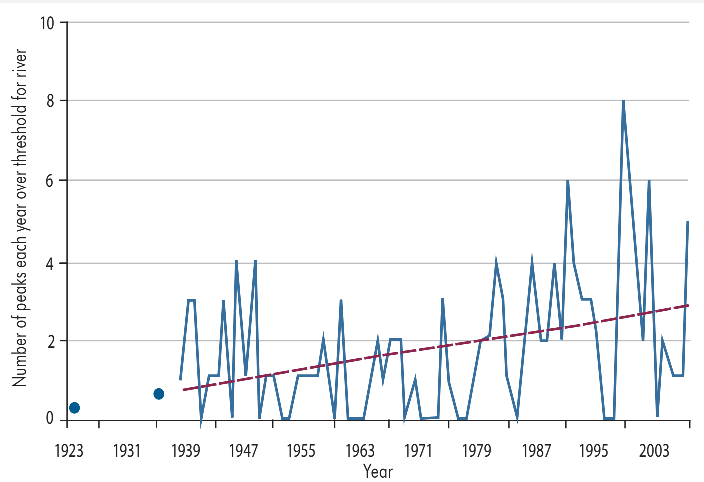


Figure 20.22 Flood events in the River Wye from 1923 to 2003. Source: Environment Agency (2005). Contains Environment Agency information © Environment Agency and database right.

Photosynthetic activity of terrestrial vegetation is influenced by seasonal factors, cloud cover and complexity of vegetation formations (e.g. multi-storey woodland). Areas of photosynthesis inferred from remote sensing, tend to show higher values in the better-vegetated lowland pastures and woodlands of Wales (**Figure 20.23**). In common with other regions of the world, biological primary production tends to decrease with altitude, so that the lowest primary productivity occurs mainly in upland habitats. Managing land to enhance primary productivity in Wales, by tree planting and conserving estuarine areas for example, could therefore contribute to important synergies with other ecosystem services (e.g. climate and water quality regulation).

Photosynthesis and primary productivity, as indexed by chlorophyll levels, are relatively high in Welsh Marine habitats when compared to other offshore zones of the British Isles. This is due, in part, to the shallow waters and lower rates of mixing in the semi-enclosed Irish Sea marine environment.

20.5.2 Regulating Services

Regulating services are the benefits accruing to humankind through the regulation of ecological processes by ecosystems. Regulating services include those ecological processes that influence water quality and quantity, pollination, climate regulation, severity and frequency of hazards, soil quality, noise, air quality and diseases and pests. The regulating services provided by ecosystems are extremely diverse. There can be a range of different indicators within each service (e.g. the various components of water quality such as acidity, pollutants and sediment levels).

20.5.2.1 Climate regulation

Biogeochemical mechanisms through which ecosystems regulate climate. Ecosystems regulate climate by acting as sources and sinks of greenhouse gases, and as sources of aerosols. It is well established that Wales has large amounts of carbon locked up in its forests, peatlands, grasslands and soils (114 Mt C in vegetation; 9,838 ± 2,463 Mt C in soils). Welsh soils hold nine times the amount of carbon than is stored in all vegetation (including forestry), with over 80% of this carbon associated with upland and grassland soils (Farrar *et al.* 2003). The amount of carbon stored in Welsh soils is currently estimated at 410 million tonnes. Soil carbon densities are greatest in semi-natural habitats (Mountains, Moorlands and Heaths, Semi-natural Grassland, Freshwaters – Openwaters, Wetlands and Floodplains) and Woodlands (including peat soils) and lower under Enclosed Farmland and Urban habitats (**Figure 20.24**). Approximately one-third (121 Mt) of Welsh soil carbon is in the form of peat (ECOSSE 2007), although peat deposits occupy only 3% of the area of Wales. This large carbon store needs to be well managed to ensure

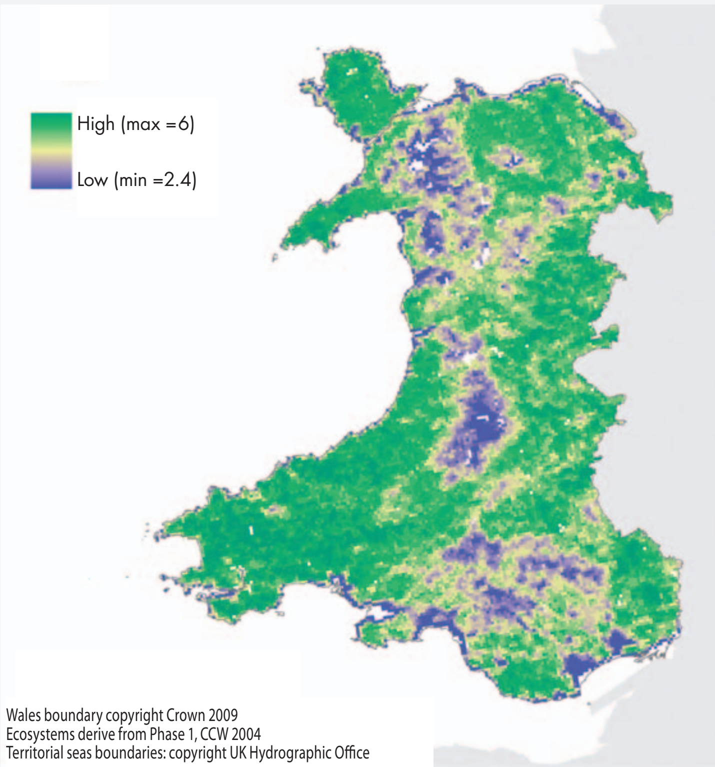


Figure 20.23 Net Primary Production of landcover, inferred from remotely-sensed vegetation mean reflectance values across Wales in 2007. Source: MARS Remote Sensing Database—European Commission, Joint Research Centre, compiled by Isabelle Durance, Cardiff University.

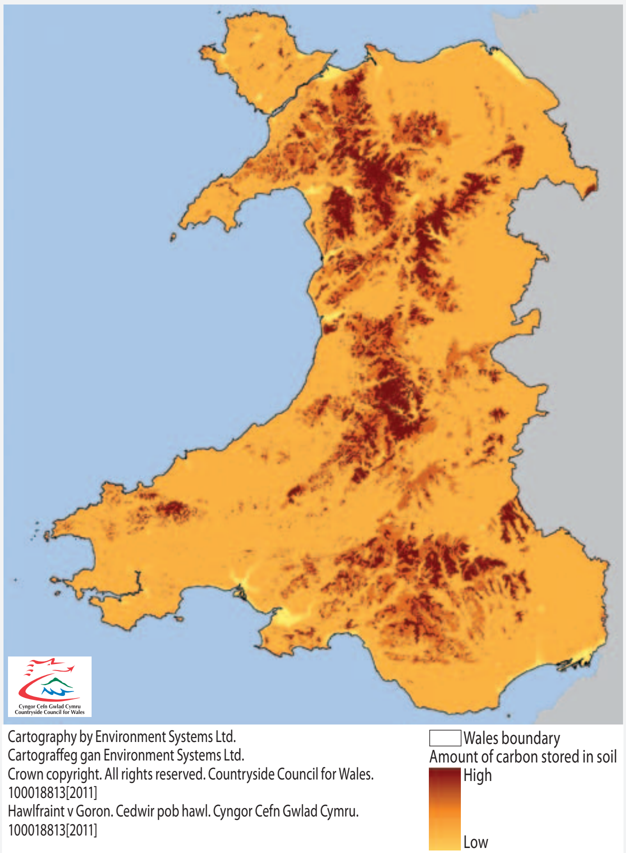


Figure 20.24 Areas important for carbon storage in soils. Based on the soil map of Wales and Phase 1 vegetation data. Source: CCW (2010).

losses do not accelerate and that the processes adding to this soil carbon store (usually incomplete decomposition of organic material in nutrient-poor, acidic and/or anaerobic/waterlogged conditions) are maintained. It has been calculated that a 1% per annum loss of stored soil carbon would increase Welsh net carbon emissions by 25% (Farrar *et al.* 2003).

The primary concern for mitigating the future effects of climate change within the Welsh uplands is to secure the existing carbon resource that is locked up within organic and organo-mineral soils. The Countryside Council for Wales suggest that Welsh peatlands may currently be sequestering an additional 5,588–10,406 tonnes of carbon per annum. Whilst a significant figure, this is dwarfed by the 121 million tonnes already stored as peat.

The total carbon stock in Welsh forests (including their soils) is approximately 140 Mt carbon dioxide equivalent (CO_2 e). The total carbon stored in Welsh forests and their soils is equivalent to more than 10 times the annual emissions from industry and services in Wales. Currently, 57 Mt CO_2 e of the carbon stock is in the trees themselves, but the greatest amount of carbon (80 Mt CO_2 e) is stored in the soils, particularly heathland and blanket bog. The soil carbon content is often a function of the soil type and therefore the primary management implication is the long-term sustainability of this carbon stock. The strength of the forest carbon sink in Wales increased between 1990 and 2004. However, projections show that within a decade, woodlands in Wales will become an annual emissions source, not a sink, as a result of the falloff in planting rates (Dyson *et al.* 2009).

Trees outside woodlands (on field margins and in hedgerows) also sequester carbon, although this has received very little research attention. A report measuring holistic carbon footprints for lamb and beef farms in the Cambrian Mountains Initiative (Taylor *et al.* 2010) suggested that woodlands and isolated trees both offer potential to sequester more carbon on farms. An extra 1 ha of woodland on the farms in the study could increase annual sequestration rates by up to 12%, while planting 50 isolated trees could increase sequestration rates by up to 5%. The report also suggested that a change in hedge cutting regimes could also offer some carbon sequestration.

In March 2010 the Welsh Assembly Government announced a programme to create 100,000 ha of new woodland over the following 20 years. This initiative would create an additional major sink of 1,600,000 t CO_2 e annually by 2040, with a net sink of 1,200,000 t CO_2 e, and an additional fuel wood potential of 1.4 terawatt-hour per year by 2030–2040, offsetting emissions of a further 350,000 t CO_2 e of fossil fuels (Land use climate change report to WAG, March 2010).

Data on soil carbon densities for Coastal Margin habitats are not readily available for Wales but are expected to be significant, although limited in extent. It is well established, but with incomplete evidence, that Marine ecosystems provide extensive carbon stores and uptake significant amounts of atmospheric carbon dioxide. In the longer term, rising carbon dioxide concentrations in seawater may lead to increased acidification of Marine environments. This could have a negative impact on hard-shelled marine organisms (e.g. molluscs, crustaceans, various plankton species), as their ability to produce calcium carbonate shells may decrease, and consequently this will affect their associated food webs (IPCC 2007; MCCIP 2008).

There is an important knowledge gap associated with quantification of the climate regulation services provided by Coastal Margins, Marine and Urban ecosystems in Wales.

Fluxes of vapour and gases from the land surface are important in regulating atmospheric concentrations of greenhouse gases, which include water vapour, carbon dioxide, nitrous oxide and methane. Welsh soils are considered to be a net sink of carbon dioxide under land use, land use change and forestry activities; unlike the soils of England, which are a net source. This is primarily due to the low incidence of land use change in Wales and the relatively young age structure of Welsh forests, rather than the overall stock of carbon held within Welsh soils.

Jackson *et al.* (2009) gave the UK distribution of regional net greenhouse gas emissions in 2005, expressed in terms of global warming potentials, as: England 78%; Scotland 8.3% and Wales 7.7%. Trends for gas emissions in Wales are provided in **Table 20.13**.

Agriculture currently contributes 11% of total greenhouse gas emissions in Wales, primarily in the form of methane and nitrous oxide. Carbon dioxide released by agriculture (1 Mt per year) contributes around 2% of total Welsh greenhouse gas emissions. Most of this arises from the conversion of pasture to cropland. There is relatively little empirical data available on carbon sequestration of soils under grazed grassland, and existing data suggest a range of possible sequestration rates.

Methane and nitrous oxide emissions from agriculture represent around 67% and 84% respectively of all anthropogenic emissions in Wales. Some 90% of the Welsh agricultural methane emissions are derived from enteric fermentation in cattle and sheep (Baggott *et al.* 2005), although many of these livestock will spend a large part

Table 20.13 Greenhouse gas emissions for Wales (megatonnes carbon dioxide equivalent): carbon dioxide, methane and nitrous oxide. Source: data from Jackson *et al.* (2009).

Greenhouse gases	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	Change (%) 1990–2005
Carbon dioxide	43.3	40.7	42.9	44.4	46.5	43.9	37.5	38.7	42.4	41.7	-4%
Methane	7.7	6.6	6.0	5.8	5.6	5.1	4.9	4.7	4.7	4.5	-41%
Nitrous oxide	3.7	3.6	3.9	3.7	3.5	3.4	3.3	3.3	3.3	3.4	-8%

of their lives on rough pasture. By contrast, the majority of nitrous oxide emissions result from the cultivation practices used on enclosed land**.**

Aggregated emission trends indicate that agriculture and waste disposal are declining as sources. This is largely due to reductions in livestock numbers and decreases in fertiliser application rates, leading to a fall in the levels of methane and nitrous oxide respectively.

Biophysical mechanisms through which ecosystems regulate climate. Whereas biogeochemical effects tend to operate at the regional/global scale, biophysical effects operate at a more local or regional scale. These local effects also assist in the avoidance of climate stress. Woody ecosystems, for example, provide localised benefits such as shade and shelter. A driver behind much of the hedgerow and farm woodland management in Wales is provision of shelter for livestock, and here, factors such as the roughness of vegetation will have an impact on wind speeds and air moisture content. Recent studies have begun to quantify the wider ecosystem service benefits of farmland shelter planting in the Welsh context, e.g. the Pontbren study in mid-Wales.

20.5.2.2 Hazard regulation

Hazard regulation implies three principle vulnerabilities in the UK context—coastal protection, erosion protection and flood regulation. There are strong links between the regulation of flooding and erosion, as interventions designed to manage the movement of water across the landscape will be likely to have an impact on both services.

Coastal protection. It is estimated that 23% of the Welsh coast (compared with 30% in England, 20% in Northern Ireland and 12% in Scotland) is experiencing erosion (Masselink & Russell 2007). Erosion of these areas represents a significant loss of important habitat.

In localised areas, there has been damage to Saltmarsh vegetation and there have been changes to sediment structure, as a result of removal of natural beach-cast materials (together with litter) during mechanical beach-cleaning operations. Microscopic plastic particles are now known to be widespread in marine sediments as a result of wear and tear of discarded plastics. There are also concerns about elevated pollutants such as polychlorinated biphenyls (PCBs) and endocrine-disrupting chemicals that may affect species through bioaccumulation (e.g. Mato *et al.* 2001; Thompson *et al.* 2004).

Erosion protection. The most comprehensive data on soil erosion in Wales exist for upland soils. In a Defra-funded study, the spatial extent of erosion assessed at 155 field sites showed that 43% of these sites contained eroded soil (Harrod *et al.* 2000; McHugh 2002a,b). Most erosion was measured on peat soils, with decreasing amounts of erosion observed on wet, peaty mineral soils, wet mineral soils and dry mineral soils. Upland soil erosion occurred uniformly throughout Wales. At 75% of sites, animals and humans were responsible for initiating erosion, and for maintaining bare soil at 77% of the sites (McHugh 2002b). Unfortunately, the 5 km sampling grid used for the Defra study excluded arable fields, which tend to be smaller in Wales than those in England. The study did not, therefore, provide quantitative data for Welsh arable sites. Erosion was measured at 28 lowland grassland sites in Wales (Harrod 1998). Five of these sites displayed erosion, with a total eroded soil volume of 0.16 m^3. It was concluded that soil erosion was not a significant process on established enclosed grassland. In a separate study in the Llafar catchment, Ford (2000) showed that while the extent of bare and poached ground was relatively small as a percentage of the catchment area, 75% of bare soil features were within 40 m of fluvial systems, thereby increasing the likelihood of soil loss to the river network.

Information on erosion rates is limited, and derives mainly from studies in the Plynlimon catchment and at Llanbrynmair (Francis & Taylor 1989; Collins *et al.* 1997). These data show that erosion tends to be highly episodic, and that rates can be high in response to specific land management activities, e.g. ploughing, forest harvesting, etc., if the correct precautions are not taken.

Landslides contribute to surface erosion in Wales. Classic, major landslides are not common, but rockfalls and peat slides occur in mountainous areas, although they are not usually a major threat to population centres. Sudden, catastrophic events have occurred in the South Wales coal fields. In 1966, 144 people were killed at Aberfan following a coal tip slide. Failure to restore habitats to fully functioning ecological conditions leads to an increased likelihood of landslides and debris flows following extreme rain events. These can cause disruption to rail and roads and expense to the public purse. Erosion in the uplands also increases the amount of peat (and carbon) in source supplies of drinking water, causing it to become peat-coloured and involving the water companies in considerable treatment costs.

Flood regulation. *Riverine floods.* Survey work in the Upper Severn catchment (Holman *et al.* 2003) identified areas of soil structural degradation as a potential contributory factor in the flooding of Shrewsbury in 2000. Flood risk management research at Pontbren in mid-Wales has studied the influence of upland land management on soil structure and flood risk in considerable detail (Marshall *et al.* 2009; Wheater *et al.* 2010). This research has shown how sheep grazing on heavy textured soils can change soil structure and hydrology (Carroll *et al.* 2004) and suggests that strategically planted linear tree features can be used to improve soil structure and alleviate flood risk (Jackson *et al.* 2008; Marshall *et al.* 2009).

The soil's ability to act as a sponge is important in influencing whether rainfall infiltrates the substrate or runs off the surface (**Figure 20.25**). Increasing soil bulk density is commonly linked to inappropriate management of agricultural land or soil-sealing by impermeable surfaces which will increase storm runoff and peak flows in watersheds. However, the Countryside Survey, at its current sampling intensity (Emmett *et al.* 2010), has shown no change in bulk density for soils across a range of Welsh habitats, nor has there been any observed increase in carbon levels which are also linked to increased infiltration.

Climate change is likely to increase the frequency of extreme weather events in the future. Within the Welsh uplands, the targeted establishment of woodland in plantations on valley sides, or as part of a network of farm hedgerows and shelterbelts, would help to reduce flood risks by increasing the rate at which rainwater percolates into the

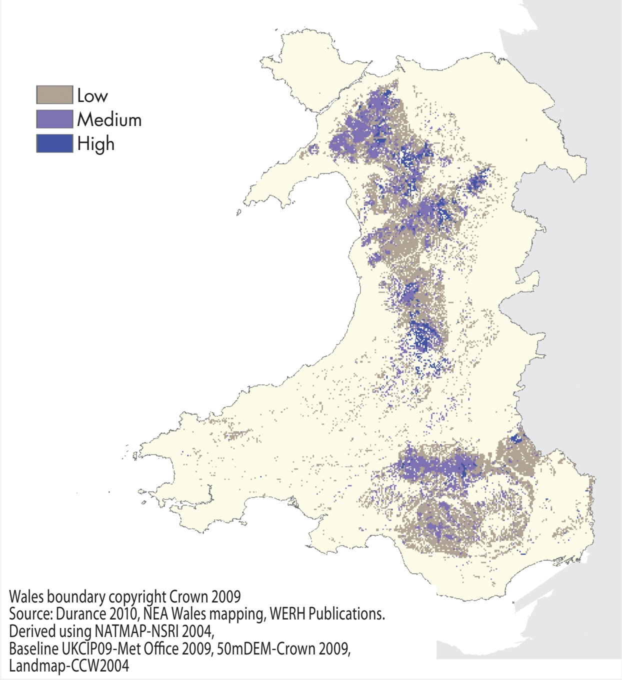


Figure 20.25 Potential for regulation of surface run-off by land cover in highly erodible areas of Wales. Run-off regulation potential modelled by Isabelle Durance, Cardiff University, using values for rainfall pattern, slope and soil texture. Source: Wales Environment Research Hub unpublished data.

soil and slowing down the rate at which it reaches nearby watercourses.

In the lowlands, the establishment of floodplain woodland and the maintenance of grazing marshes can also provide increased water storage capacity at times of heavy rainfall. At first sight this could appear to be an uneconomic use of high grade agricultural land which is scarce in Wales, especially if only the potential timber values are taken into account. In the wider context, however, it might be preferable to accept some localised reduction in food production capacity, in the interests of reducing the risks, for example, to urban infrastructure. Under the ecosystem approach that is central to the thinking behind the new Natural Environment Framework for Wales, there is likely to be greater demand for targeted planting of woodland, establishment of wetlands, etc., in the most effective locations for the delivery of ecosystem services, thereby leading to multiple benefits to humans and the environment.

Investment in green infrastructure of this type usually requires action at a scale larger than that of the individual farm or forestry business. Reduction of flood risk and provision of improved water storage are best undertaken at the catchment scale. This is likely to require greater cooperation between private landowners and land managers than has been usual in the past.

In downstream and at-risk areas, Wales has adopted a policy that promotes Sustainable Drainage Systems (SuDS; WAG 2010d). This integrated approach aims to reduce flood risk, minimise diffuse pollution, maintain or restore natural flow regimes and enhance amenity in urban areas. However, uptake of the SuDS schemes is at a relatively early stage and has so far been patchy across local authority areas in Wales.

Coastal floods. Wales has approximately 2,740 km of coastline, and flood risk is highest along the low-lying zones of the North Wales coast, and at Llanelli, Port Talbot, and the Severn Estuary in the south (Farrar & Vaze 2000). The Towyn flood of 1990 affected 2,800 homes between Pensarn and Rhyl. Given changes in population, predictions of sea-level rise due to climate change and possible increases in storm surge events, it is likely that coastal flooding will increase over the next 90 years. The economic impact will depend upon infrastructure development and levels of affluence in the coastal regions. Erosion of natural flood defences, such as dunes and wetlands, makes Welsh coasts more susceptible to risk.

20.5.2.3 Disease and pest regulation

Disease and pest regulation are primary/intermediate ecosystem services which affect human health and well-being directly, or through effects on the provision of final ecosystem services such as crops and livestock, food and fibre. This regulating service relates largely to the role of ecosystems in regulating the incidence of insect and fungal pests and pathogens. (All the UK NEA Broad Habitat types are home to diseases and pests, and to natural predators of those pests.)

In Woodland habitats there are increasing impacts of grey squirrels on the regeneration of native tree species, some instances of disease outbreak (e.g. Dutch Elm Disease) and increasing impacts of invasive species (e.g. Japanese knotweed). There has also been a significant presence of invasive trees species e.g. *Rhododendron ponticum* (L.). Although this rhododendron possesses attractive flowers, it has few other attributes that can offset the negative impact it has on invaded sites. It has been shown to reduce the numbers of earthworms, birds and plants, and reduce the regenerative capacity of a site, leading to a reduction in the biodiversity of the area.

Information on disease and pest regulation is poor. Independent data for Wales regarding disease regulation are not currently available as they are included with statistics for England. The reader is therefore referred to the analysis in Chapter 13 of the UK report.

20.5.2.4 Pollination

The production function value of biotic pollination as a contribution to UK crop market value in 2007 was £430 million, comprised of: England, £367 million; Northern Ireland, £19 million; and Scotland, £43 million. Unfortunately, figures for Wales are unknown at present, as data are not collected due to the relatively small amount of arable crops in Wales compared to other parts of the UK. However, insect pollinators are known to be essential for the maintenance of many vegetation types across all the terrestrial habitats of Wales, and the valuation of pollination services in Wales is therefore an important area for future research. This is particularly so because, although honey bees are the most common pollinators of commercial field crops across the UK, they have shown a 23% decline in Wales between 1985 and 2005, with this trend continuing at present (Klein *et al.* 2007; Potts *et al.* 2010).

20.5.2.5 Noise regulation

Moderation of sounds by ecosystems is a regulating service, but natural sound may also be considered as a cultural service, sometimes beneficial, and at other times a disservice (unwanted sound). Noise regulation is of particular significance in urban settings and vegetation is well known to have a capacity for noise abatement in Urban habitats and along transport corridors, for example. There are no readily available data on the relationship between urban tree density and noise regulation; this service is discussed in more detail in the section on Urban habitats in Wales.

20.5.2.6 Soil quality regulation

This regulating service is closely linked to soil formation (a supporting service) and erosion regulation—discussed above. There is no statutory soil monitoring programme within the UK at present. The Countryside Survey report for Wales (Smart *et al.* 2009) is the most thorough compilation of results indicating changes in Welsh soils for broad habitats. In Wales, soil pH has shown a significant increase under Improved Grassland; and an increase in Neutral Grassland; however, no change was observed in Acid Grassland. Soil carbon acts as a surrogate measure for soil organic matter content, which is a vital intermediate regulating service, particularly in terms of its impact on nutrient retention and cycling, and its physical effect on structure which regulates gas and water fluxes. Since the 1970s, topsoil carbon content has shown no significant change in soils under most semi-natural habitats. The carbon stock in the Arable and Horticultural component habitat is considered to be approximately 33 tonnes per hectare in Wales, lower than the same habitats in England and Scotland (Smart *et al.* 2009). However, the carbon stock in Improved Grassland is approximately 62 tonnes per hectare, comparable with the GB level. Wales, with a large amount of upland area and high rainfall, is vulnerable to soil erosion. The habitats and ground cover provide important protection for the soil surface and prevent erosion.

20.5.2.7 Air quality regulation

The main air pollutants of concern, which are considered under the national Air Quality Strategy (Defra 2007) and in international policy evaluation, are particulate matter, ozone, nitrogen oxides, ammonia and the deposition of nitrogen and sulphur. In Wales, acid deposition has been a major issue. Between 1987 and 2005, there was an 80% reduction in UK sulphur dioxide emissions; over the same period, non-marine sulphur deposition to Wales declined by 72%. Non-marine sulphur deposition is predicted to decrease by a further 40% of 2004–06 values by 2020, assuming full implementation of emission controls. There was little change in total nitrogen oxides loading to Wales between 1987 and 1997, despite a 25% reduction in UK nitrogen oxides emissions over this period. Subsequently there was a further 10% decline in deposition between 1997 and 2005. Over the same period, UK nitrogen oxides emissions decreased by 26%. Deposition of ammonia changed little between 1987 and 2005. No emissions data are available prior to 1990, but UK emissions declined by about 14% between 1997 and 2005, whilst in Wales the corresponding decline in deposition was 8%. For all pollutants, there is evidence to suggest non-linearity in the relationship between UK-level emission reductions and deposition in Wales which needs further investigation.

Each year in Wales, existing urban trees absorb between 45 and 73 megatonnes of particulates and between 91 and 165 megatonnes of sulphur dioxide (Small 2009). The health effects of this pollution absorption are significant, delaying deaths and preventing hospital admissions related to air quality causes, and these benefits could be enhanced through further urban tree planting. Willis *et al.* (2003) valued the benefits at £124,998 for each death avoided by 1 year due to PM10 (air pollution with particle diameters of less than 10 microns) and sulphur dioxide absorption by trees, and at £602 for an 11-day hospital stay avoided due to reduced respiratory illness, totalling an annual value of £0.04 million in Wales in 2002.

Vegetation in urban areas can reduce particulate air pollution, with woodland removing three times more than grassland (NUFU 2005). Rough Wood in Walsall was estimated to remove 50 kg of dust pollution per hectare per year (NUFU 1999). The Welsh Assembly Government has determined that there is a risk that PM10 levels in the Neath-Port Talbot area will be exceeded (WAG 2009d) and the local authority is working with the steel maker Corus to plant trees to help intercept particulate air pollution (WAQF 2008).

20.5.2.8 Water quality regulation

Water quality is strongly linked to ecosystem processes in the Welsh uplands. These areas are subject to a range of environmental pressures, particularly acidification. Upland waters and wetland habitats are a major source of clean drinking water. Being relatively unpolluted, water draining the uplands performs a key regulatory service by diluting pollution that enters river systems further downstream. These services are strongly linked to flow rates.

In terrestrial systems, the quality of water is heavily influenced by the ecosystems it interacts with. Freshwater habitats such as fens, bogs and riparian woodlands provide important filtering services. Management activities, particularly within enclosed agriculture systems, have a strong influence on quality water. The extent to which these various habitats provide a benefit will be dependent on the number of people or properties potentially affected in a given location. In addition to surface water systems, groundwater systems in Wales are also important sources of public water supply. These systems are also heavily influenced by land management activities.

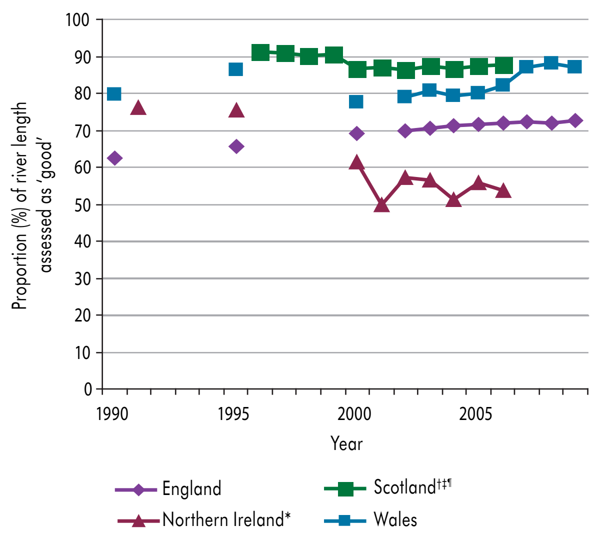
Forestry Commission Wales's Forest Design Plans for the government woodland estate take account of riparian areas and include changes to tree cover and species choice when areas of trees are felled adjacent to rivers. Large-scale riparian management projects include the WoodLIFE Ravine project in the Wye Valley, the government-funded Riverine project and the Environment Agency Fishing Wales Objective 1 project. Strict adherence to UK Forestry Standard (UKFS) Forests and Water Guidelines is currently considered sufficient to address the contribution of forests to acidification in Wales.

Water quality monitoring by national environmental agencies is mainly targeted at rivers draining larger, mixed catchments. Chemical General Quality Assessments, which measure organic pollution, showed that 95% of Welsh rivers were of good chemical quality in 2008, compared to only 86% in 1990 (Defra 2009b; **Figure 20.26; Figure 20.27**). This sign of improvement is corroborated by the Countryside Survey for Wales (Smart *et al.* 2009). The most commonly recorded reason for water quality degradation is nutrient enrichment (eutrophication). Concentrations of phosphates were high (greater than 0.1 milligrams per litre) in 8% of rivers in Wales, by length, but show declines since 1980. Nitrates cause eutrophication in coastal waters and can impair drinking water quality. Work presented by Pretty *et al.* (2003) for the UK showed that the incidence of algal blooms per water body, per decade was highest in Wales, with a value of 1.6 from 1990 to 1999. Nitrate levels remain generally stable, after increasing in the 1990s, with a small decline since 2000. Indicators of organic pollution (biological oxygen demand and ammoniacal nitrogen) have declined in Wales since the 1980s, leading to improved water quality survey results for these factors (Figure 14.6, Chapter 14).

Acidification of surface waters is an important aspect of water quality in Wales, with implications for aquatic ecosystems and salmonid fisheries. Statistics for freshwaters in Wales show that in 1986–88 nearly 80% of sites exceeded critical levels for total acid deposition. This figure reduced by 30% over the next 20-year period, so that just over half the total number of Welsh sites exceeded critical levels in 2002–4. Under the reduced emissions scenario predicted for 2020, 70% of sites will be receiving total acid deposition loadings that are less than the critical load. As would be anticipated, the amount by which deposition exceeds the critical load at individual sites also diminishes over time. In 2002–4 there were no sites exceeded by more than 2.0 kilogram equivalents of element per hectare per year (keq/ha/yr) and only five sites are expected to fall into the 1.0–2.0 keq/ha/yr category by 2020.

Environment Agency monitoring of acidification in Wales has shown that surface waters are beginning to recover chemically, with increases in pH and acid neutralising capacity (ANC) observed at sampling sites, along with reductions in sulphate and aluminium concentrations. The rate and extent varies spatially throughout Wales, depending on site conditions and local atmospheric deposition. There is evidence that episodes of adverse chemical conditions are still occurring, but their severity is reducing. However, the episodes are still sufficient to inhibit and slow biological recovery. The majority of freshwater sites that exceed critical limits lie in north Wales, along the Cambrian Mountains and in the Brecon Beacons, reflecting the combined effects of high deposition loading and acid-sensitive fresh waters. This distribution does not change significantly over time.

Dissolved organic carbon (DOC) concentrations in upland waters have increased, suggesting that soil carbon stocks may be destabilising in response to climate change (see Evan *et al.* 2007) However, these increases may also be associated with recovery from acidification in peatlands and agricultural intensification in managed systems.



* The length of rivers monitored in Northern Ireland more than doubled between 1995 and 2000.
† In 2000 Scotland changed to a Digitised River Network.
‡ Scotland figures were calculated on a different basis in 1990 and 1995—bands were 'good' and 'moderate' rather than 'good' and 'fair'.
¶ Scotland from 2000 uses grades A1 and A2 as 'good' and grade B as 'fair'.

Figure 20.26 Rivers of good biological quality in the UK from 1990 to 2009. Source: JNCC (2010b); Defra (2009b).

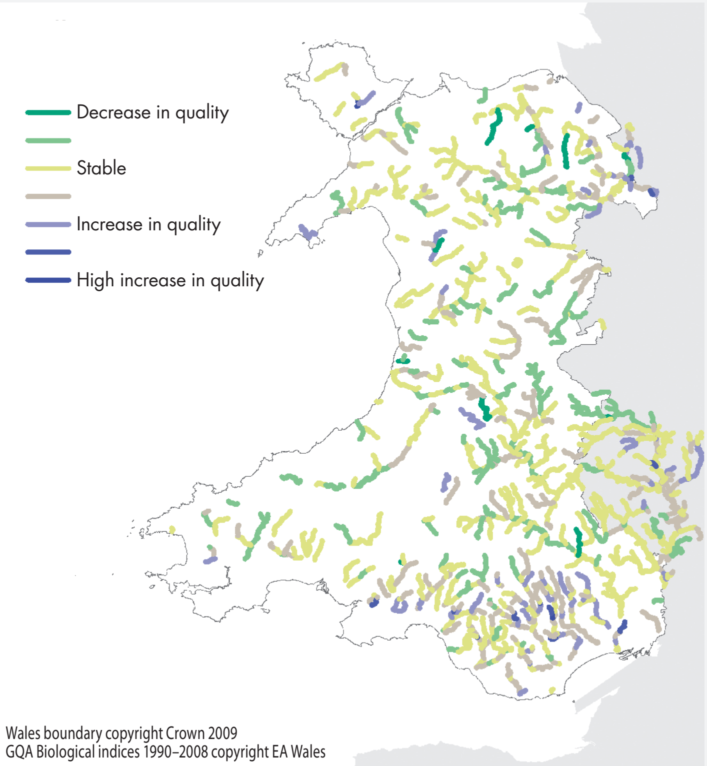


Figure 20.27 Trends in biological quality of streams in Wales between 1990 and 2008. Source: Environment Agency Wales data mapped by I Durance, Cardiff University.

Seasonal changes in precipitation due to climate change are likely to affect species in estuaries, although this has not yet been recorded. The predicted higher winter rainfall on western UK coasts, including Wales, may result in higher flows of fresh water extending further down estuaries, which may lead to contamination and eutrophication as well as sustained reductions in salinity. At the same time, drier summer periods will see the influence of marine water moving upstream, a trend likely to be exacerbated by increased abstraction from watercourses (MCCIP 2008).

20.5.3 Provisioning Services

In this section the focus is on documenting the trends in the supply of goods provided directly to humans by Welsh ecosystems, and understanding how this service has interacted with UK NEA Broad Habitats. Long-term data sets do not exist for all ecosystem goods in Wales and where they do exist for the UK, it is not always possible to disaggregate them for Wales.

20.5.3.1 Food from agriculture

Enclosed Farmland makes a substantial contribution to Welsh food production and the Welsh economy. Unfortunately, statistics for enclosed land alone are not available, owing to the interconnected way in which improved land and unenclosed rough grazing are still used throughout the year across much of rural Wales. The situation is further complicated by the routine use of winter housing on many beef and sheep farms in Wales. Nevertheless, it is clear that Enclosed Farmland contributes substantially to livestock production in Wales. Indicative figures for overall production in 2005 were 4.22 million lambs (30% of UK total) and 137,000 cattle. Welsh slaughtering resulted in 76,600 tonnes of sheep meat and 44,000 tonnes of beef in 2005 (Hybu Cig Cymru 2007). Enclosed land also underpins Welsh dairy and arable production, as well as the smaller horticulture, poultry and pig meat sectors. The total numbers of holdings of each farm type are summarised in **Table 20.14**.

The high percentage of land above 150 m altitude in Wales (60%), and the predominance of peaty and gley soils with relatively low fertility and limited agricultural potential, result in 76% of Wales being classified as Less Favoured Area (LFA; see Section 20.2 and Figure 20.31). This has had a profound influence on the history and economy of Wales, and soil management regimes and conditions will continue to play a fundamental role in provisioning and other ecosystem services for Wales in the future.

Twenty-three per cent of land in Wales is classified in the Disadvantaged Area (DA) and 56% in the Severely Disadvantaged Area (SDA)—**Figure 20.28**. Most of the holdings in these areas are eligible for compensatory allowances (amounting to £25.1 million in 2010) from the Tir Mynydd agri-environment scheme (Farming Facts and Figures, WAG 2010b). This programme supports livestock production in the less productive farming areas.

Figure 20.29 charts long-term trends in the areas of different agricultural land uses in Wales since 1867, and **Table 20.15** shows more detailed information on changes in agricultural activity since 1998.

Livestock. The number of adult sheep and lambs in Wales increased substantially from 4 million to 11 million during the period between 1950 and 1990 (Fuller & Gough 1999). Since 2000, however, numbers have steadily declined, with the total population of sheep and lambs standing at just over 8.5 million in 2008 (**Figure 20.30**). Cattle numbers have remained relatively stable, declining by 11% from 1.3 million cattle and calves in 1999 to 1.2 million in 2007 (**Figure 20.31**). The total number of holdings with dairy cows has declined over the same period from 4,596 to 3,835 whilst the total number of dairy animals has fallen from 278,533 to 234,081 (WAS 2008). It should be borne in mind,

Table 20.14 Welsh holdings by farm type. Source: data from Welsh Assembly Government (WAG 2010b).

Farm type	Holdings 2009 (number)	Share of total (%)
Cattle and sheep (LFA)	11,425	29.3
Cattle and sheep (lowland)	2,169	5.6
Dairy	2,094	5.4
Mixed*	796	2.0
Cereal	394	1.0
Pigs and poultry	361	0.9
Horticulture	332	0.9†
General cropping	148	0.4
Other types‡	2,394	6.1
Minor holdings¶	3,771	9.7
Dormant holdings	15,140	38.8
Total number of holdings	39,024	

* Combination of cropping and various types of livestock
† Although it represents a low area, horticulture represents a potential high value
‡ Mainly grass and forage or specialist horses
¶ Holdings with small amounts of agricultural activity.

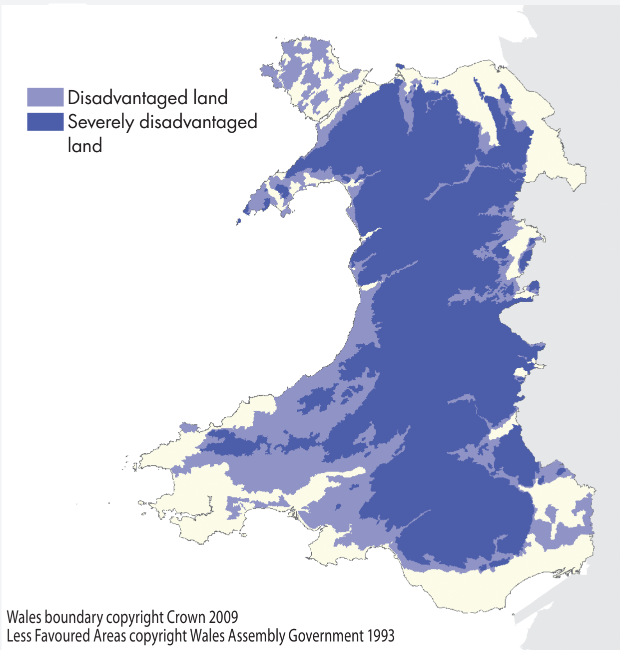
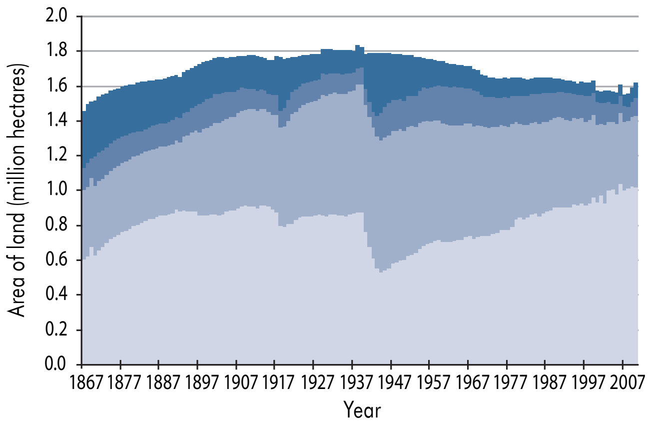


Figure 20.28 Agricultural Less Favoured Areas in Wales. Source: WAG (2011).

however, that such statistics mask substantial changes in both the distribution and the nature of agricultural activity. For instance, the number of farms describing themselves primarily as dairying operations has declined by 43% over the period from 1997 to 2007 (WAS 2008). Similarly, sheep numbers have reduced more slowly in mid-Wales than is the case in the north and the south (probably due to there being fewer alternative land uses available in central Wales), whilst a pronounced shift to larger, more productive breeds is evident in the beef and dairy industries as well as in the sheep sector.

In 2003, agriculture contributed some £418 million or 1.1 % to Welsh Gross Value Added (GVA). If direct subsidies are excluded, the agricultural contribution falls to less than 1.0% (Welsh Assembly Government 2008). Whilst this figure appears modest, the industry also provides substantial downstream benefits through the multiplier effects associated with the processing and supply industries, which provide more than 10% of total employment (calculated as full-time equivalents) in many parts of rural Wales. Agriculture is therefore relatively more important within the economy of rural Wales, contributing 3.2% of GVA in 2003, in comparison to 0.3% across the rest of Wales (Welsh Assembly Government 2008).

Crops. Towards the end of the 19th Century, arable crops covered about 300,000 ha or 20% of the agricultural area of Wales, with cereals accounting for over half of this

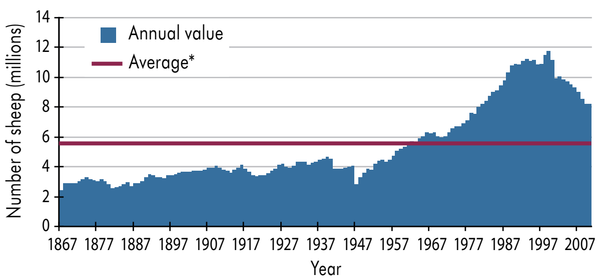


* Permanent pasture is grassland aged at least 5 years.
† Rough grazing sole rights rough grazing excluding use of common land
‡ The distinction between permanent pasture and rough grazing is made by the farmer.
¶ New grass is grassland less than 5 years old.
§ Crops is mainly cereals but includes all other crops for human consumption or for stockfeed.

Figure 20.29 Land on Welsh farm holdings from 1867 to 2007. Results are taken from the Welsh Agricultural Survey at June each year and exclude common land (around 180,000 hectares in 2007). Source: WAG (2010f).

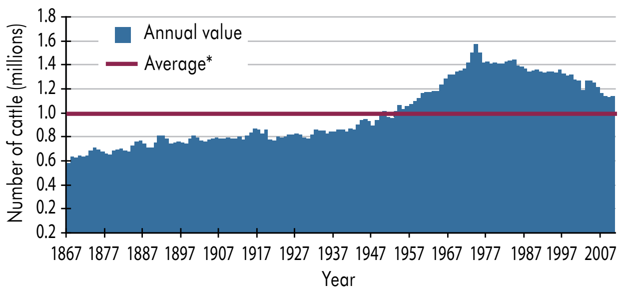
Table 20.15 Changes in land area of Welsh agricultural activities since 1998. Source: WAG (2010f).

Land area	1998	2008	2009	2010	Change 2009–2010
	('000 ha)				(%)
Total agricultural area	1,677	1,635	1,670	1,710	2
Total area on agricultural holdings	1,497	1,455	1,489	1,529	3
Total crops	72	74	82	85	4
Total vegetables/fruits/ horticulture	1	1	1	1	0
Permanent grassland	927	1,017	1,027	1,021	-1
Grass under 5 years old	141	87	88	103	17
Sole rights rough grazing	298	200	213	230	8
All other land (including farm woodland)	58	76	78	90	15
Common rough grazing	180	180	180	180	0



* The average figure shows the annual average over the period 1867 to 2010.

Figure 20.30 Total number of sheep and lambs in Wales from 1867 to 2007. Results are taken from the Welsh Agricultural Survey at June each year. Figures include all sheep and lambs of both sexes and all ages. Source: WAG (2010f).



* The average figure shows the annual average over the period 1867 to 2010.

Figure 20.31 Total number of cattle and calves in Wales from 1867 to 2008. Results from 1867 to 2003 are taken from the Welsh Agricultural Survey in June each year. Results from June 2004 onwards are based on data from the Cattle Tracing System. Figures include all cattle and calves of both sexes and all ages, and animals used for dairy and beef purposes. Source: WAG (2010f).

and the remainder consisting of roots, brassicas, peas and beans (Ashby & Evans 1944). Crops were grown for domestic consumption as well as for feeding livestock such as horses. At the end of the 19th Century, however, livestock feed began to be imported, which led to a movement away from mixed farms and towards greater specialisation. In general, the importance of crops declined and the area of land under grass increased, so that by the late 1930s the area of crops had reduced markedly in Wales. Despite a brief surge as more land was ploughed during WWII, the switch from arable to grassland accelerated from 1947 onwards, especially as horses were replaced by tractors. In Wales, the area of cereals and total crops dropped significantly from 198,000 ha in 1940 to 83,000 ha in 2009. Crops now account for only 3% of the agricultural land area (Blackstock *et al* 2010). Substantial amounts of forage maize are grown in Wales, but the exact figures are not readily available.

It is important to remember that the production of food in Wales does not directly relate to the consumption of food by Welsh citizens. Some food items are produced in Wales and exported, while other foodstuffs consumed in Wales are imported from overseas, e.g. tropical fruits. The UK exported 94,500 tonnes of sheep meat in 2009 and imported 115,000 tonnes. Only 4% of Welsh lamb output is consumed in Wales and recent food price increases have served to underline the interconnectedness of Wales with the global food market.

20.5.3.2 Fibre from agriculture

Plants. There is a small amount of hemp and flax production in Wales, but exact figures are unavailable. Projects to help promote hemp and flax agronomy have been undertaken as part of farm diversification in Wales, e.g. Project Cywarch a Llîn at the Bangor University Henfaes Research Farm.

Animal. Fleece production in Wales is predominantly from sheep, with very small quantities of mohair and cashmere from goats (**Table 20.16**).

Table 20.16 Trends in wool production in Wales. *Cash payments to producers by the British Wool Marketing Board. Source: data from Welsh Government Agricultural Statistics annual reports, 2007–2010.

	Total fleece wool production (million kg)	Valuation of clip to producers (£ million)*
1998–1999	12.1	5.3
1999–2000	11.5	4.9
2000–2001	10.9	5.1
2001–2002	9.5	4
2002–2003	9.7	4.3
2003–2004	9.5	4.9
2004–2005	9.7	4.9
2005–2006	10.0	4.7
2006–2007	8.8	2.7
2007–2008	8.0	2.7

Biomass and biofuels. Welsh woodlands (within the Woodlands and Enclosed Farmland UK NEA Broad Habitats) provide logs, chip, pellets and charcoal for domestic and commercial consumption in Wales. There is currently no data available on total amounts produced. However, the wood fuel market has become buoyant recently, due to increases in energy prices, cold winters and an interest in reducing carbon dioxide emissions. There is potential for Welsh woodlands to provide more wood fuel in the future, particularly through harvesting a greater proportion of the hardwood increment. The demand for fuel from woodlands is likely to continue to rise and it is possible that demand could outstrip domestic supply, leading to an increase in imports (Clubb & Tansley 2010).

Most of the Welsh hardwood harvest of 0.024 million tonnes is used for domestic firewood. However, this is dwarfed by the amount of softwood from conifers that is used in the three large biomass plants in Wales (approximately 0.56 million tonnes), most of which is imported. The commercial woodchip market accounts for approximately 0.3 million tonnes a year (Mike Pitcher, pers. comm.).

20.5.3.3 Fish from Marine systems

Offshore. Approximately 30% of landings of marine species from UK vessels occurred in England and Wales during survey years 1994 and 2008, with 68% and 63% landing in Scotland in those 2 years. Over 50% of the UK's shellfish landings occurred in England and Wales during the same periods. Marine Management Organisation and UK Sea Fisheries annual statistics give landings into Welsh ports, but they are not necessarily catches which have been sourced from Welsh waters (**Table 20.17**).

Inshore. The inshore fleet is mainly comprised of boats fishing within 6nm of the shore. These craft work out of 33 recognised ports across Wales, primarily targeting bass, crabs, scallops, lobsters, prawns, brill, turbot, plaice, rays and cod. Complete historical data are not readily available for the Welsh inshore fleet, which mainly comprises small vessels (craft less than 15 m long are not legally obliged to report their catches nationally or to the European Commission).

Shellfish. Shellfish production is important to the Welsh fishing industry. Mussels (*Mytilus edulis)* make up the bulk of production; live, fresh produce is primarily exported to Europe. Production rose from 8,000 tonnes in 2001 to 16,000 tonnes in 2008; Wales is the UK leader in seabed mussel production (WAG 2008c). There is currently a niche market for oyster (*Ostrea edulis)* production in Wales (less than 20 tonnes per year). Scallops, clams and abalone are potential new species for cultivation, again for the niche market. Shellfish cultivation in Wales was valued at approximately £12 million in 2005.

20.5.3.4 Inland fisheries

Commercial fishing for salmon, sea trout and eels, which spend part of their lifecycle at sea, and part in estuaries and rivers, is still practised around the coast and rivers of Wales, but is declining (**Figure 20.32**). Traditional methods of fishing for these species are recognised as having a heritage value.

Table 20.17 Weight and value of species (categorised by demersal, pelagic and shellfish) landed into three major Welsh ports and as a total for Wales. Source: reprinted from Welsh Assembly Government (WAG 2008c).

Port	Milford Haven		Holyhead		Bangor		Total for Wales	
	Weight (tonnes)	Value (£ '000)	Weight (tonnes)	Value (£ '000)	Weight (tonnes)	Value (£ '000)	Weight (tonnes)	Value (£ '000)
Demersal								
2003 2006	1,753 1,737	3,144 3,653	414 190	531 270	- -	- -	**2,302**	**3,956**
Pelagic								
2003 2006	14 4	10 2	- -	- -	- -	- -	**14**	**10**
Shellfish								
2003 2006	471 597	900 1,843	2,939 2,617	1,456 1,901	- 5,129	- 193*	**6,796**	**6,771**
Total								
2003 2006	**2,238 2,238**	**4,053 5,498**	**3,353 2,807**	**1,987 2,170**	**- 5,129**	**- -**	**9,112**	**10,737**

* Value of 4,965 tonnes of mussels unknown.

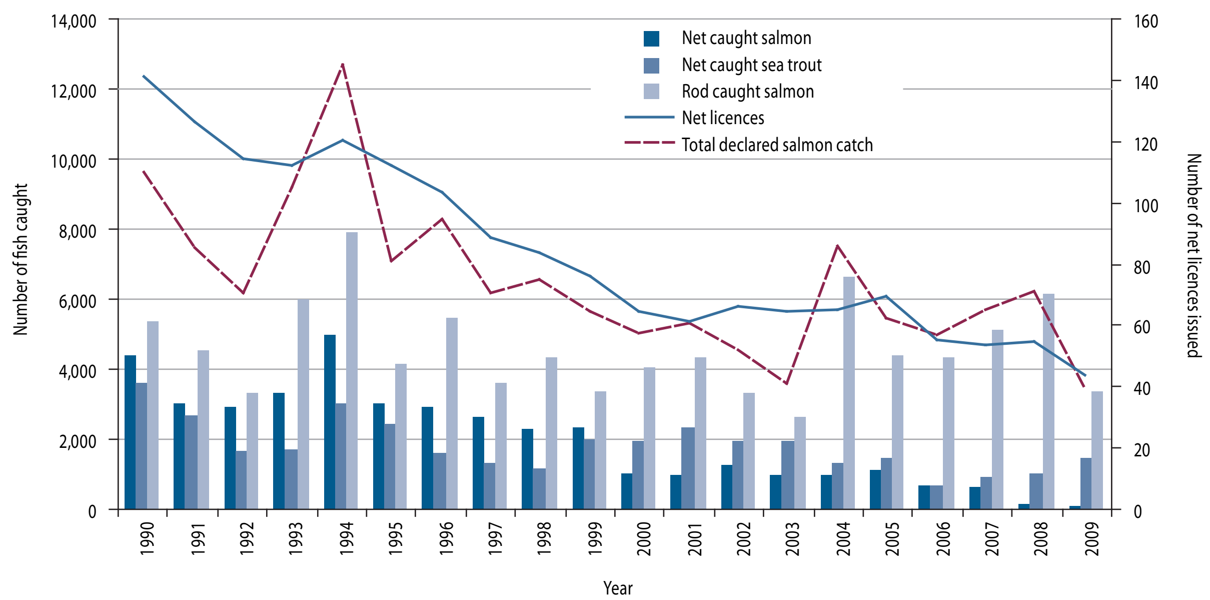


Figure 20.32 Trends in declared catches of salmon (net, rod and total) and net-caught sea trout between 1990 and 2006 in Wales. Source: WAG 2008c with updated data provided by the Environment Agency. © Environment Agency and database right.

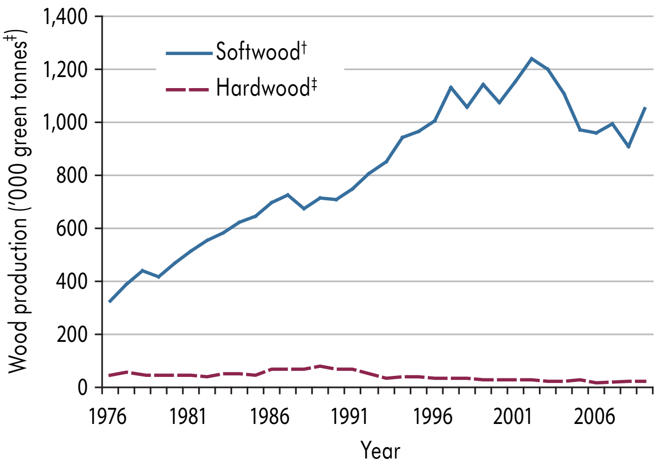
20.5.3.5 Game—food from birds and mammals provided by hunting

Interest in both farmed and wild caught (hunted) meat has grown in recent years (Mintel Game and Exotic Meat Report 2007) and there are now three approved game meat-handling establishments in Wales (Food Standards Agency data). No specific data on volumes or value of this niche market in Wales were available for inclusion in this study.

20.5.3.6 Timber and forest products

Timber. From a peak in 2003, there has been a decline in recent years to 1.1 million green tonnes of coniferous timber harvested annually in Wales, representing 76% of annual increment (**Figure 20.33**). A further 0.024 million tonnes of hardwood are produced from broadleaves, mostly for wood fuel. This is about 5% of annual increment, and current policy is to increase this proportion further, although there are market and attitudinal barriers to harvesting more of the Welsh hardwood stand at present.

Total consumption of wood products increased from 1999 to 2007, but dropped in 2008 (Forestry Commission 2009a). Use of home-produced and imported timber in construction could increase in future because of its potential to substitute for products such as concrete and



* The figures for softwood (conifers) production are based on Forestry Commission (FC) administrative records and on trends reported by the largest harvesting companies.
† The figures shown for hardwood (broadleaved) production are estimates, based on reported deliveries to wood processing industries and FC administrative records.
‡ One green tonne is equivalent to approximately 0.98 m^3 underbark softwood or 0.88 m^3 underbark hardwood, and to approximately 1.22 m^3 overbark standing softwood or 1.11 m^3 overbark standing hardwood.

Figure 20.33 Timber harvested from woodlands in Wales from 1976 to 2009. Source: Environment Agency Wales data mapped by I Durance, Cardiff University.

brick which involve higher emissions (Southey *et al.* 2009).

The gross value added to the Welsh economy in forestry and primary wood processing was in the region of £400 million in 2007, and 9,000 people were employed in these activities.

Non-timber forest products, ornamental and genetic resources. In common with the rest of the Britain (Chapter 15), there are very limited data on non-timber forest products, ornamental and genetic resources in Wales. There is increasing interest in wild-harvested products, and foraging for wild foods is now promoted in Wales as a tourism activity (Visit Wales website accessed March 2011). However, no information on volumes or trends in these activities were available for this study.

20.5.3.7 Water

The topography and climate of Wales combine to provide a relatively high supply of water in many parts of Wales. Water moves through catchments—and interacts to a greater or lesser extent with all the terrestrial habitats. Agriculture and land use clearly play important roles in delivering high quality water resources.

Assessments of the availability of water resources for licensing are conducted by the Environment Agency as part of Catchment Abstraction Management Strategies (CAMS). **Figure 20.34** shows the amounts abstracted in Wales in 2008. Abstractions in Wales were 40% greater in 2007 than in 1995. The major reasons for abstraction related to electricity supply and represented 75% of total Welsh abstractions. Abstractions for water supply represented 18% of Welsh abstractions, and these had increased over 1995 levels. Not all of the water abstracted for this use is consumed in Wales as there are considerable transfers to English regions. For example, the Elan valley supplies an average 360 million litres of water a day to Birmingham.

The Environment Agency has identified significant pressures on the water environment in parts of Wales. Only 46 of the 100 surface water CAMS units in Wales currently have water available that can be licensed for abstraction without restrictions at low flows. Additionally, 16 CAMS units are currently over-licensed or over-abstracted, meaning that existing abstractions could be adversely impacting the environment, particularly during times of low flow. Levels of leakage in Wales have declined to 23.5% of total water supplied. There has been an increase in the average consumption of water, from 148 litres per person per day in 2001 to 152 litres per person per day in 2009.

The amounts of available water are increasingly likely to be affected by climate change. Current research suggests that by 2050, river flows in winter may rise by 10–15% due to changes in rainfall patterns. However, river flows in the summer and early autumn could reduce by over 50%, and by as much as 80% in some places. These patterns would result in a drop in total annual average river flow of up to 15% (Environment Agency 2008). Projections for housing growth in Wales forecast the numbers of homes in Wales to increase by 20% to 1.48 million by 2026 (WAG 2006b).

Effect of woodland cover on supply of potable water. After large increases in forest cover in the uplands of Wales during the 20th Century, some deforestation has occurred with the purpose of restoring open upland habitats (approximately 4,000 ha in the last 10 years). Forest cover is known to reduce the availability of water supply, and Willis (2003) estimated that it would cost £35.4 million per year if water companies had to replace all the water 'lost' to forest

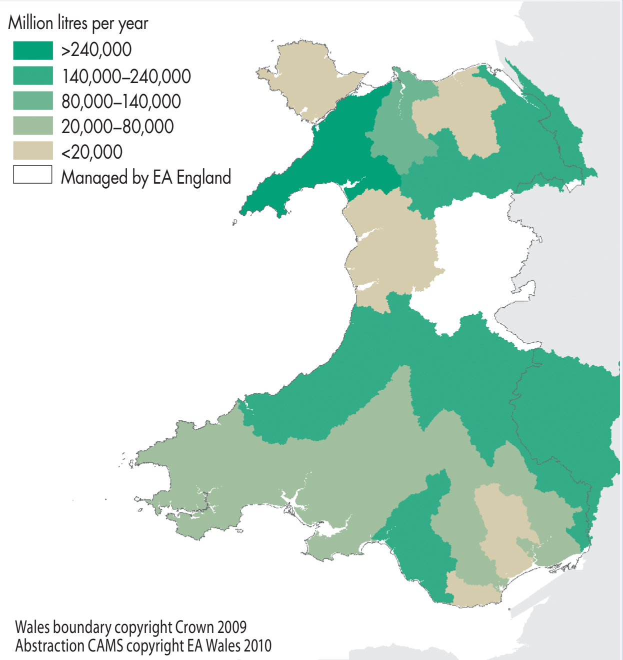


Figure 20.34 Actual amount of water abstracted in 2008 from surface and groundwater for each of the Environment Agency Wales CAMS. Source: Environment Agency Wales data mapped by I Durance, Cardiff University.

cover in Wales. However, whilst hydrologists point to the theoretically large impact of forestry on water availability, British water companies currently internalise the impact of forest cover in water supply costs (Willis 2002).

20.5.4 Cultural Services

"Mae'r dolydd blodeuog o dan gysgod Pen-y-Fâl, Powys yn adlewyrchu'r canrifoedd o ofalaeth a greodd dirweddau amrywiol Cymru."

"The flower-rich meadows under the shadow of Sugar Loaf Mountain, Powys, testify to the centuries of stewardship which have created the variety of landscapes of Wales".
Caring for the Historic Landscapes—CADW (2007, p2)

This section focuses on aspects of habitats and cultural services which relate to human well-being in Wales. It aligns with the conceptual basis of the UK NEA main chapter on cultural services (Chapter 16), including the New Economics Foundation's 'Five Ways to Well-being', namely: being active, connecting, learning, giving and taking notice. It is qualitative in its approach, since it does not attempt to estimate volumes of ecosystem products or services. It is mainly based on policy and strategy documents related to the promotion and optimisation of cultural services in Wales. Academic material is covered in more detail in the UK-level chapter on cultural services.

The cultural services addressed here comprise: tourism and recreation, education, tradition and language, sense of place and community development, spiritual and religious services, and aesthetic and inspirational services. There is considerable overlap and convergence between these various services; for example, culture and language have fundamental links to the services associated with a sense of place and community development, and are intimately associated with the perception of and responses to landscape and nature. Initiatives and projects that are planned to conserve and enhance awareness in one area will have implications and benefits for others.

The following sections discuss each cultural aspect and identify the key ecosystem services and opportunities associated with it.

20.5.4.1 Tourism and recreation

Wales has a wide variety of habitats which display a range of aspects from gently undulating lowlands and vales, to upland 'wilderness' areas, rugged mountains and sweeping or dissected coastlines. These offer a significant range of types and levels of physical activity for residents and visitors alike. As well as the main benefits of physical and mental challenge, health and well-being offered by recreation in these habitats, many outdoor activities also create opportunities for developing a greater awareness and understanding of the natural environment.

The economic and social benefits arising from countryside recreation are now widely acknowledged. Walking in Wales alone has been estimated as being worth over £500 million per annum to the Welsh economy. The Foot and Mouth Disease outbreak in 2001 demonstrated that trips to the countryside by local residents and visitors make a huge contribution to rural areas (**Table 20.18**). During the outbreak, the economic losses to UK businesses dependent on tourism were estimated as ranging from £2.7 billion to £3.2 billion.

Direct tourism spend in Wales was estimated at £753 million per year averaged across 2006–2008 (UKTS 2009). The Tourism Satellite Account for Wales, compiled by Cardiff Business School for Visit Wales, estimated that the wider impact of tourist spend on the Welsh economy was an estimated £4.2 billion in 2007, with direct support of 78,000 full-time equivalent jobs. The report found that 50% of tourist spending in Wales is by day trip visitors, 32.5% by longer-stay UK holidaymakers, 8% by international visitors and 6% by business tourists.

A major current driver of rural tourism is the Wales Rural Development Plan, which uses European Convergence funds to support farm diversification into visitor services and niche activities such as green tourism and wildlife-watching. Wales also has strategies that aim to increase well-being and healthy lifestyles through physical activity and sports for a wide range of Welsh people. Examples of this include support for the national long distance footpaths, cycle routes and the Wales Coastal Path.

The value of recreational angling to Wales is now estimated at more than £100 m (WAG 2008b, p39). Lakes, rivers and seas are being targeted for the expansion of recreational services. Environment Agency Wales is aiming for a substantial increase in water-related leisure activities by 2013, including an increase in recreational angling. Typical of such initiatives is the Get Hooked on Fishing (GHOF) strategy, which is developing a range of angling-related local projects in Wales. In 2009 the first such scheme was launched in Flintshire, coordinated by the local Neighbourhood Watch Association,

Table 20.18 Welsh Outdoor Recreation Survey summary.
Source: data from Countryside Council for Wales and Forestry Commission Wales (CCW & FCW 2009).

Types of activity	Proportion of visits (%)	Places visited	Proportion of visits (%)
Short walks	35	Local parks	15
Dog walking	31	Woodlands or forests	14
Long walks	28	Roadside pavements	12
Hill walking	14	Hills/moorland	11
Visits to playgrounds	11	Farmland	8
Wildlife watching	11	Rivers/lakes/canals	8
Sightseeing	10	Local open space	8
Running	6	Beaches	7
Informal games	5	Other coastline	6
Picnicking	4	The sea	2
Road/off road cycling	3		
Horse riding	3		
Other	3		

with additional schemes planned for the Anglesey/Gwynedd area, Brynmawr and Neath.

Information on tourism earnings for the Welsh seaboard is given in the section on the Coastal Margins in Wales. In line with European directives on coastal waters, it is planned that there will be 100 blue/green coast award beaches and nine blue flag marinas in Wales by 2015, all of which are likely to contribute to increased visitor numbers to this habitat.

Tourism to rural Wales frequently focuses on opportunities for a range of landscape and wildlife-related activities. The existence of a mosaic of healthy habitats is therefore important for the tourist experience, and for the biodiversity that these land-/seascapes support. The Government recognises the potential for growth in wildlife-related tourism and the fact that this form of tourism relies on the good condition of the ecosystems on which it depends:

> "Increased development of the wildlife tourism sector could have considerable 'knock-on' benefits, including increases in conservation activity, particularly if it occurs alongside additional associated investment in the protection and management of Wales's wildlife resource". (CCW 2007).

Wales's national tourism strategy, Achieving our Potential 2006–2013, is supported by regional strategies and sectoral tourism policies, such as the Wales Coastal Tourism Strategy, the Green Sea Development Strategy 2006–2015 and specific initiatives such as the Brecon Beacons National Park and Powys Green Tourism Scheme 2009 and Wild and Green Tourism (Powys Rural Development Plan).

An example of a major initiative which is based on ecosystem service principles, and which has been designed to develop, expand and enhance the tourism potential of the South Wales valleys, is the Valleys Regional Park project (VRP), see **Figure 20.35**. This scheme aims to create a mosaic of high-quality countryside recreation and heritage amenities including country parks, urban parks, greenspaces, upland commons, reservoirs, lakes, canals, nature reserves and river corridors, as well as historic sites and visitor attractions, all linked together by an extensive rights of way network, trails, tramways and cycle routes. Fundamental to the VRP approach is the concept of cross-sector and cross-boundary collaboration between 40 organisations, focusing on an ecosystem services approach to maximise the wider opportunities afforded by the environment. The project will cover an area of over 200,000 hectares which is home to over 1 million people (nearly one-third of the Welsh population). Part of the programme is focusing on maximising the economic opportunities offered by the environment for business through the ecosystem services approach.

Wales has a 33,000 km network of public rights of way. Local Authority survey data for 2008/9 showed that 49.26% of routes were classed as 'easy to use' and the overall picture is one of gradual improvement since 2002/3 when the Wales average was 43.7%. Nevertheless, the current position means that just over half the public rights of way in Wales are still not easy to use according to the performance measures used by Local Authorities. This is likely to significantly affect the ability of walkers to access areas of open country and coastline.

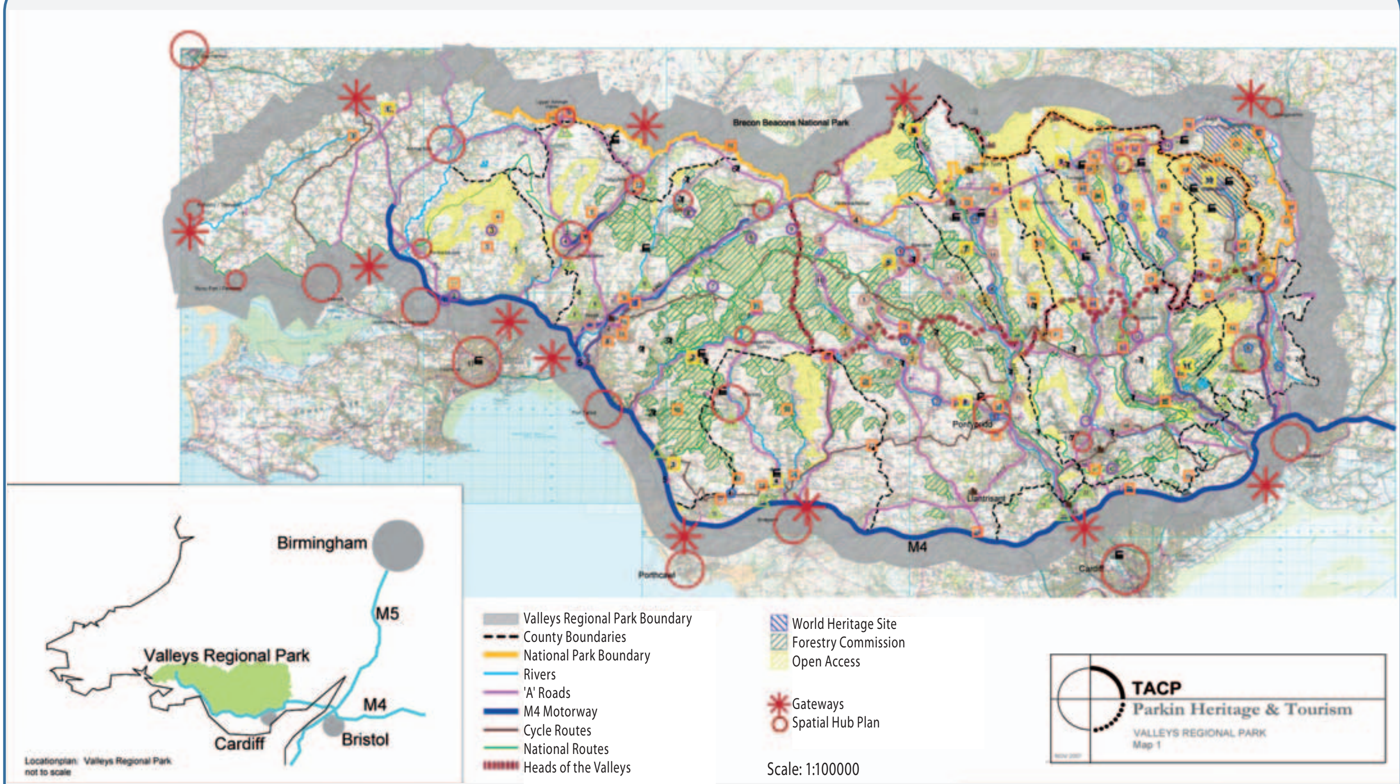


Figure 20.35 Valleys Regional Park Masterplan. Source: VRP (2007).

The impact of land management on public rights of way can be significant and can lead to problems such as poor surface condition (caused by ploughing, livestock trampling, etc.) as well as obstruction (growth of surface vegetation, installation of fence lines and deterioration of gates and stiles). The potential exists for significantly reducing problems on public rights of way, thus improving both accessibility and quality of experience by users as well as bringing associated cost benefits to the public sector.

Welsh tourism and recreation strategies target walking as a main activity to attract visitors to Wales. Research in 2001 showed that 74% of trips to Wales by UK holidaymakers involved walking as an important component of their visits. The Welsh Coastal Tourism Strategy 2008 indicates that 68% of people cite walking as their main activity when visiting Wales, and the Welsh Outdoor Recreation Strategy 2009 states that 86% of all outdoor activity involves walking (see **Table 20.18** above).

The health benefits of walking are well known and the importance of outdoor physical activity in relation to health and well-being has been recognised by the National Institute for Clinical Excellence (NICE) in its guidance on physical activity and the environment:

> "Ensure public open spaces and public paths are maintained to a high standard. They should be safe, attractive and welcoming to everyone."(NICE 2008, p8).

20.5.4.2 Education

Education and ecological knowledge can be derived from all the other cultural ecosystem services covered here. Learning is both 'giving and taking notice', and is encountered either through formal or informal education or through site-specific interpretation.

Schools use the ecosystems of Wales, urban greenspaces, LNRs, the woodland estate, etc., for many educational activities as part of the National Curriculum. Colleges and Universities rely on Welsh habitats for training in many fields, including countryside management, agriculture, marine science, geology, hydrology, heritage and outdoor sports. Many continuing and further education activities also focus on the learning opportunities presented by the Welsh environment, and Wales is well served by a range of field centres, which include the UK's only residential Environmental Studies Centre entirely owned and managed by a National Park Authority (Plas Tan-y-Bwlch in Snowdonia).

Urban wildlife habitats also score highly for education services because urban farms, Learning through Landscapes schemes, school eco-projects and wildlife gardens provide a variety of hands-on educational experiences that are embedded in the formal curriculum. The Enclosed Farmland habitat also offers educational opportunities through schemes such as the Schools Food and Farming Initiative.

20.5.4.3 Tradition and language

Some ecosystem services have acquired cultural status through their association with human stories, legend and myth. These services are especially important in Wales because of the significance of the Welsh language, which has often preserved and enshrined local and particular aspects of ecosystems. Welsh words and terms define specific elements or aspects of biodiversity, traditional skills and agricultural/marine products and practices. The Welsh language is also firmly associated with unique literary responses to ecosystem services.

Such services and products are reflected in a variety of cultural and creative initiatives and opportunities, including events such as eisteddfodau; agricultural and breed society shows, countryside and community events, and heritage and interpretation projects in Wales. An example is Iaith Pawb, the action plan for a bilingual Wales, which not only aims to implement policy and law on culture and language, but also has a specific brief to conserve and develop links between the language and its traditional connections to wildlife and the landscape of Wales.

Bwrlwm Eryri is a cultural landscape initiative launched in 2005 and led by the Snowdonia National Park Authority, which aims to encourage communities and organisations to become involved in recording and safeguarding the Park's cultural heritage and to promote greater awareness, understanding and enjoyment of this rich resource amongst residents and visitors (SNPA 2010). Cymdeithas Edward Llwyd has a programme of over 100 walks every year, focusing on different aspects of the natural and historical life of Wales. The online facility Llên Natur gives access to current information about biodiversity, with sections on traditional lore associated with various habitats. It also provides access to nature terminology in the Welsh language.

Cultural and historic features of the landscapes of Wales have been recorded by government initiatives such the Register of Landscapes of Historic Interest in Wales (Cadw, Countryside Council for Wales, ICOMOS UK) and the Historic Landscape Characterisation Project (Cadw, Countryside Council for Wales and four Welsh Archaeological Trusts). Cultural and traditional/historical landscape features are also evaluated alongside geological, habitat/biodiversity and visual/sensory criteria, and are held in a nationally consistent data set and Geographical Information System (LANDMAP), which assists with planning decisions in Wales (CCW 2009).

There are nearly 5,000 Scheduled Ancient Monuments in Welsh woodlands and the relative lack of ground disturbance, for example by tilling, contributes to the preservation of these features of the historic environment. However, Willis *et al.* (2003) were unable to assign a monetised benefit to the archaeological resources of Wales.

20.5.4.4 Sense of place and community development

There is a significant relationship between ecosystem goods associated with tradition and those that reinforce a sense of place and community development in Wales. Recently, there has been a growing emphasis on local products, animal breeds, foods and crafts, and how they can be used to regenerate and animate the local rural economy. Food festivals, farmers' markets, farm tourism, local energy provision, traditional building with local materials and 'sustainable livelihood' projects are typical manifestations of this. The fish festivals of Anglesey, Llŷn, Aberaeron and Pembrokeshire, for example, derive their distinctive character from the provisioning services of the marine environment and its cultural relationship to local human communities.

There are several schemes in Wales which demonstrate how underlying ecosystem services can contribute to community development and an enhanced sense of belonging and commitment to regions and localities. The four Welsh Landscape Partnership schemes supported by the Heritage Lottery Fund are focused on: 1) moorland/heathland habitat (Heather and Hillforts—Clwydian Hills); 2) a coastal/farmland area (Llyn); 3) the semi-natural upland grassland of the area around Blaenavon (Forgotten Landscapes); and 4) the river valley of the Tywi (Afon yr Oesoedd). The purpose of these projects is to create interaction between nature conservation and agricultural initiatives, traditional culture, communities and educational/interpretive programmes.

The Communities and Nature programme (CAN) is administered by the Countryside Council for Wales and aims to: "generate increased economic growth and sustainable jobs … by enabling a wider range of Wales' residents to benefit … from the country's environmental qualities, particularly its landscape and wildlife".

Wales's Geoparks and the Eco Dyfi project in the UNESCO Biosphere Reserve in West Wales, are further examples of the way in which ecosystem goods and services are being used to stimulate social and economic development and local community engagement.

Figure 20.36 Route of the Cistercian Way. Source: The Cistercian Way (2011).

20.5.4.5 Spiritual and religious services

Ecosystem features associated with spiritual and religious feelings, include landscape features linked to deities or to human experiences such as renewal, healing and burial. Some of these elements form a bridge between Christian and pagan beliefs, and holy sites in Wales are often linked to more than one religion. In some instances, large landscape features such as mountains, lakes or rivers are recognised for their connections with mythical figures, with the power of a deity or as entrances to another world.

Just as droving routes are an important feature of the working landscape, so pilgrimage routes offer opportunities for an experience of landscape that is marked out by religious elements such as holy wells and churchyards, or sacred trees and stones. One example is the Cistercian Way, which is a long distance footpath, begun in 1998, linking sites associated with Cistercian monasticism in Wales (**Figure 20.36**). Cistercian monasteries were often sited in remote places with a sense of wildness and isolation, and were closely linked to the natural environment through practical (farming) and spiritual (meditation) activities. Corpse routes were used to take coffins across a mountain, usually when returning a person to their home village after death. Such spirit paths and ancient trackways are best preserved in upland areas, partly because they have not been overlain with roads or other development.

The spiritual and religious aspects of ecosystem services are of interest to many more people than the members of practising faith communities. Urban churchyards and cemeteries are often valued as wildlife havens and for conservation projects, e.g. the Gwent Wildlife Trust's Living Churchyards project. Sacred sites and church trails also offer opportunities for special-interest tourism.

Wales's heritage organisation, Cadw, includes in its cultural heritage initiative, a theme dedicated to the 'spiritual and inspirational'. The intention of this programme is to: "… connect individual heritage sites with other heritage attractions and with the local community and the surrounding area, as well as to link to broader interpretive stories and themes".

There is a strong religious or sacred element in two of the Welsh Landscape Partnership projects. Death and Religion—an exploration of the Sacred Sites and Landscapes of the Tywi Valley, is a main theme for the Afon yr Oesoedd (River through Time) project; and in the Llyn Peninsula, churches and sacred wells mark out the ancient pilgrimage route to Ynys Enlli (Bardsey Island). Bardsey is also an NNR and SSSI. It has 350 species of lichen and 10–16,000 breeding Manx shearwaters (*Puffinus puffinus*).

20.5.4.6 Aesthetic and inspirational services

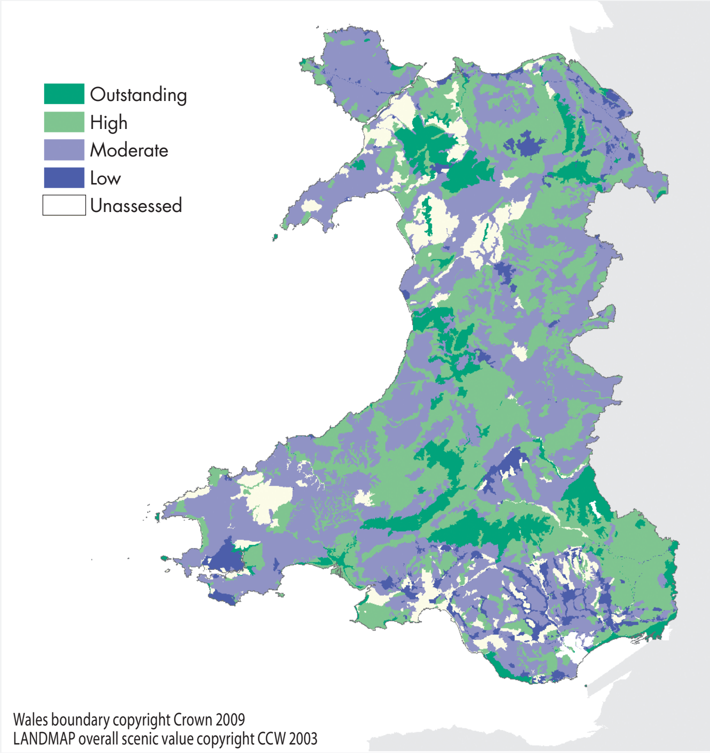
Aesthetic services and benefits are intensely personal, but there tends to be consensus concerning the link between habitats such as mountains and the sea, and the positive aesthetic experiences that they offer. The aesthetic characteristics of the Welsh landscape have been analysed and mapped by the Countryside Council for Wales, and the evaluations are held in the 'visual and sensory' layer of the LANDMAP database. The project considered the physical attributes of landform and land cover, the visible patterns and distribution of landscape features and their interrelationships. Allowance was also made for auditory and olfactory (hearing and smell) signatures of landscape.

Figure 20.37, taken from the LANDMAP inventory, rates much of upland and coastal Wales as of high aesthetic value, with some areas classed as outstanding. This coincides with the observation that habitats and ecosystems of wild, lonely and dramatic places tend to elicit some of the strongest aesthetic responses, including motivations to conserve and protect such places.

However, individual aesthetic experiences may also arise from familiarity or from sensory detail in intimate and unexpected places. Details of form, colour and texture may be valued and provide inspiration and contemplation in places that are far from 'natural'. Such places might include the surprisingly rich local biodiversity of abandoned land in an urban setting, or the 'patchwork quilt' of farmed landscapes.

Outside of the flagship protected areas, examples of culturally important landscapes are found throughout Wales. Anglesey is thought to have one of the highest densities of Neolithic remains anywhere in Europe (GeoMon website accessed March 2011). Prehistoric field systems have survived in large parts of North and South West Wales where stone is plentiful, much of the land marginal and where it has been uneconomic to clear away redundant boundaries. Areas on the Historic Register exhibiting this type of cultural landscape include the Lower Conwy Valley, North Arllechwedd, Ogen Valley, Dinorwig and Ardudwy, Preseli, St David's Peninsula, Pen Caer and Strumble Head.

The Gwent Levels preserve clear evidence of successive periods of human activity in reclaiming land from the sea since Roman times. Rhossili Vale in the Gower peninsula demonstrates a traditional mediaeval strip farming system, and other such open farming systems have become 'fossilised' in later enclosure patterns at Wrexham Maelor, the Vale of Clwyd, Lleyn and Manorbier.



* The LANDMAP Visual & Sensory evaluation identifies those landscape qualities that are perceived through the senses. It deals with the individual physical attributes of landform and land cover, as well as their visual patterns of distribution and sensory characteristics, and the relationships between them in a particular area, for example:
Scenic Quality: The area will have accessibly-viewed scenes which are of a picturesque quality, demonstrating aesthetically-pleasing elements in composition.
Integrity: The area should be generally unspoilt by large-scale, visually intrusive or other inharmonious development.
Character: The area should have a distinctive and common character including topographic and visual unity and a clear sense of place.
Rarity: The area should exhibit features or qualities that are both rare/representative and valuable for any other Visual & Sensory criteria.
LANDMAP Visual and Sensory Guidance. [online] <http://landmap.ccw.gov.uk/methodology/> [Accessed 13.07.2011].

Figure 20.37 Visual and sensory evaluation of Wales, LANDMAP landscape values. *Source: copyright Countryside Council for Wales (CCW 2003).

20.5.4.7 Case study—cultural services of Welsh Woodlands

Trees and woodlands are highly valued by people in Wales for their historic and cultural values and as places for quiet recreation. Woodland is cited as one of the most popular destinations for countryside visits—around 12 million day visits per year in Wales—and public opinion survey data show an increasing use of rural and urban woodlands for exercise and recreation, including walking, jogging, cycling and horse riding, with concomitant health benefits (Forestry Commission 2009b).

Welsh woodlands host a number of world-renowned mountain biking centres. United Kingdom tourism figures, averaged for 2006–2008, showed that mountain biking generated a tourism spend of over £18 million per year in the Welsh economy (UKTS 2009).

Walking is an activity undertaken by the majority (60%) of day visitors to woodlands in Wales (TNS 2004). Willis *et al.* (2003) attribute a total annual recreational value for Welsh forests of £13.84 million. A number of internationally significant events are staged in woodlands, generating significant economic input to the local and national economies. For example, the Wales Motor Rally GB brought £7 million into the Welsh economy in 2004, including £3.8 million in short-term visitor expenditure (Econactive 2005).

In Wales, 22% of the woodland area has open public access, some of which is secured under the Countryside and Rights of Way Act, mainly through the dedication of the Forestry Commission's public estate, voluntary and public bodies. Seventy-two per cent of the Welsh population have access to woods greater than 20 ha within 4 km of their home, but only 17% have access to woods greater than 2 ha within 500 m. There are a number of initiatives to encourage people to use woodlands for benefits relating to their health and well-being. The Forestry Commission Wales is working in partnership with Coed Lleol (the Smallwoods Association initiative in Wales) in two Regeneration Areas—the Heads of the Valleys and Aberystwyth. Here, the focus will be specifically on groups with, or at risk of developing, chronic illness. Expansion of access to woodlands for walking/cycling, education and social/community activities is taking place, but more woodland is needed within or near to urban areas if the educational opportunities and benefits to well-being are to be more widely available.

There was a perceived 'loss of connection' between people and local woodlands during the 20th Century, but during the last 10 years there has been an increase in the number of community woodland groups to 138, and a significant increase in the number of educational and recreational visits to the forest estate. The Forestry Commission Wales encourages local people to use the Assembly Government Woodland Estate for such activities, and there are now 140 Forest Schools in Wales, set up to promote outdoor learning for school children. The Forestry Commission Wales Education Strategy supports a range of other local community and social forestry initiatives that include educational benefits, e.g. Coed Lleol, Llais y Goedwig, Cyd Coed and Forest School Wales.

Woodlands can contribute to the protection of cultural artefacts and archaeological remains beneath them, providing a link with the past. Welsh forests contain nearly 1,000 Scheduled Ancient Monuments, and a much larger but unknown number of sites of archaeological interest. Forests can help protect such evidence from disturbance, unless events such as catastrophic windthrow occur.

Trees and woodlands increase the diversity of landscape character. They provide a sense of place in key locations and form the major components of many landscapes, such as the hanging oakwoods of North Wales. There is some association between perceptions of landscape value and woodland characteristics: for example, woodland type (broadleaves tend to be more favoured than conifers), tree age (large, old trees tend to be favoured over younger ones), openness (valued more than dense, closed areas) and diversity (mixtures and variation valued over uniformity; Willis *et al.* 2003). These authors and others have explored ways of expressing preferences in value terms via willingness-to-pay calculations, deriving an annual value of £7.25 million for Welsh forests, attributable largely to their landscape characteristics and attractions (Willis *et al.* 2003).

Concluding remarks. Cultural ecosystem services are prized by the people of Wales, for personal, social and economic reasons. They also form an internationally important patrimony that deserves careful nurturing and protection in a global context.

> "I am aware when I'm walking here that there is much more to the landscapes of Wales than fine views—the landscape, its geology and the society which grew out of the geology are all part of the same thing, and it is important that we do not forget that link. The fact that the mountains and the slate rocks were created in the first place has had a dramatic influence on Wales and its people". Lord Dafydd Elis Thomas, Presiding Officer of the Senedd—Welsh Assembly, in: I Care for Wales…do you? (CPRW 2004, p10–11).

20.6 Status and Trends in the Ecosystem Services of Wales

Figure 20.38 provides an assessment of the relative importance of ecosystems in Wales for the delivery of specific ecosystem services, and the direction of change in these services over the past 20 years. The assessment is based on the expert judgement of contributors to the Wales synthesis chapter of the UK NEA, but cannot be regarded as definitive, due to generalisation, differing opinions and gaps in knowledge. There are issues with combining a range of differing component habitats into the UK NEA Broad Habitat types, and complex trends into a single direction of travel. However, as with the equivalent diagrams in the UK NEA section on ecosystem service trends at the UK level, **Figure 20.38** helps to highlight positive and negative areas of ecosystem management and health over the past 20 years, and forms a good basis for discussion and planning of response options for sustainable management of ecosystem services in the future.

20.7 Valuation of Wales's Ecosystem Services

Where studies exist, monetary values have been given in preceding sections for ecosystem services in Wales. These include provisioning services such as agriculture, fisheries and forestry, tourism and the wildlife economy. The Valuing Our Environment study of 2001 (Countryside Council for Wales and the National Trust) estimated that the environment contributed £8.8 billion of goods and services annually to the Welsh economy; 9% of Welsh GDP; one in six Welsh jobs and wages worth £1.8 billion to the people of Wales. The report found that jobs that are strongly dependent on the environment and ecosystem services are mainly in the leisure and tourism, agriculture, water abstraction, conservation and waste management sectors. It also found that the environment is relatively more important to the Welsh economy than is the case for the other UK nations. This study relied on conventional economic measures of financial worth and did not attempt to place a value on many of the services that have been addressed in the present study. The reader is referred to the UK NEA chapter on valuation for further information (Chapter 22). Studies on the valuation of Welsh ecosystem services have been identified as a priority workstream within the Welsh Assembly Government's new Natural Environment Framework, and are being carried forward in parallel with the spatial mapping of ecosystem services in Wales.

Evidence of the value of biodiversity and ecosystems to human society in Wales is still developing. The value of wildlife-based activity to the Welsh economy was investigated in 2007 and the final report, Wildlife Economy Wales (CCW 2007) found that there was:

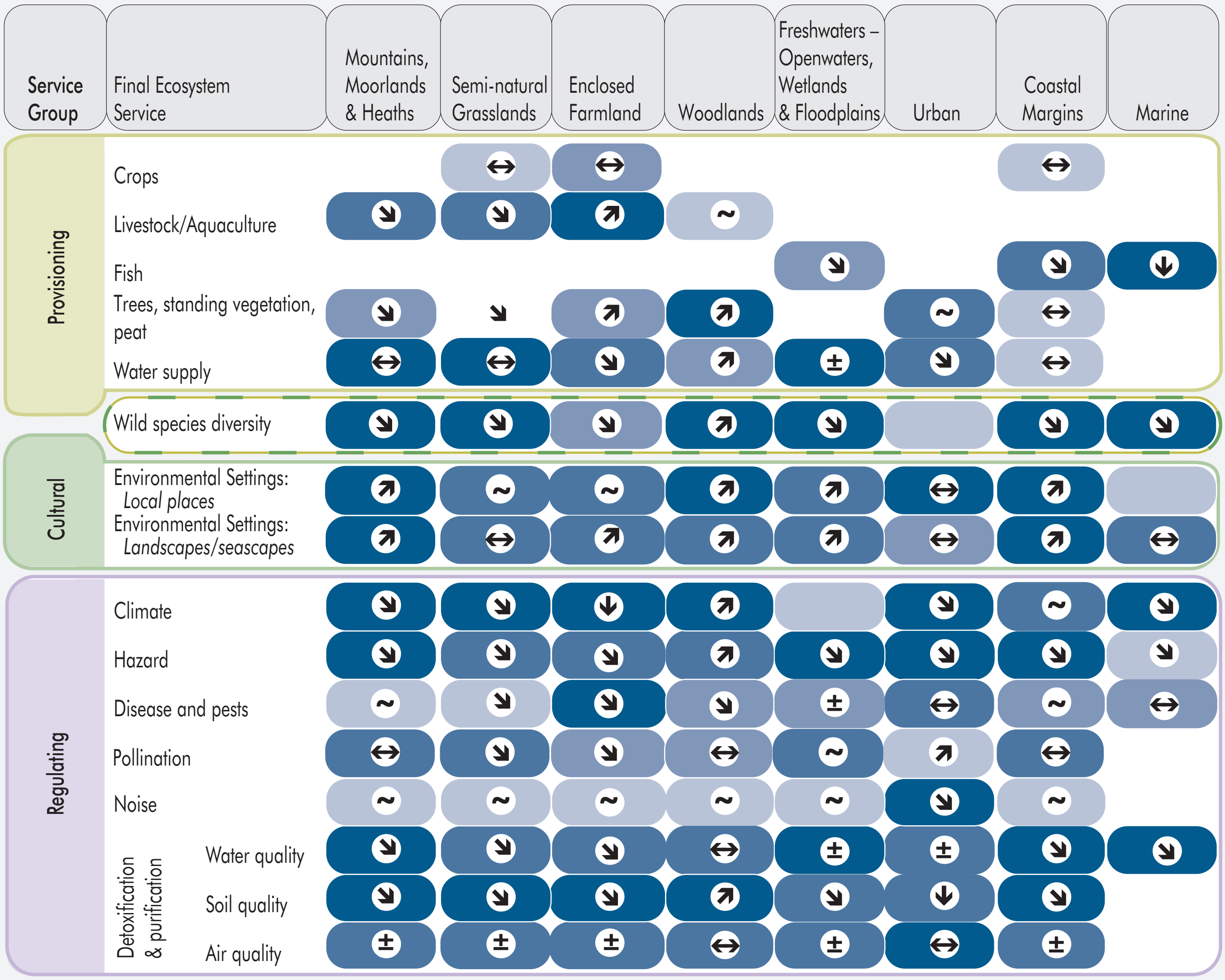


Figure 20.38 Relative importance of UK NEA Broad Habitats in delivering ecosystem services and overall direction of change in service flow in Wales since 1990. This figure is based on information synthesized from this chapter and the habitat and ecosystem service chapters of the UK NEA Technical Report (Chapters 5–16), as well as expert opinion. This figure represents an overview in Wales and will vary regionally and locally. It will therefore also inevitably include a level of uncertainty. Blank cells represent services that are not applicable to a particular Broad Habitat.

Importance of Broad Habitat for delivering the ecosystem service

- High
- Medium – High
- Medium – Low
- Low

Direction of change in the flow of the service

- ↑ Improving
- ↗ Some improvement
- ↔ No net change
- ± Improvement and/or deterioration in different locations
- ↘ Some deterioration
- ↓ Deterioration
- ~ Unknown

- total output of £1,936 million with a direct output value of £1,426 million;
- total employment of 31,766 (full-time equivalents);
- total GVA of £894.9 million; and
- total income to labour of £478.5 million.

This indicates that wildlife-related activities in Wales could be contributing 2.9% of Wales's national output, 3% of employment, 2.2% of GVA and 2.6% of incomes. Much of the output is driven by or linked strongly to wildlife-related public services, hospitality/retail and agriculture-related activities, with all other linked sectors making relatively smaller contributions. However, these figures only refer to wildlife-related conventional economic activity and they do not provide an assessment of the value of biodiversity as a whole through the provision of ecosystem services to Welsh society. More information on the value of biodiversity in the wider UK is provided in Chapter 22 (Norris *et al.*) and further discussion of the role of biodiversity in Wales is included in the sections on habitats and ecosystem services.

20.8 Wales's Dependence on Non-Welsh Ecosystem Services

The Stockholm Environment Institute has calculated the average Welsh person's ecological footprint as equivalent to 5.16 global hectares (Welsh Assembly Government Sustainable Development Indicator). This is the equivalent of 'three-planet living' for the average Welsh citizen. Data shows that Wales imports considerably more foodstuffs in all categories than it exports, except in the case of animal feedstuffs (**Figure 20.39**). This is just one indicator of the way in which the lifestyles of Welsh citizens rely upon, and will impact upon, ecosystem services beyond the borders of Wales.

20.9 Drivers and Consequences of Change

A broad definition of drivers of change is: "any natural or human-induced factor that directly or indirectly causes a change in an ecosystem" (MA 2005). The UK NEA has adopted this definition and a modified classification of direct and indirect drivers. Direct drivers are those which directly impact on biodiversity and ecosystems, e.g. land use and climate change. Indirect drivers are those which influence the direct drivers of change, e.g. economic and population growth resulting in increased demands for food, fibre, water and energy (UK NEA 2011).

The range and nature of drivers affecting the Welsh environment are numerous, and many are shared with other areas of the UK.

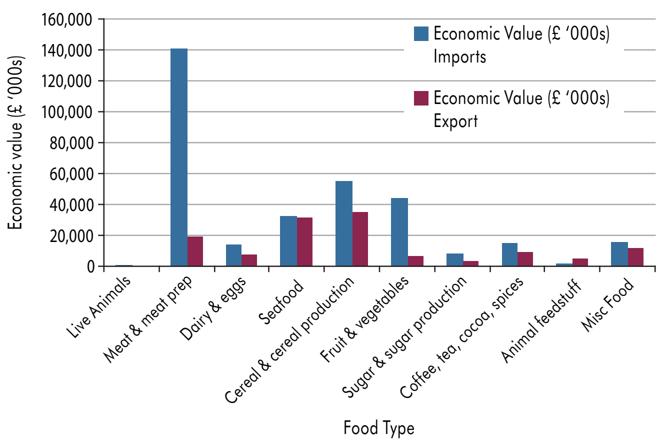


Figure 20.39 Imports and exports of food commodities in Wales. Source: WAG (2009e).

Direct drivers include:

- the impacts of global warming and the environmental consequences of climate change such as sea-level rise, changes in temperature and precipitation and extreme events such as storms, drought and floods, which may trigger irreversible changes of state in systems;
- habitat destruction—direct physical loss due to land-use conversion by the plough, the axe and the bulldozer;
- habitat degradation—due to neglect, overgrazing, fertiliser and pesticide use;
- non-native species—alien introductions and invasives;
- eutrophication—on land mainly due to fertilisers; more complex sources in fresh water and the sea;
- air quality—e.g. particulates, nitrogen oxides, sulphur dioxide, etc.;
- wild harvesting—e.g. damage to marine fish stocks by overharvesting and by-catch effects;
- toxic chemicals—pollutants and new substances with little-known effects, e.g. nanoparticles; and
- soil erosion and compaction.

Indirect drivers include:

- social and demographic change, e.g. population growth and movement, increased affluence and consumption;
- national and supra-national policies, e.g. European agricultural subsidies; and
- competition for financial resources to support environmental initiatives.

Land use has been a major driver of change in Wales. According to Swetnam (2007) between 1930 and 2008 England and Wales saw "an increase in forestry, the intensification and spatial polarisation of agriculture, and the expansion of urban areas". In England the proportion of land used by agriculture declined by approximately 7% between 1950 and 2008, with similar reductions occurring in Wales (Angus *et al.* 2010).

As mentioned in many of the sections on habitats in this chapter, climate change is likely to assume greater importance as a driver of change in the future. Satellite altimetry indicates that increases of 3.36 ± 0.41 mm/yr in sea level have already occurred (1993–2007; Beckley *et al.* 2007), and average wave heights are also increasing in the North Atlantic (Gulev & Hasse 1999). Sea-level rise and increased severity of storms are therefore expected to affect the Coastal Margins of Wales through increased flood events, for example.

Population increase brings about added pressures through demands for services, infrastructure development, production of waste, etc. According to the Welsh Assembly Government, the population of Wales is projected to increase by 11% to 3.3 million in 2031. Tourism as a major industry in Wales is expected to add to this pressure on the environment.

A key instrument of governance in Wales is the Welsh Assembly Government's Sustainable Development Scheme—the One Wales, One Planet agenda—which sets out sustainable development as the central organising principle for the delivery of Welsh Assembly Government policy making. It emphasises the importance of living within environmental limits, developing economic resilience and promoting social justice. The Wales Environment Strategy and the new Natural Environment Framework for Wales are key parts of the One Wales, One Planet agenda. The principle delivery mechanism for these Strategies is the Wales Spatial Plan, which has the potential to apply the ecosystem approach. Examples of policy instruments and levers in Wales are shown in **Table 20.19.**

The following factors have affected natural resource management in Wales in the past, and will influence responses to environmental change and societal needs in the future:

Conflicting political forces which have determined the use of Wales's natural resources, e.g. local needs, national legislation and the requirements of different European Directives.

- The legacy of habitat and resource fragmentation, and the consequent loss of connectivity resulting from patterns of land use driven by previous development pressures and subsidy regimes.
- The tradition of working independently and micro-managing land at a farm scale, rather than collectively at the landscape scale.
- The extensification, and even abandonment, of areas of upland Wales, and the lack of manpower in rural areas to undertake sustainable forms of natural resource management activity.
- The reduction in the area of woodlands in active management and the limited successes in bringing small private woodlands into sustainable woodland management regimes.
- The differences in attitude among different segments of the population in regard to competition for space on land and sea, for the production of different goods and services, e.g. food, fibre, renewable energy, water, public amenity, etc.

Drivers are discussed in more detail in relation to individual habitats in the relevant sections above (20.4) and within the main UK Synthesis Chapter.

20.10 Options for Sustainable Management

Ecosystem services and the ecosystem approach are assuming increasing importance in governance, economics, planning and land management globally (TEEB 2010; Volans 2010) and locally in Wales (Glastir 2010; Natural Environment Framework 2010). Pathways for ecosystem management at the UK level are addressed in the UK NEA main chapter on response options. Further discussion is provided here, on how Wales can achieve the greatest benefit from the management of its own 'critical environmental resources'. The following factors offer necessary context for this discussion:

- Wales has a range of particular social and economic problems, e.g. 22.7% of the population suffer long-term illness and there are areas of high social deprivation.
- The health/social budget in Wales accounts for about 35% of the grant received from the UK Government. Spend per head on environmental protection is low, yet the contribution the environment makes to the economy is high (see section on valuation of ecosystem services).
- The Sustainable Development Scheme and the new Natural Environment Framework imply a re-orientation of government policy and an integrated approach to the management of natural resources in Wales. This also implies prioritisation and tailoring of incentives for ecosystem service management through policy levers and fiscal measures.
- There is a desire to promote a transition to more locally integrated and sustainable economies which reflect high environmental standards, but which also provide added security for both local food and energy supplies.
- There has been an emergence of risk-based regulations to protect the integrity of critical environmental resources on which public goods and services depend.

Table 20.19 Examples of policy instruments and levers in Wales. Source: CCW, March 2011:

Level/Strategy	Policy instrument or lever		
EU	EU Common Agricultural Policy and Fisheries Policy	EU Territorial Cohesion	EU Directives (Water Framework; Species; Habitats; Air Quality; Strategic Environmental Assessment, etc.)
UK	UK Government National Policy Statements	UK Marine Policy Statement, Energy Policy	UK Biodiversity Action Plan
One Wales	One Wales – Programme for Government	One Wales: One Planet Sustainable Development Scheme	Wales Spatial Plan
Local	Local Development Plans	National Park and AONB Plans	National Park and AONB Plans
Sectoral	Sectoral programmes – Economic Renewal; Rural Development Programme; National Infrastructure Plan; Wales Transport Strategy	Sectoral programmes – Climate Change Strategy; Waste Strategy; Wales Environment Strategy; Natural Environment Framework; Woodlands for Wales	Other sectoral plans, e.g. Health; Education; Farming; Food and Countryside; Sport; Social Care; Fisheries Strategy; Coastal Zone Strategy
Other	Town and Country Planning consents	Protected area designations; management agreements	Grant aid, e.g. Glastir agri-environment scheme

- There are signs of the appearance of new technologies to help reduce the carbon footprint of rural development, especially agricultural activities.
- There is a large amount of land in rural Wales which is of limited value for high intensity agricultural production.
- There has been a wide range of agricultural and environmental management initiatives in Wales with challenges for the degree of strategic coordination between them, for management and evaluation, and for the level of 'buy-in' among stakeholders in these schemes.
- There is already a relatively large area of land in Wales under environmentally focused forms of stewardship (including the National Parks and Areas of Outstanding Natural Beauty). The public and political appetite for protection of further areas of land and seascape for ecosystem services delivery is as yet unknown.
- There has been a public motivation to protect traditional family farm structures and the associated approaches to traditional livestock husbandry.
- There has been inadequate recognition of the connectivity between terrestrial and marine ecosystems, and these realms have traditionally been regarded as two independent resources for management purposes.

Considerable work has been carried out by the scenarios assessment team for the UK NEA, and the reader is referred to Chapter 25 of the UK NEA report for information that is relevant to the UK and Wales in general. Assessments have not yet been carried out at the country level (England, Scotland, Wales and Northern Ireland) during the NEA process, but the UK-level work provides a valuable conceptual framework for the planning of response options within the nations.

A sample of response narratives is given below, for some but not all of the sectors of the Welsh 'natural economy', namely: soils, the uplands, urban habitats, coastal margins and fisheries. For information on scenarios and potential response options in agricultural habitats in Wales, the reader is referred to the detailed treatment in the recent report on Land Use and Climate Change in Wales (Wyn Jones *et al.* 2010).

20.10.1 Soil Management in Wales

The sustainable management of soils in Wales has to take account of the nature and distribution of land use within the country which results from its particular combination of hilly topography, ancient geology and moist, cool climate. Agricultural land use is dominated by extensive livestock grazing. Twenty per cent of Wales's grassland and 25% of woodland occur on 95% of the organo-mineral and peat soils in Wales (Jones & Emmett 2009). Therefore, sustainable management of soil carbon, for example, has to use measures appropriate to these two land-use types. In a review of mitigation options for greenhouse gas emissions from Welsh agriculture, Jones & Emmett (2009) concluded that forestry (increased tree planting) and better management of improved grasslands had the greatest capability for locking up atmospheric carbon in soils and reducing nitrous oxide emissions. Unimproved grassland and bogs also need to be managed sustainably in order to preserve the large amounts of carbon stored in these soils and to prevent them from becoming an enhanced source of carbon dioxide.

Within Wales, the Welsh Soils Action Plan (WAG 2008a) and Woodland for Wales strategy (WAG 2009b) provide a policy framework for addressing sustainable soil management. Glastir (WAG 2010c), the new agri-environment scheme for Wales, provides farmers with financial incentives for appropriate soil management alongside other requirements for farm payments. Within the planning sector, recommendations have been made to review the Technical Advice Notes (TANs) which guide planning policy so that soil-related issues are specifically included (Stevens *et al.* 2002); the TANs in place for mineral extraction were considered a good model to follow. The effects of transboundary air pollution on UK soils has also been reviewed recently (RoTAP, 2010) and emission control legislation formulated at the European level will continue to be the main management tool. Thus, a number of policy instruments already exist in Wales to promote sustainable soil management. However, there is a requirement for appropriate soil monitoring in Wales to measure whether policies are successful and to identify areas of continuing concern.

20.10.2 Management of the Welsh Uplands

The success of agri-environment schemes in the uplands of Wales has been partly limited by the inability to effectively target management at key habitats, or to secure agreements across common land. Common land accounts for a large proportion of upland habitats and includes some of the most biologically degraded areas in Wales. Current legislation covering common land and its unique governance structures presents particular difficulties in terms of achieving agreement over the right approach to land management, but will be a major consideration in addressing many of the issues affecting the uplands of Wales in the future.

There is a continuous demand for a range of different land uses in the uplands of Wales, raising concerns about potential future conflicts. Trade-offs will have to be made when seeking to reconcile multiple objectives. For example, the methane emitted by livestock is, by volume, 21 times more effective than carbon dioxide in trapping thermal infrared radiation, but grazing is still the most cost-effective means of maintaining many of the habitats characteristic of the Welsh uplands. Careful management of the timing, types and numbers of stock animals used, with low levels of grazing designed to increase biodiversity value, could help optimise the condition of Welsh upland habitats (e.g. partial substitution of cattle for sheep flocks). Such management could also help to tackle problems of soil compaction and erosion, water runoff and downstream flooding/pollution which are current on a number of the 'drier' upland sites in Wales.

Consideration might be given to the withdrawal of 'traditional' agricultural management in some sensitive areas. The end result need not necessarily involve 're-wilding', but the adoption of alternatives to the current pattern of management might include minimal intervention in some places, with judicious use of grazing animals in others, and not necessarily with food production as the primary purpose. The challenge will be to plan where such approaches could best be applied, taking into account market forces, the need to manage ecosystem services and the increasing demand for recreational access.

A developed framework for the conservation of the Welsh uplands would help to highlight where it is most important to conserve particular habitats, and would act as a guide to inform decision making on land management. Knowledge of where it might be regionally most important to expand and restore woodland or species-rich grassland, for example, would ease decision making at any particular site. Larger sites will have a greater range of possibilities for habitat conservation measures. This approach is outlined in The Countryside Council for Wales's Upland Framework (Jones 2007), which attempts to convert the conservation objectives for statutory upland sites into a long-term vision of the actual vegetation that would exist on these sites if the objectives were fully realised.

20.10.3 Urban Environments

The provision and management of greenspace in towns and cities has often been reactive and opportunistic. In order to deliver a 'full basket' of ecosystem services, the provision of urban greenspace should be planned according to evidence of need. The Countryside Council for Wales Accessible Natural Greenspace Toolkit (CCW 2006) provides a model which can be followed to determine the need for a particular suite of ecosystem services (using clear, evidence-based standards) and for determining the areas where greenspace could most usefully be situated, taking other demands into account. The toolkit then provides a methodology to determine deficiencies or over-provision, and suggested policy responses to remedy any deficiencies. Such responses may include allowing development on greenspace where it is over-supplied in order to release funds to acquire land where greenspaces are lacking.

Sustainable Drainage Systems (SuDS) is a more integrated approach to urban drainage and has been adopted as policy in Wales (Prosper 2002). Traditional drainage design has typically been based upon the principle of removing surface waters in urban areas as quickly and conveniently as possible, usually via an existing watercourse or soakaway. This can contribute to an increased likelihood of flooding and diffuse pollution during high rainfall events. The SuDS approach takes into account the aesthetic and biodiversity potential of urban watercourses and drainage systems, while contributing to increases in water quality and natural replenishment of groundwater and watercourses.

20.10.4 Management of the Welsh Coastal Margins

Built infrastructure constrains the natural evolution of the coast and may locally lead to a build-up of sediments among intertidal rocky habitats, potentially leading to smothering (muds), scouring (sands) and/or a reduced photic zone (depth at which sunlight can penetrate to allow photosynthesis to occur) as a result of greater suspended sediment loads in the water column. Construction of piers, breakwaters and harbours (largely historic) within and at the mouths of estuaries throughout Wales have reduced wave exposure and changed the hydrology of rocky habitats within such estuaries. Construction may locally impact biological communities on estuarine rocky habitats. Coastal infrastructure is generally considered a poor surrogate for intertidal rocky shores, in terms of the diversity and abundance of colonising species, and reduced structural complexity of the surface available for colonisation (Moschella *et al.* 2005).

Managed realignment, or roll-back, has primarily been applied to saltmarshes in England, but is increasingly being considered in Wales and for other habitats (Pye *et al.* 2007). Managed realignment can help to maintain the extent of Coastal Margin habitats threatened by sea-level rise, and the ecosystem services they provide. Artificial re-mobilisation of over-stabilised or reclaimed habitats may rejuvenate dynamic 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 (Garbutt *et al.* 2006; Jones *et al.* 2010b).

In general therefore, sustainable management should take into account the uniqueness and non-replaceability of the existing ecosystem services of Coastal Margin habitats in Wales, and aim to enhance or maintain their specific characteristics, rather than replicating services provided better elsewhere.

20.10.5 Fisheries Management in Wales

The Wales Fisheries Strategy (2008c) identified several modes for improving ecosystem service provision in the marine environment while minimising the impact of fisheries and maximising human gain from this service. One major cross-sector challenge for sustainable fisheries development is the issue of economic headroom or scope for growth. Some of the key approaches outlined in the strategy (WAG 2008c) are outlined below:

- The centralisation of research and technological development activities to ensure that infrastructures are in place and that these activities are coordinated and responsive to the needs of the ecosystems and species, fisheries industry, regulators and the public.
- Greater capitalisation of under-utilised species such as mackerel and sprats (although levels should be monitored) and further investment in shoreside handling/holding and transport facilities to ensure greater economic returns from existing targeted species.
- Greater provision of training for commercial fisheries workers to promote sustainable practices, with significant emphasis on conservation awareness and safety in the workplace.

20.11 Knowledge Gaps and Research Capacity

20.11.1 Knowledge Gaps

An assessment of research needs in relation to the Wales Environment Strategy has been carried out by the Wales Environment Research Hub (WERH 2009). Several hundred specific research questions were identified by scientists and policy makers across Wales, and the reader is referred to the cited document for details of these findings (WEHR 2009).

A set of general research questions were raised in relation to response options for dealing with environmental pressures, and by implication, ecosystem services in Wales, namely:

- Research is needed to address issues of unsustainable resource use that impact on Wales, and pressures that originate from within and beyond our borders. We need to more closely define requirements for sustainable living in urban and rural contexts in Wales, including a full environmental costing of our current development framework. Carbon footprints need to be gauged and the potential for organisational and personal carbon accounting explored in the Welsh context.
- Further research is needed on the environmental implications of a balanced energy mix and a sustainable transport system for Wales. Additional studies are also required of water budgets, waste minimisation and local environmental quality, including air pollution and greenspace in Welsh urban environments.
- Further research is also required to develop and refine sustainable farming practices in light of CAP reform and climate change, and to tackle the environmental, health and social consequences of food, fibre and fuel production within and beyond our borders.
- Ongoing scientific assessments are needed of the impacts of development and environmental change on the biodiversity and landscapes of Wales, including the role of habitat connectivity in planning for 'networked regions'. More studies are needed of our important but relatively neglected Marine habitats, with research to underpin truly sustainable fisheries and the understanding of climate change impacts in our coastal seas. Further knowledge is also needed of Welsh soils, particularly the impacts of climate change on our soils with high organic carbon content (peatlands).
- Sustained observations are essential in Wales, for key environmental parameters that impact on ecosystems and human health, and are predictive of environmental progress and sustainability. This includes research to refine the suite of indicators for the Wales Environment Strategy and the Natural Environment Framework. Locally-relevant research into human behaviour and societal change is also crucial if we are to successfully understand and equitably address the environmental and developmental challenges facing Wales.

In relation to ecosystem services and land management, general questions raised by the review included:

- What is the current knowledge and understanding of ecosystem services in Welsh society?
- How should our thinking evolve on incorporation of the value of ecosystems and their services into national accounts and local decision making?
- How can we spatially map ecosystem services and determine weights for individual services when assessing ecosystem health and deciding on land-use interventions?

Research is needed on the following specific problems within the Enclosed Farmland habitat and the agriculture sector more widely in Wales:

- Reducing methane emissions from extensive livestock grazing.
- Reducing nitrogen oxides emissions from cultivation.
- Enhancing carbon sequestration within arable soils and Improved Grassland.
- Improving the management of Improved Grassland to reduce flood risks and pollution of watercourses.
- Developing cultivation techniques that enhance biodiversity whilst at the same time reducing greenhouse gas emissions.
- Developing the use of crop residues and other waste products for energy production.

To wisely apportion resources for sustainable land management and agri-environment schemes in Wales, further information is needed on optimum stock/crop ratios under climate change scenarios, tree and hedge planting regimes for catchment water quantity and quality management, and field boundary management prescriptions for biodiversity enhancement, etc.

Knowledge gaps in Marine and Coastal Margins habitats include:

- accurate estimates of change in extent and condition of the Coastal Margins habitat over time;
- management options required to respond to sea-level rise; in particular, how to apply roll-back or managed realignment to Coastal Margin habitats other than Saltmarsh;
- better knowledge, including mapping, of the Welsh subtidal habitat and its ecosystem services; and
- quantification of the links between marine biodiversity and ecosystem functioning to better understand the effects of human impacts on Marine ecosystems in Wales.

20.11.2 Research Capacity

There is a broad range of research into ecosystem services going on currently in Wales. The website of the Wales Environment Research Hub (www.werh.org) contains links to environmental science research groups at the Universities, and a map of long-term field experimental sites in Wales. The Centre for Ecology and Hydrology (CEH) has a good skills base and infrastructure for conducting ecosystem studies, but insufficient capacity to carry out the increased level of research and long-term monitoring studies that will be required for a robust evidence base if Wales and the wider UK are to pursue new governance models founded on the ecosystem approach.

Examples of current CEH ecosystem studies in Wales include work at the following sites:

- Conwy: 'carbon catchment'—soils for climate regulation
- Clocaenog: climate manipulation experiment—soils for carbon storage
- Lake Vrynwy: climate regulation, nutrient cycling, waste filtration
- Plynlimon: soils for water quality and fibre production
- Pontbren: sustainable management of farm grasslands for multiple services

- Berwyn: restoration of peatland for multiple services.

Wales has good capacity for marine research in its universities and, currently, in the Countryside Council for Wales. The universities are assisting the Welsh Assembly Government with planning for marine conservation zones, and The Countryside Council for Wales has carried out many marine assessments on which management decisions have been based.

20.11.3 Spatial and Temporal Scales, and Linkages Between Ecosystems

There are several initiatives to map the spatial distribution of ecosystem services in Wales, including the mapping of ecological connectivity being carried out by The Countryside Council for Wales. **Figure 20.40** shows an example of broadleaved woodland habitat functional networks as predicted by least-cost modelling, a method developed by The Countryside Council for Wales in collaboration with Forest Research (Watts *et al.* 2005; Latham *et al.* 2008).

Figure 20.40 Broadleaved woodland habitat networks in Wales, as predicted by least-cost modelling (Latham *et al.* 2008). Networks comprise woodland and areas of other habitats around them that species may use to move between woodland patches; actual woodland boundaries are not shown. **Dark green** areas are core networks for species demanding a large minimum habitat area and with low dispersal ability; **light green** areas are networks for species with a low minimum habitat area and moderate dispersal ability. Many species will lie between these extremes. Source: CCW (2009). Map is © Crown copyright. All rights reserved. Countryside Council for Wales, 100018813 [2007].

A further programme of research in The Countryside Council for Wales, in collaboration with Environmental Systems Ltd of Aberystwyth, has mapped the following ecosystem services in Wales:

- Areas important for carbon storage in soils
- Areas important for carbon storage in vegetation
- Areas important for carbon storage (in soil or vegetation)
- Potential factors contributing to high surface water runoff
- Areas potentially contributing to the regulation of surface water runoff
- River catchments and flood risk areas
- Agricultural intensity
- Range of fishing activities
- Areas important for current renewable energy provision
- Areas with potential for additional renewable energy provision
- Areas important for current fibre provision
- Recreation resources: legally accessible resource
- Promoted areas and routes
- Outdoor recreation opportunities and health deprivation.

Further evidence gathering to support decision making for ecosystems management is being pursued through the workstreams of the Wales Natural Environment Framework, and through work in other government agencies, non-governmental organisations and the Universities in Wales. However, cutbacks in funding for state environment-related agencies, pressures on university budgets, and 'belt tightening' by private citizens, which in turn affects what NGOs and voluntary organisations can contribute, are all likely to impact on environmental evidence gathering and environmental action in Wales. It will be particularly important not to let austerity measures adversely affect long-term environmental monitoring programmes that provide the benchmarks and trend information on which future policy and practice will be based. Such information is crucial to the ecosystem approach and will become more so as environmental change impacts Welsh society and land/seascapes over the coming years.

20.12 Conclusions

The Wales synthesis has found and presented information relevant to Wales for five of the key questions addressed by the UK NEA:

- What are the status and trends of the UK's ecosystems and the services they provide to society?
- What are the drivers causing changes in ecosystems in the UK and their services?
- What is the current public understanding of ecosystem services and the benefits they provide?
- How can we secure and improve the continued delivery of ecosystem services?
- How have we advanced our understanding of the influence of ecosystem services on human well-being and what are the knowledge constraints on more informed decision making?

However, knowledge gaps and/or lack of capacity at the Wales level, have made it difficult to provide adequate answers to the remaining five questions:

- How do ecosystem services affect human well-being, who and where are the beneficiaries, and how does this affect how they are valued and managed?
- Why should we incorporate the economic values of ecosystem services into decision making?
- How might ecosystems and their services in the UK change in the future under plausible futures?
- What are the economic implications of the different plausible futures?
- What provisioning services upon which the UK depends are not provided by UK ecosystems?

As mentioned above, research is already going on to address some of these uncertainties, e.g. spatial mapping of ecosystem services by Environment Systems (Aberystwyth) for The Countryside Council for Wales and the Wales Environment Research Hub, and valuation of ecosystem services as part of the economics workstream of the Welsh Assembly Government's Natural Environment Framework. Work is also continuing on the ecological footprint of Wales and our reliance on external/global ecosystem services. Scenarios work at the Wales level is desirable as follow-up to the first phase of the UK NEA, and there are still large gaps in our understanding of the effects of ecosystem service changes on human well-being and the distribution of these effects in Wales. This area of research will require a cross-disciplinary collaboration between social scientists, economists and environmental scientists, if answers are to be found to the complex questions of human motivation and behaviour that will underpin our personal and policy responses to sustainable management of ecosystem services in the future.

The Welsh Assembly Government is already moving to address these issues and has begun to: "radically rethink how it manages and protects its living environment … in order to achieve the best environmental and economic outcomes" (WAG 2010c). The Living Wales policy initiative is establishing a Natural Environment Framework for governance in Wales, based on the ecosystem approach. This policy initiative retains sustainable development as a central organising principle through which all polices will be developed and delivered, and by means of which, natural capital will be conserved or enhanced.

> "The policy implies a new contract between environmental managers and regulators, industry and commerce, and the public. It is intended to result in better decision making about the use of land and water, that reflects all the costs and benefits to society, so as to promote healthier environments and the conservation of wildlife and environmental assets, while allowing developments in the right places. It recognises the value and importance of the efforts of every individual contributing to a healthy environment, and it aims for prosperous livelihoods, where the provision of public goods and services is well rewarded and where nature thrives. Larger, connected and diverse habitats will allow full ecological functionality and adaptation to climatic change, while Welsh rivers lakes and seas should sustain healthy fisheries through good regulation that benefits everyone now and into the future. A simpler regulatory system is envisioned, based on the assessment of risk to the ecosystem and clearer guidance on what should be avoided, and a more integrated system of environmental management will be pursued, which is administratively simple, cost-effective but fully protective of Welsh environmental assets. Wales aims to be the first country to explicitly embed the ecosystem approach into governance and grass roots action, based on sound scientific evidence." (WAG 2010c).

The UK NEA has come at the right time to provide an, albeit as yet incomplete, evidence base for the Natural Environment Framework policy and governance initiative in Wales. It serves to highlight, after centuries of scientific endeavour, just how much is known about the environment of Wales and the wider UK, but also how much we still need to discover about the complexities and interconnections between ourselves and our natural surroundings, if we are to manage our relationship with ecosystems wisely in the future.

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