Cyfoeth Naturiol Cymru
Natural Resources Wales

The State of Natural Resources Report (SoNaRR): Assessment of the Sustainable Management of Natural Resources. Annex Technical Annex for Chapter 3

Natural Resources Wales

Final Report

About Natural Resources Wales

We look after Wales' environment so that it can look after nature, people and the economy.

Our air, land, water, wildlife, plants and soil – our natural resources - provide us with our basic needs, including food, energy, health and enjoyment.

When cared for in the right way, they can help us to reduce flooding, improve air quality and provide materials for construction. They also provide a home for some rare and beautiful wildlife and iconic landscapes we can enjoy and which boost the economy.

But they are coming under increasing pressure – from climate change, from a growing population and the need for energy production. We aim to find better solutions to these challenges and create a more successful, healthy and resilient Wales.

Evidence at Natural Resources Wales

Natural Resources Wales is an evidence based organisation. We seek to ensure that our strategy, decisions, operations and advice to Welsh Government and others are underpinned by sound and quality-assured evidence. We recognise that it is critically important to have a good understanding of our changing environment.

We will realise this vision by:

- Maintaining and developing the technical specialist skills of our staff;
- Securing our data and information;
- Having a well resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

The State of Natural Resources Report (SoNaRR) Report Contents

This document is one of six annexes to the State of Natural Resources Report.

All of the SoNaRR documents can be downloaded from the NRW website: www.naturalresources.wales/sonarr.

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Introduction

This technical annex provides the evidence base to support the key messages included in Chapter 3 of The State of Natural Resources Report. The headings and numbering system used correspond to the sections in chapter 3, with the relevant references included at the end of this document. This material has been brought together from a great number of sources and contributors and compiled by technical specialists within Natural Resources Wales.

Part A – Natural Resources

3.1. Animals, plants and other organisms

In a report such as this it would be impossible to provide information on the extent, status and condition of even a fraction of our fauna and flora (even if it were available), but some examples where we have good long-term and reliable datasets are presented here. The set of species groups presented here provides a good overview of the status and trends of species across the taxonomic range, with a reasonable probability of being able to report on them again in the future.

In addition, these species groups present examples of the range of protection mechanisms that exist. Species that are threatened at the European level are included in the Annexes of the Habitats Directive and Birds Directive. For example, all the UK bat and cetacean species are included, along with both widespread and very restricted species such as dormouse *Muscardinus avellanarius* and shore dock *Rumex rupestris*. UK-level protection is afforded through the Schedules of the Wildlife and Countryside Act 1981, and includes species such as adder *Vipera berus*, Snowdon rainbow beetle *Chrysolina cerealis*, spiked speedwell *Veronica spicata* and red squirrel *Sciurus vulgaris*.

Section 7 of the Environment (Wales) Act 2016 places on Welsh Ministers a requirement to publish, review and revise lists of the species and habitats of principal importance for maintaining and enhancing biodiversity in Wales. Section 7 replaces the now repealed section 42 of the Natural Environment and Rural Communities Act 2006 and until the new section 7 list has been published, the Welsh Ministers have adopted the list of species and habitats under the now repealed section 42 to act as an interim list. This interim list has 557 priority species and 55 priority habitats, which were originally selected for prioritised action based on their level of threat, the level of responsibility in Wales for their populations, and the ability to carry out remedial action to improve their status. These include species as diverse as slowworm *Anguis fragilis*, hornet robber fly *Asilus crabroniformis* and long snouted seahorse *Hippocampus guttulatus*. A full list of the interim Section 7 species and habitats can be found on the Wales Biodiversity Partnership website[1].

Extent

It is not possible to provide information on the extent of all species. Various Atlas projects demonstrate the geographical extent or range of taxonomic groups with the addition of a clear temporal attribute. For example, *The New Atlas of the British and Irish Flora*[2] shows changes in vascular plant distribution between 1962 and 2000, whilst *The Bird Atlas 2007-2011*[3] covers the period from 1968 to 2011. The availability of such long-term time series is a valuable tool in assessing the changing patterns of species distribution.

Welsh marine waters contain a variety of habitats that support a diverse range of species. Larger fish and shellfish species form the basis of commercial and recreational fishing and some tourism related activities. It is important to realise that a healthy marine environment is critical to deliver these ecosystem services and benefits. There are numerous EU and national regulations controlling access to commercial and recreational fishing opportunities with underpinning stock or landings data. However this data is often incomplete or at an inappropriate scale to determine accurate extent data in a Welsh context.

Condition

The protected site network in Wales includes the Natura 2000 sites of Special Areas of Conservation (SACs) alongside Special Protection Areas (SPAs), in addition to the national designations of National Nature Reserves (NNRs) and Sites of Special Scientific Interest (SSSIs). All of these designations provide protection for a wide variety of species and their habitats.

The 2013 reports on the Annexes of the Habitats Directive (‘Article 17 report’) and Birds Directive (‘Article 12 report’), summarise the UK status and trends of the selected habitats and species and are important evidence resources[4, 5, 6, 7].This information is presented in Chapter 3.1 of SoNaRR.

Another way to prioritise action and report on species condition and trend is to look at the International Union for Conservation of Nature (IUCN) red list criteria, which determine those species that are under the most imminent threat of extinction.

The use of ‘red listing’ as a method of quantifying and comparing the threat of extinction for a particular species has been well established and developed since the early listings of large African mammals in the 1960s. This is a globally accepted way of identifying species conservation priorities. The process is objective and based on scientific information and can be applied at differing scales. The latest phase of the project in the UK uses the 2012 IUCN criteria[8] (Glossary in Table 1). The red list process takes account of population, range and trend data, and so provides a holistic overview of the status of a species that can then be applied to many different reporting and conservation needs.

Table 1 IUCN Red List Criteria Glossary

RE – Regionally Extinct A taxon is Extinct when there is no reasonable doubt that the last individual has died. In this review the last date for a record is set at 50 years before publication.
CR – Critically Endangered A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered.

EN – Endangered A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered.
VU – Vulnerable A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable.
NT – Near Threatened A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
LC – Least Concern A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.
DD – Data Deficient A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.
NE – Not Evaluated A taxon is Not Evaluated when it is has not yet been evaluated against the criteria.

Plants

Wales has the benefit of several red list analyses for plant species (Figure 1).

Of the 1,467 species of vascular plant in Wales, 38 (2.5%) have become Extinct since 1800, over 100 (7.7%) are Critically Endangered or Endangered and almost 10% are Vulnerable.

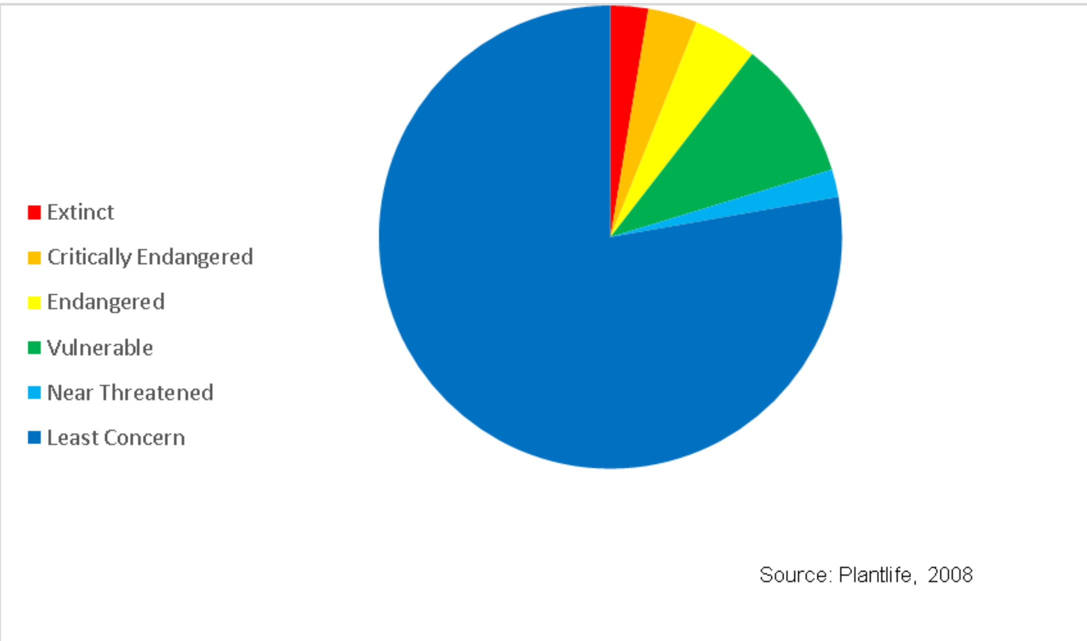

Figure 1 Red list chart for Vascular plants in Wales[9].

Invertebrates
There are 44 species for which Wales has particular responsibility in Great Britain, including arctic-alpine species at the southern edge of their range, endemic *Sorbus* species, and specialists of the Atlantic fringe.

Our arable-associated flora is probably the most threatened group of plants in Wales, with eight of the extinct species being typical of cultivated fields[9]. Arable plants have been particularly affected by changes in cropping cycles, seed cleaning, and conversion of mixed farming practices to grassland for grazing[10].

Table 2 shows the outputs from the completed invertebrate assessments in the UK and the relevant figures for those species that occur in Wales. As with the plant red lists, these analyses have been undertaken to inform conservation action and protected site feature selection. The highest levels of threat (CR to VU) are shown as red text. These species are most at risk with the potential to slip into the extinct category (RE).

Table 2 Invertebrate Red Lists compiled from NRW data. RE – Regionally extinct; CR – Critically endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NE – Not Evaluated

Order	Taxon	Date of Review	No. of species	% threatened (CR-VU)	RE	CR	EN	VU	No. CR-VU species in UK	No. CR-VU species in Wales	NT	LC	DD	NE
Coleoptera	darkling beetles	2014	180	11	9	0	0	19	19	3	1	111	6	34
Coleoptera	ground beetles	in prep	369	12	3	10	19	16	45	13	33	266	3	19
Coleoptera	leaf beetles	2014	283	13	3	7	17	12	36	10	5	208	7	18
Coleoptera	soldier beetles	2014	114	7	5	1	3	4	8	1	5	79	0	17
Coleoptera	water beetles	2010	391	9	5	4	9	23	36	10	35	234	1	80
Diptera	Hoverflies	2014	282	5	0	4	3	6	13	0	10	249	8	2
Diptera	larger brachyceran flies	in prep	161	14	4	4	9	10	23	4	11	120	2	1
Diptera	marsh flies	in prep	305	5	2	7	2	6	15	4	11	230	39	8
Ephemeroptera	Mayflies	in prep	53	9	2	0	3	2	5	2	0	38	6	0
Hemiptera	Shieldbugs	in prep	69	10	3	4	2	1	7	1	0	50	0	9
Hemiptera	water bugs	in prep	93	4	0	1	0	3	4	1	4	79	2	4
Lepidoptera	Butterflies	2010	62	31	4	2	8	9	19	11	11	28	0	0
Odonata	Dragonflies	2008	43	14	3	0	4	2	6	2	6	27	1	0
Orthoptera	grasshoppers & crickets	in prep	79	5	0	1	1	2	4	1	2	27	0	46
Plectoptera	Stoneflies	in prep	34	6	1	1	0	1	2	2	0	27	4	0
Trichoptera	caddis flies	in prep	197	9	0	6	3	8	17	7	6	154	19	1
Araneae	Spiders	in prep	664	17	3	20	27	64	111	25	24	490	11	25
Mollusca	slugs & snails	2014	205	9	0	4	2	13	19	5	10	143	10	23
Myriapoda & Isopoda	Millipedes, centipedes & woodlice	in prep	187	3	0	0	2	4	6	1	7	110	10	54
		TOTAL	**3,771**	**193**	**47**	**76**	**114**	**205**	**395**	**103**	**181**	**2,670**	**129**	**341**

Fish

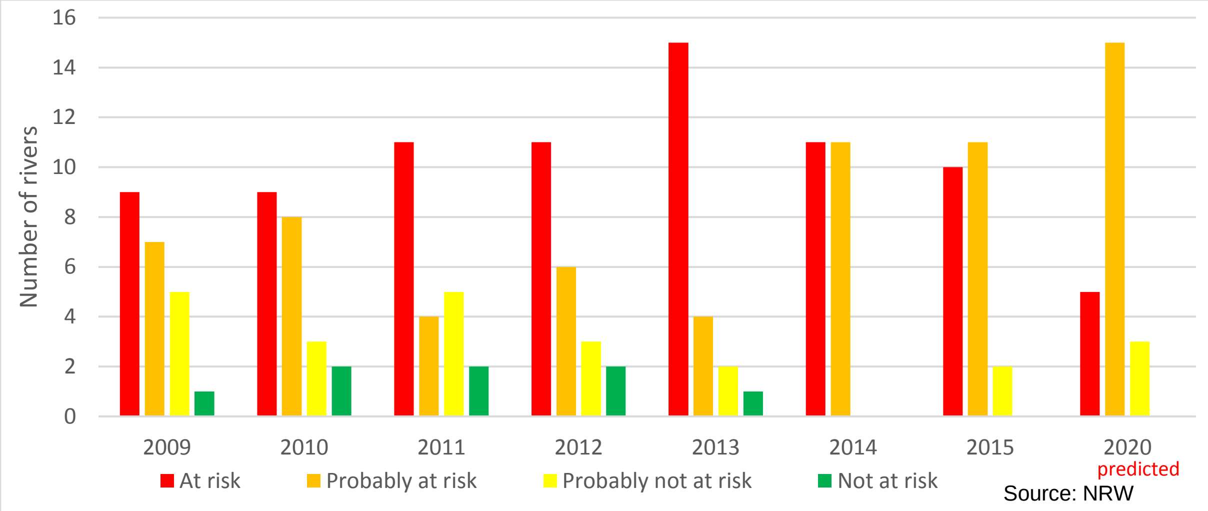

Figure 2 Salmon river condition[11].

We have 23 principal Atlantic salmon rivers in Wales (including 3 cross-border rivers), with all but two stocks (Severn and Glaslyn) currently assessed as ‘At Risk’ or ‘Probably at Risk’ of failing to achieve their Management Target in 2016 (Figure 3).

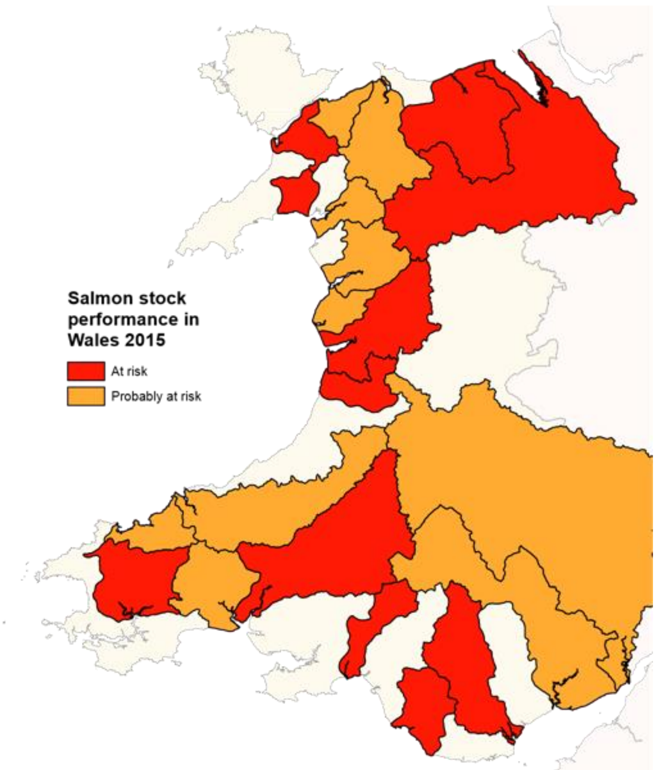

Figure 3 Salmon stock Assessment 2015)[11]

The latest assessment of salmon stocks indicates that most rivers in England and Wales are in a depleted state. Their condition is unlikely to improve within the next 5 years[11]. Figure 4 provides catch details for the Afon Tywi.

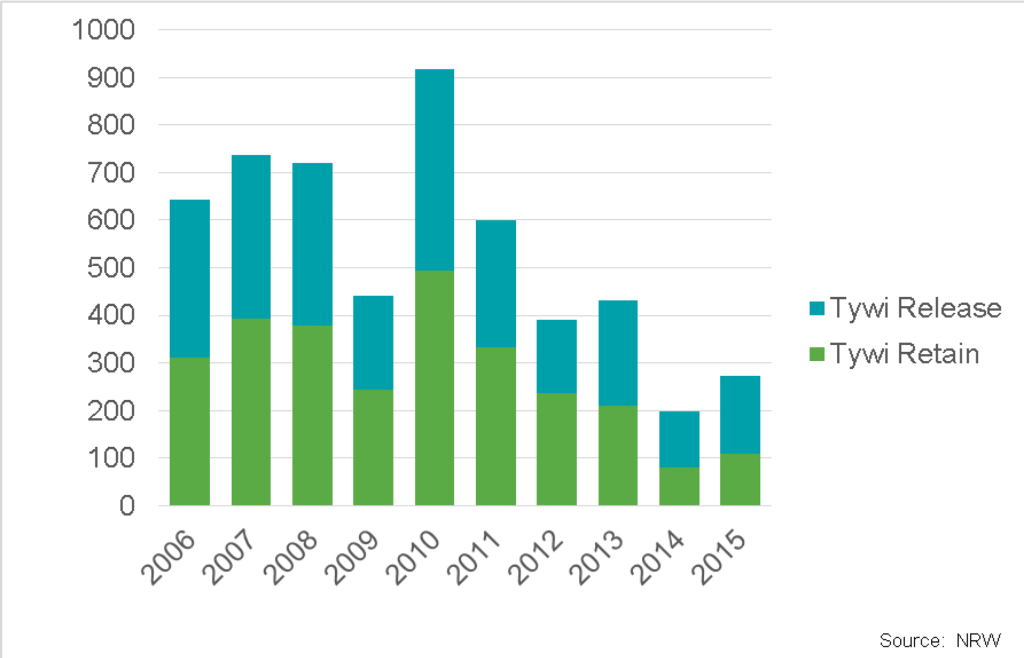

Figure 4 Afon Tywi Declared Salmon Rod Catch [12]

The use of 'Conservation Limits' (CL) provides an objective reference point against which to assess the status of salmon stocks in individual rivers. The quality and quantity of accessible spawning and rearing areas affects the numbers of salmon a river can produce, and consequently the catches that the stocks support. This is why, in general, big rivers have larger catches and have correspondingly larger total spawning requirements than small rivers. The CL represents the number of eggs that must be deposited each year within a given catchment in order to conserve salmon stocks in the future, and each river should have an optimum level of stock which the CL seeks to protect. Figure 5 illustrates this process for the Afon Dyfi. The current number of eggs being deposited puts stocks and the population condition at risk into the future.

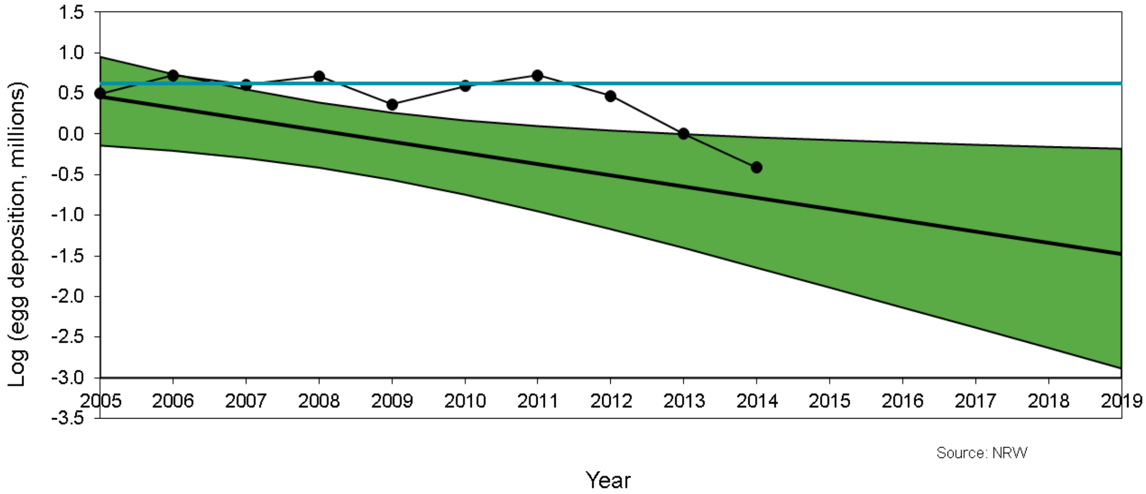

Figure 5 Egg deposition estimates, Afon Dyfi[13]. The blue line represents the number of eggs required to be deposited to sustain a healthy salmon stock. The black line represents the 80% trend line, with associated confidence limits.

The condition of other freshwater fish species can also be related to returns from anglers, and consequently we have concerns about sea trout. There are 34 main sea trout rivers in Wales of which 15 are assessed as 'At Risk' or 'probably at Risk', although a number of rivers, mainly in North Wales, have improved in recent years[11].

Estimates of European Eel *Anguilla anguilla* populations up to 2011[14] show that the recruitment level of glass eels (the number of baby eel produced each year) was 1% of levels before the 1980s. Despite a statistically significant increase in glass eel recruitment since 2011, the abundance of eels at all the stages of their lifecycle remains very low. NRW is aiming to improve its condition across Wales by the application of the England & Wales Eel Regulations (2009) and leading on delivering, with stakeholders, the Dee and West Wales Eel Management Plans[15].

Fin Fish and elasmobranchs

The International Council for the Exploration of the Sea (ICES) provides scientific advice on commercially targeted fish stocks that are subject to Total Allowable Catch (TACs) and quota under the Common Fisheries Policy (CFP). Each Member State has an EU statutory obligation to collect data under the Data Collection Framework (DCF) for species managed by the CFP. ICES collate this data into area- and stock-specific reports for each species, resulting in multiple reports advising stock status. These reports are utilised by the European Commission to allocate annual fishing opportunities for each species within each sea area.

The quantity of fish available to catch is determined by a TAC, but a precautionary reduction in TAC can be advised where data is lacking or if the previous year's TAC was not caught. This may not necessarily be indicative of a stock in poor or declining condition, but rather data deficiency. In addition, landings cannot be taken as an indication of stock condition, as a number of factors including fishing effort, number of vessels, price and discards may have an unevaluated impact. ICES have developed a new approach to data-limited fish stocks that enables the identification of upper limits of sustainable fishing quotas based on biological information relating to the sensitivity and abundance of species.

Catch data are reported for specific ICES areas, including those that overlap with the Welsh inshore area, and are used to carry out annual stock condition assessments. Assessments are at the scale of the Irish Sea, Celtic Sea and Bristol Channel ICES areas (areas VIIa, VIIg and VIIf respectively), and although it is difficult to extract information specifically for the Welsh inshore area, this often represents the best available evidence[11].

Establishing an accurate assessment of the state of fish populations specifically within the Welsh inshore area is difficult due to data deficiencies and the highly mobile nature of many species. The infrastructure in Wales, including limited first sale market opportunities, makes it difficult to collect landing data for quota species. Additionally, these species can also be subject to natural cycles and fluctuations over periods of several years, influenced by a complex interrelationship of factors such as climate change, reproductive success, predation and prey availabilit[y16, 17.]

Welsh Government have commissioned a project which assesses the impacts of fishing on the wider ecosystem .The outputs from the Assessing Welsh Fisheries Activities Project and the Welsh Government's marine fisheries legislative review, together with the marine fisheries related actions set out in the LIFE Natura 2000 Programme, will contribute valuable information on the sustainability of marine fisheries activities and their locations in Welsh waters.

Shellfish

Scallop stocks in Welsh waters are subject to management under the Scallop Fishery (Wales) (No. 2) Order 2010 and have recently undergone annual stock surveys in Welsh waters[18]. The condition of other shellfish stocks is under review, with additionally sampling programmes underway to address data deficiencies. The most important shellfish species in terms of economic value are not subject to TAC and quota under the CFP, and so are not subject to ICES stock assessments. However, there is an EU statutory duty to provide data pertaining to important shellfish species that can lead to wider EU management. CEFAS will be conducting the stock assessment analysis of these species on behalf of Welsh Government and also provide stock assessments of the status of main shellfish stocks within UK waters[19, 20].

Welsh Government are currently drafting a Data Collection Programme, which will outline the approach that they will be taking to access their shellfish stocks and manage, where possible, to MSY.

Mussel fisheries in the Menai Strait are dependent on annual cultivation of seed stock to produce annual yields. The cockle fishery in the Burry Inlet has been subject to mass atypical mortalities since 2002, with extensive research suggesting a complex array of causal factors, including parasitic infection[21]. Although parasites have also been detected in the Dee estuary, occasional die-offs there have been attributed to overcrowded beds rather than parasitic infection.

Aquaculture
In 2012, fin fish aquaculture in Wales produced predominantly rainbow trout *Oncorhynchus mykiss* and bass *Dicentrarchus labrax* for human consumption or release into the wild[22]. Fin fish aquaculture production decreased from 790 tonnes in 2010 to 453 tonnes in in 2012[22]. Welsh Government is committed to supporting the sustainable growth of aquaculture and has plans to double Wales' annual aquaculture output for fin fish and shellfish production by 2020[23].

Marine Mammals
Around 20 species of marine mammal (18 species of cetacean and 2 species of seal) have been recorded in Welsh waters since 1990[24]. The conservation status of harbour porpoise *Phocoena phocoena*, bottlenose dolphin *Tursiops truncatus*, common dolphin *Delphinus delphis* and minke whale *Balaenoptera acutorostrata* was reported as favourable in the Article 17 report. The status of Risso's dolphin was unknown due to lack of data[4]. Most research on cetaceans in Wales has focused on bottlenose dolphins and harbour porpoise, and there has been some monitoring of Risso's dolphins[25, 26]. Little is known about the biology, conservation and status of other cetacean species in Welsh waters.

The grey seal *Halichoerus grypus* and the common (or harbour) seal *Phoca vitulina* are the two resident seal species in the UK. There are a number of important grey seal breeding sites in Pembrokeshire, the Llŷn Peninsula and Anglesey[27, 28, 29], but there are no records of common seal breeding sites in Wales. The UK population of grey seals as a whole is thought to be increasing[30] as are numbers in well-monitored Welsh colonies[31].

Trends

Population trends are available for a number of taxonomic groupings where there are long-term statistically robust recording and monitoring schemes which often contribute to UK Indicators. Additionally, data is also available for those species for which there is a statutory requirement to report. Table 3 presents a selection of Welsh freshwater species data from the last report Habitats Directive Annex 1 in 2013 as an illustration of the type of data available.

Table 3 Status of a selection of Habitats Directive Annex 1 species in Wales.

S – short-term trend; L – long-term trend. - Stable; ↑ Increasing; ↓ Decreasing

Grey cells - unknown; Greyed arrows - low confidence trend

Species	Range Trend		Population Trend		Habitat			Notes
	S	L	S	L	Quality	S	L	
Otter *Lutra lutra*	→		↑	↑	Good	↑	↑	Otters have recovered well from a population crash in the 1960s caused by persistent use of pesticides, and are now once again widespread throughout the country[32].
Medicinal leech *Hirudo medicinalis*	→	↓	→	↓		→	→	Rare. All populations in protected sites[33].
Desmoulin's whorl snail *Vertigo moulinsiana*			→			→		Relatively recently discovered (1998). Limited data[34].
Freshwater pearl mussel *Margaritifera margaritifera*	→	↓	→	→	Bad	→		Critically Endangered in Wales and globally. Habitat quality recorded as Bad. Article 17 metrics do not reflect the endangered status of this species in Wales[35].
Southern damselfly *Coenagrion mercuriale*	→	↓	↓	↓	Moderate	↓		All Welsh populations in protected sites. Main issue is undergrazing[36].
White-clawed crayfish *Austropotamobius pallipes*	↓	↓↓	↓	↓	Moderate	↓	↓	Habitat assessed as moderate, with siltation, disease, sheep dip and invasive signal crayfish the main issues[37].
Sea lamprey *Petromyzon marinus*	↑		→		Moderate			Still widespread and the largest populations are protected. Although data are poor, not thought to be under serious threat in Wales[38].
Brook lamprey *Lampetra planeri*	→				Moderate			Still widespread and very common, probably under-recorded. The largest populations are protected. Although data are poor, not thought to be threatened in Wales[39].

River lamprey *Lampetra fluviatilis*	→		→	→	Moderate			Widespread and common in Wales. The main threats are obstructions to migration[40].
Allis shad *Alosa alosa*		↓	↑	↑		↑	↑	Likely to benefit from warming climate. The main pressure is barriers to migration, which have been addressed by management work[41].
Twaite shad *Alosa fallax*		↓	↑	↑	Good	↑	↑	Likely to benefit from warming climate. The main pressure is barriers to migration, which have been addressed by management work[42].
Atlantic salmon *Salmo salar*	→	↓	↓	↓	Moderate	↓	↓	Populations have been actively managed by improving river connectivity. Reductions in exploitation by rod and net fisheries have also contributed. However, salmon are very vulnerable to climate change and future decline seems likely[43].
Grayling *Thymallus thymallus*			→	→	Moderate			A very difficult species to survey. Water quality is likely to be the most significant pressure[44].
Bullhead *Cottus gobio*	→				Moderate	→		Still a common and widespread species in Wales, with no evidence of decline[45].
Gwyniad *Coregonus lavaretus*	→	→	↑		Moderate	→		Only one population, in Llyn Tegid. Vulnerable to eutrophication and climate change[46].

Trend information for the Section 7 species was last produced at the UK level in the 2008 report on the UKBAP priority species, most of which align with the Section 7 list. The results revealed that less than half were measured as having stable or increasing trends (Figure 6). There have been no UK reports since that time to assess if the situation has improved or not, but data are presented in the sections below on a selection of taxonomic groups that have long-term monitoring programmes and which include many of the Section 7 species.

In addition, the State of Nature Report 2016[47] presents trend data for the Section 7 species at a Wales level.

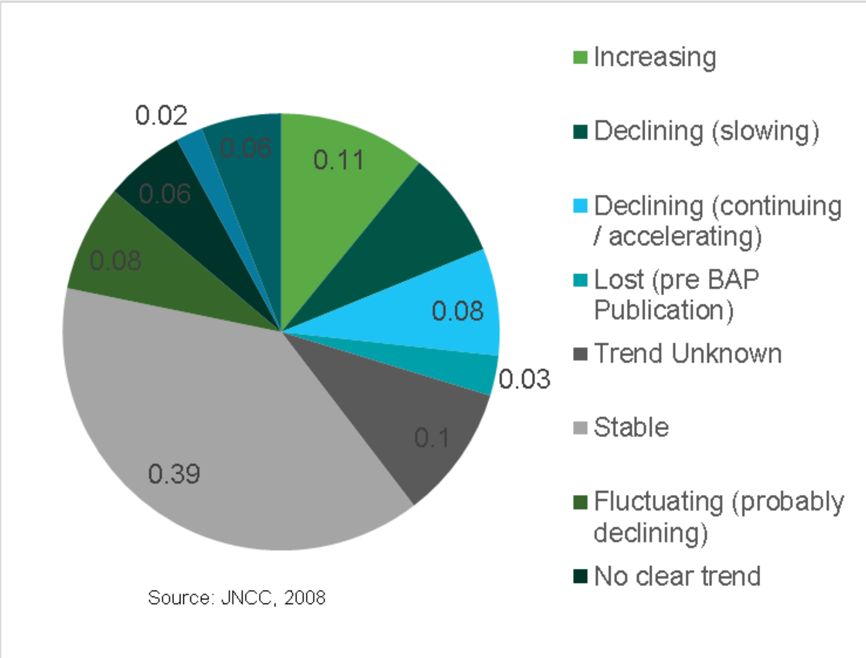

Figure 6 UK single species action plan trends[48]

Butterflies

The UK Butterfly Monitoring Scheme (UKBMS) and Butterflies for the New Millennium (BNM) provide us with robust data on the changing status and distribution of our butterfly species at the UK level, forming part of the suite of UK Biodiversity Indicators. Of the 42 species of butterfly in Wales, 16 are included in the Section 7 list of species and habitats of priority importance for biodiversity.

The latest *State of the UK's Butterflies*[49] reports on the long-term (since 1976) and 10-year analyses (2005-2014) of butterfly trends which provide further evidence of the serious, long-term and ongoing decline of UK butterflies. 70% of species are declining in occurrence (based on the BNM distribution data) and 57% declining in abundance (based on the UKBMS) since 1976.

The long-term picture is that 76% of the UK resident and regular migratory species declined in population or occurrence, or both, over the last 40 years. In contrast, 47% of the species increased in one or both of those attributes. The short-term, ten-year trends show that 47% of species decreased in occurrence and 52% of species decreased in abundance.

While this indicates a partially improving situation, the declines of some threatened species (e.g. marsh fritillary *Euphydryas aurinia*) show little signs of abating and populations of some common species (e.g. gatekeeper *Pyronia tithonus* and small skipper *Thymelicus sylvestris*) have dwindled in recent years. In contrast, species that were previously more restricted have increased, including marbled white *Melanargia galathea*.

The value of the long-term data analysis is highlighted by the continuing short-term declines exhibited in response to the recent run of poor summer weather. The combined, all-species index declined by 6%, with generally below-average populations for many species. In Wales, the specialist butterfly species showed a decline in long-term trends and wider countryside species were stable. A fuller analysis of Welsh butterfly data will be produced in due course, and the data that emerge from the co-located habitat, pollinator and bird plots of the Glastir Monitoring & Evaluation Programme (GMEP) will provide some information on the impact of habitat extent and quality on butterfly populations[50]. This project is also generating information on a range of pollinators including bees and hoverflies as well as butterflies. The mean count of total numbers of pollinators recorded between 2013 and 2015, which ranges from 138 to 193 per 1 km square, will be put into the context of habitat management condition and extent as the time series of samples extends[50].

Larger moths

There are 92 species of larger moths in Wales included in the Section 7 list of species and habitats of priority importance for biodiversity. Data on status and trends is provided by the Rothamsted Insect Survey (RIS- a national network of nightly run moth traps since 1968 in England, Scotland and Wales) which has generated around 9 million records, and the National Moth Recording Scheme (NMRS) run since 2007 with over 15 million records[51].

The scheme covers some 900 species, with thousands of active recorders, and has the potential to generate an enormous dataset of distribution. A similar scheme ran from 1967 to 1982 (organised by the Biological Records Centre) and this provides important historical data about moth distributions, against which we can assess change. More than 100 micro and macro moths have been recorded for the first time in the 20th century and a further 27 species have colonised since 2000[51].

Two thirds of 337 species of common and widespread larger moths declined over the 40 year study (1968-2007). 37% of the 337 species declined by at least 50%. One third became more abundant with 53 species (16%) more than doubling their population levels. Across the UK, the total abundance of larger moths declined significantly by 28% during the 40-year period 1968-2007. Sixty-two macro- and micro-moth species have become extinct during the 20th century and a further 4 may be extinct.

The belted beauty *Lycia zonaria* appears to have become extinct in Wales, not having been seen since 2012 at Morfa Conwy (its only station) despite dedicated habitat management and translocations to other sites[52].

Bats

The 17 bat species in the UK are all protected under the Habitats Directive and the Wildlife and Countryside Act and are listed in the Section 7 list of priority species in Wales. As such, they are some of the most highly protected species in Wales. This level of concern was prompted by the significant decline in bat species during the 1950-70s caused by direct persecution, poisoning from pesticides (e.g. wood worm treatment in roost spaces) and destruction of their roosting sites. Banning toxic chemicals and protecting bats and their roosts through legislation has resulted in population recovery for the many species that are most associated with human habitation.

The National Bat Monitoring Programme (NBMP)[53] combines data from several recording schemes; a field and waterway survey with bat detectors, hibernation surveys, and roost counts at maternity roosts. NBMP has been running since 1997 and now provides data for the UK Bat Indicator using eight bat species: lesser horseshoe bat *Rhinolophus hipposideros,* common pipistrelle *Pipistrellus pipistrellus*, soprano pipistrelle *Pipistrellus pygmaeus*, Daubenton's bat *Myotis daubentonii*, Natterer's bat *Myotis natereri*, serotine *Eptesicus serotinus*, and noctule, *Nyctalus noctula*.

The 2015 results show that all species surveyed appear to be stable or increasing, based on data from at least one of the survey methodologies. Species considered to have increased in Great Britain since the baseline year are lesser horseshoe bat, greater horseshoe bat *Rhinolophus ferrumequinum*, common pipistrelle and soprano pipistrelle. It is also possible that Natterer's bat and Daubenton's bat have increased, but the statistics from hibernation and field surveys are contradictory. Species considered to have been stable in Great Britain since the baseline year are noctule, serotine, brown long-eared bat, *Plecotus auritus* and whiskered/Brandt's bat, *Myotis mystacinus/M.brandtii*. However, sample sizes for serotine are relatively small, therefore trends for this species may be difficult to detect. No species for which population trends are available is considered to have declined significantly since the baseline year.

Dormouse

Dormice are generally a species of high quality, well managed broadleaved woodland with abundant hazel, bramble and honeysuckle and a well-structured shrub and ground layer. They hibernate and are particularly susceptible to poor weather conditions and shortages of food at crucial points in their life cycle. They are probably always a low density species. In Wales, dormice also use thick, mature hedges for breeding as well as linkages between woodland blocks, and they have been found in habitats previously considered to be atypical such as scrub and along the edges of coniferous plantations at quite high altitudes in north and west Wales.

The National Dormouse Monitoring Programme collates information on the presence of dormice in artificial nest boxes around England and Wales which are visited up to four times a year. The summary report for 2014 notes the changes in dormouse populations based on nest box surveys since 1990, with over 94,000 records[54]. Data presented for south Wales and south west England show a continued decline in the population index after some levelling out between 2001 and 2007. Individual site monitoring results indicate a mixture of increases and decreases in populations for sites across Wales over the last 14 years, with a particularly poor period between 2011 and 2013[54].

Terrestrial Birds

Terrestrial birds are one of the few species groups with a long-term robust evidence resource derived from the data collected by the British Trust for Ornithology (BTO) in its various schemes. These include the Breeding Bird Survey (BBS), the Ringing Scheme and the Nest Record Scheme (NRS). The BTO, Royal Society for the Protection of Birds (RSPB) and Wildfowl and Wetland Trust (WWT) produce the 'State of UK Birds and Birds of Conservation Concern' reports which provide the evidence and analysis of status and trends that inform the UK Bird Indicators for seabirds, woodland, wetland and farmland species groups as well as for individual species.

In addition there is a UK Migratory Bird Indicator produced for species which overwinter in different climatological zones. There are sufficient data from Wales to produce some figures at a country level which are used to inform the Welsh Government Wild Bird Indicator.

The Indicator relates to two bird population indices. The widespread breeding bird index (13 species of lowland farmland birds, 19 species of birds of farmed habitats, and 29 species of woodland birds) and a measure of long-term range change (birds of farmed habitats, woodland, urban and other). The most recent data show that yellowhammer *Emberiza citronella*, linnet *Carduelis cannabina*, starling *Sternus vulgaris*, and curlew *Numenius arquata* declined significantly in Wales between 1995 and 2010. Nine woodland species increased significantly and 2 decreased significantly, with 8 species showing no significant change[55]. Concerns over the state of UK breeding upland birds are reflected in figures for curlew (81% decline 1993-2010) and golden plover *Pluvialis apricaria* (83% decline 1982-2007) in Birds of Conservation Concern 4[56]. Wales now has the southernmost breeding population of golden plover in Europe. Other upland fringe species such as black grouse *Tetrao tetrix* have increased at some sites due to intense conservation management, but their range has continued to diminish. There is a similar story for hen harriers *Circus cyaneus*, as there has been a decline in illegal killing. Nightjar *Caprimulgus europaeus* are increasing due to clearance of mature conifer plantations, but continuous cover policy may reverse this.

Farmland bird populations in Wales are at a historic low following long-term declines across western Europe. They are now relatively stable, albeit with signs of new declines occurring over the last decade, especially among lowland species (Figure 7). Reasons for the recent changes have not been established, but they suggest that large-scale agri-environment uptakes have failed to deliver the intended increases. Mean count of total numbers of pollinators (butterflies, bees and hoverflies) ranged from 138-193 per 1km^2 between 2013 and 2015[50]. These numbers are likely to reflect annual variation in weather and any directional relationship with management including hedgerow extent or condition or other factors will become clearer as the time series is extended[50].

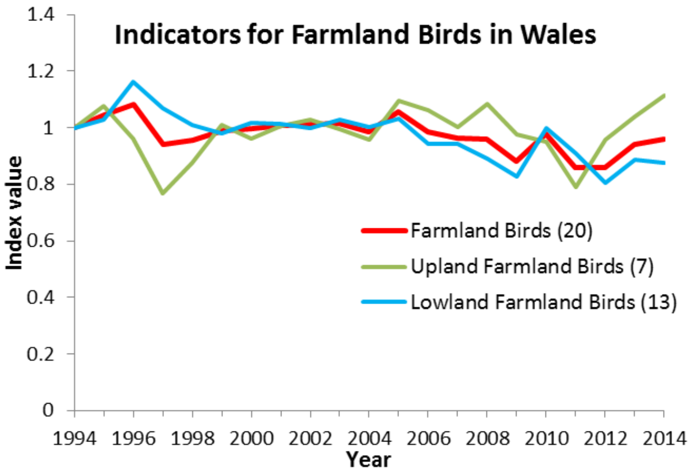

Figure 7 Summary indicator trends for farmland birds in Wales, derived from the BTO/JNCC/RSPB Breeding Bird Survey, both combined and divided into lowland and upland species (BBS 2016)[57],[50].

Seabirds

Wales' rocky coastline and numerous islands provide important habitat for a number of seabird species, with 20 species commonly found in Wales[58] (Table 4). The population trends of these species in the UK and Wales are summarised in the Joint Nature Conservation Committee (JNCC) Seabird Monitoring Programme[59].

Auk species (guillemot, razorbill and puffin) have shown an increase in Wales, however, puffin are a red listed species in the UK[56] and assessed as Vulnerable on the international red list[60]. These assessments are mainly due to a massive decrease in the puffin population in Iceland, where about half of the global population lives, rather than any particular reflection of status in Welsh waters.

Wales has two internationally important sites for red-throated diver *Gavia stellata*, and common scoter *Melanitta nigra*; Carmarthen Bay Special Protection Area (SPA) and Liverpool Bay SPA.

Skokholm and Skomer SPA holds approximately 316,000 breeding pairs of Manx shearwater[61] representing over 50% of the global population, so it is imperative that the islands remain free from rats and other mammalian predators.

Kittiwake, fulmar and shag have all decreased in Wales during the period 2000-2014 and these decreases are mirrored across the UK. This is most probably due to a decrease in productivity relating to declines in the abundance of sand eel prey, potentially due to climate effects.

Table 4 Percentage decrease or increase in UK and Welsh seabirds

Species	UK population change 2000-2014	Wales population change 2000-2014
Guillemot *Uria aalge*	+22%	+69%
Razorbill *Alca torda*	+6%	+80%
Puffin *Fratercula arctica**	-	+62%
Black guillemot *Cepphus grille*	-	-
Gannet *Morus bassanus*	-	+17%
Common tern *Sterna hirundo*	-20%	+20%
Arctic tern *Sterna paradisaea*	+34%	+108%
Sandwich tern *Halasseus sandvicensis*	-3%	+470%
Roseate tern *Sterna dougallii**	+127%	0
Little tern *Sternula albifrons*	-9%	+72%
Kittiwake *Rissa tridactyla**	-47%	-41%
Fulmar *Fulmarus glacialis*	-18%	-16%
Greater black backed gull *Larus marinus*	-6%	+60%
Lesser black backed gull *Larus fuscus*	-41%	-35%
Herring gull *Larus argentatus**	-17%	-13%
Black-headed gull *Chroicocephalus ridibundus*	+102%	-
Cormorant *Phalacrocorax carbo*	-12%	+15%
Shag *Phalacrocorax aristotelis**	-38%	-24%
Manx shearwater *Puffinus puffinus*	-	-
Storm petrel *Hydrobates pelagicus*	-	-

- denotes insufficient data
* denotes red-listed species in the Birds of Conservation Concern 4 report[58].
UK data are taken directly from the *Seabird Population Trends and Causes of Change: 1986-2014 Report*[58]. Welsh data is compiled from the JNCC Seabird Monitoring Programme[59]

Waterbirds

Many species and populations of waterbirds take advantage of the UK's wetland habitats and relatively mild winter climate. Welsh estuaries are hugely important for non-breeding waterbirds. In colder winters an increased number of birds will seek refuge in Wales and elsewhere in the UK. Milder weather conditions may affect migration distance. Birds responding to changing weather conditions is resulting in a shift of wintering ranges. This shift is referred to as ‘short-stopping’.

Data in Table 5 analysed from the latest Wetland Birds Survey (WeBS)[62] show that, in Wales, a number of waterbirds that are of international and national importance show mixed fortunes. Over the last 15 years, 9 species have declined and 10 species increased[63].

Table 5 Trends (% changes) for a selection of wildfowl and wader species

Species	Wales population 25 year change (1989/94 - 2009/14; 5 year peak mean)	Wales population 15 year % change (1999/00 - 2009/14; 5 year peak mean)	Population status[55]
Wintering wader species			
Oystercatcher *Haematopus ostralegus*	1	7	
Curlew *Numenius arquata*	-14	-5	
Dunlin *Calidris alpina*	-35	-25	
Knot *Calidris canutus*	2	1	
Redshank *Tringa tetanus*	21	12	
Grey plover *Pluvialis squatarola*	-29	-9	
Bar-tailed godwit *Limosa lapponica*	-36	-63	
Black-tailed godwit *Limosa limosa*	15	71	
Wintering wildfowl species			
European white fronted goose† *Anser albifrons albifrons*	-86	-66	
Greenland white fronted goose *Anser albifrons flavirostris*	-57	-55	
Bewicks swan† *Cygnus columbianus*	-17	-21	
Shelduck *Tadorna tadorna*	13	-5	
Pintail *Anas acuta*	-43	-35	
Shoveler *Anas clypeata*	215	10	
Wigeon *Anas penelope*	39	3.6	
Teal *Anas crecca*	22	9	
Gadwall *Anas strepera*	n/a	n/a	
Great crested grebe *Podiceps cristatus*	>600	198	

† These species winter almost exclusively on the English part of the Severn Estuary SPA. Data derived from WeBS counts[63].

Freshwater fish

Trends in population data for juvenile Atlantic salmon *Salmo salar* and brown/sea trout *Salmo trutta* can be assessed using a Bayesian statistical model. The data were analysed using a linear model which fits a straight line to the data in order to determine whether a trend (upwards or downwards) is present in fish numbers over the timeframe.

Data have been analysed for the period 2005 to 2014, which represents the period for which the surveys have been standardised and undertaken every year. Figure 8 and Figure 9 below display trends in juvenile fish numbers over this period (note log scale).

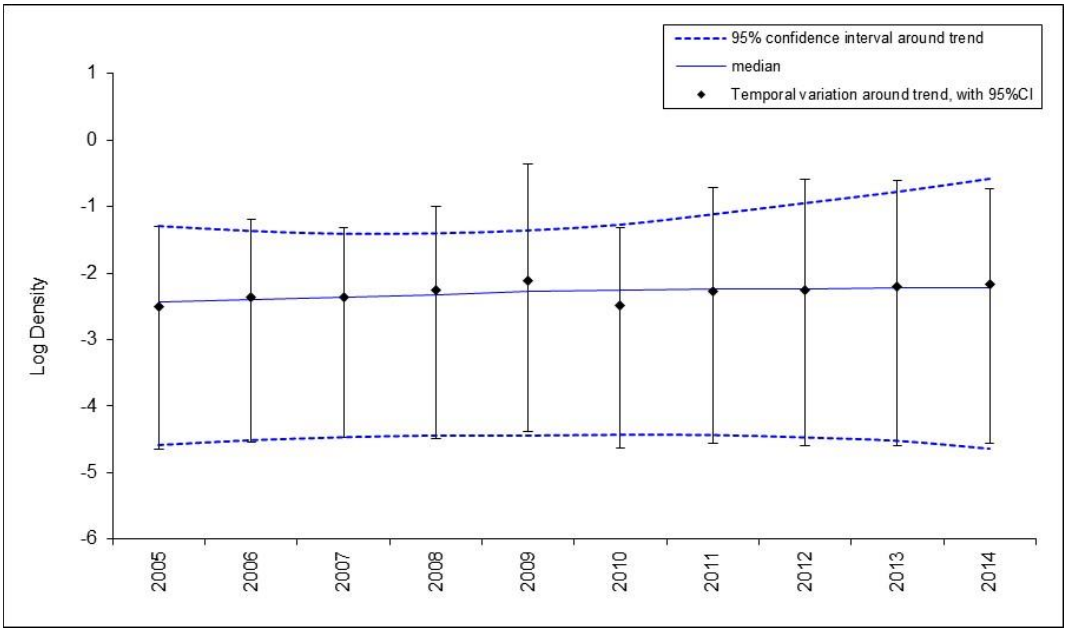

Figure 8 Juvenile salmon *Salmo salar* density on the Afon Dyfi[13].

The data (Figure 8) show that the trend for juvenile salmon has remained stable since 2005 on the Dyfi, with no significant increase or decrease trend (P = 0.6). This site has a steady population of juvenile salmon, which is excellent when considering the poor salmon runs which have been seen across the UK in 2013.

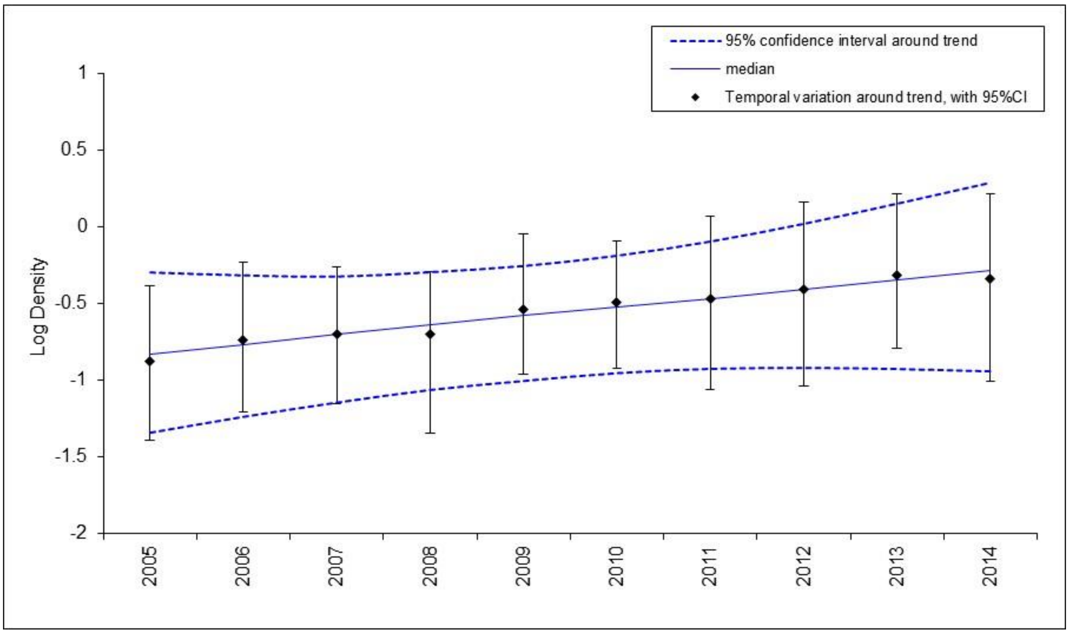

Figure 9 Juvenile brown/sea trout *Salmo trutta* density on the Afon Dyfi[13].

Similarly, although there is an apparent improvement in the trends for juvenile trout populations on the Dyfi since 2005 (Figure 9), the result is not significant (P = 0.9), but it follows a general improvement in sea trout catches throughout the country.

Fin fish and elasmobranchs

Estimating trends is problematic due to the scale of fisheries assessments and the lack of data for many species. Broadly speaking, Welsh landings of fish species have declined over the years due to reductions in fishing opportunities and, additionally, larger vessels have left the fleet as a result of decommissioning. Recreational fishing also impacts fish stocks but assessing the catch and effort of this activity is very difficult. Member states have statutory data collection duties under the DCF to collect data on recreational fishing. This data is valuable in order to obtain an accurate assessment of the overall fishing mortality of a particular stock or species. CEFAS are collecting this data on behalf of Welsh Government. The European Commission recognise the impact that recreational fishing can have on a species and have introduced more stringent management measures as a result[64].

Looking ahead, one of the main objectives of the reformed (2013) CFP is that all species will be managed to Maximum Sustainable Yield. This is a phased process and the target is to manage all commercial TAC and quota fish species to MSY by 2020.

Shellfish

In the absence of accurate assessments of shellfish stocks, landings data can provide some insight into recent trends (Table 6). However, the data is subjective as it does not give an indication of fishing effort. In addition, the impact of recreational fishers' catch and effort is also unknown.

Table 6 Weight and value of shellfish landings into Welsh ports from 2010 to 2014

Species	Quantity (1000 tonnes)					Value (£ million)				
	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014
Crabs	1.1	1	1	0.8	0.6	1.4	1.3	1.2	0.9	0.6
Lobsters	0.2	0.2	0.2	0.2	0.2	2.3	2.2	2.2	1.6	1.8
Scallops	3.5	4.3	5.9	5.5	3.6	4.1	5	7.6	5	3.6
Whelks	5	3.8	4.6	5	4.4	3.3	2.5	3.1	3.6	3.6
Shrimps and prawns						0.1				
Other shellfish	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.5	0.5	0.5
Total shellfish	10	9.4	11.9	11.6	9†	11.6	11.4	14.8	11.6	10.3

All data from MMO fisheries statistics[65].
† Impacted by winter storms 2014.

Mussel production in 2012 was 8,999 tonnes and valued at £9 million, constituting 33% of the total UK shellfish aquaculture production by weight and 27% by value. This production exceeded that of 2010 and 2011 but is broadly in line with previous years' production levels in excess of 8,000 tonnes. Cockle landings have fluctuated since the mass mortalities began in 2002, with recorded landings at Burry Inlet declining from an average of 2,901 tonnes per year between 1987 and 2001 (pre-mortality) to 1,162 tonnes per year between 2002 and 2014. Landings from the Three Rivers averaged 857 tonnes per year between 1987 and 2004, and 1,155 tonnes from 2005 to 2014.

3.2. Air Quality

The quality of air in Wales has greatly improved since the 1970s, with statutory emission control and a decreasing industrial base leading to a reduction in industrial emissions. However, the nature of air pollution has changed: in 2010 the UK Environment Audit Committee (EAC)[66] reported that many parts of the UK (including Wales) were continuing to breach the mandatory targets for nitrogen dioxide (NO_2) and particulate matter[67], concluding that air quality still poses a major threat to human health and the natural environment. In February 2016 it was reported that poor air quality in the UK is attributable for an additional 40,000 deaths per annum. These costs add up to £20 billion a year[68].

Extent and Condition

The seven pollutants discussed are the most common pollutants encountered and therefore have the greatest impact on human health and the environment. Legislative drivers to monitor these pollutants (Air Quality Standards Regulations[69] and the Local Air Quality Management regime under the Environment Act 1995[70] result in a great deal of information being available as compared to other pollutants which are encountered less often.

There are around forty Local Air Quality Management Areas in Wales (one for PM_{10} and the rest for NO_2)[71] where air quality objective are not being achieved or are likely not to be achieved.The location of the air quality monitors and current pollution levels can be found on the website for Air Quality in Wales[72].

Primary particulate matter
Primary particles are those emitted directly from a source. They include particles that arise directly from combustion sources such as road vehicles and large industry, as well as those generated by mechanical processes. Particulate matter is measured as PM_{10} (larger particles) and $PM_{2.5}$ (fine particles), the finer particles being more hazardous to health.

The total emissions of PM_{10} for 2013 for Wales was 11,000 tonnes. Residential sources in Wales contributed 30% of total PM_{10} emissions[67], with iron and steel production producing 14%, agriculture 11%, road transport 11% and electricity production and oil refining industries a further 11%.The remainder comes from a variety of small sources. Overall mean pollutant (PM_{10}) concentrations in Cardiff Centre have decreased from nearly 40 $\mu g/m^3$ in 1992 to below 20 $\mu g/m^3$ in 2014 (Figure 10). PM_{10} concentrations have been monitored extensively and are well understood.

No figures for the smaller fractions exist due to limited legislative drivers to measure $PM_{2.5}$ emissions in the past. There is now an air quality limit for $PM_{2.5}$ and monitoring has begun at several locations in Wales. As monitoring for this increases, it is likely to show that action will be needed to reduce secondary formation of particles. This will be challenging due to the complex formation pathways.

Secondary particulate matter
One example of secondary particulate matter formation is through interactions between ammonium nitrate from livestock farming and other pollutants. As agriculture is the dominant source of ammonia emissions, tackling rural sources of ammonia will help address the human health impacts of particulates in urban environments[73].

Bioaerosols are particles of biological origin, such as bacteria, fungi and plant fibres, also known as organic dust. They are often found in confined buildings e.g. poultry sheds. Recent interest in bioaerosols has largely been due to the recognition that exposure to biological agents in both occupational and residential indoor environments is associated with a wide range of adverse health effects.

Secondary particles are not emitted directly from sources. Chemical interactions in the atmosphere lead to the formation of substances which condense into the solid or liquid phase, becoming particulate matter (PM). These reactions mainly involve sulphur dioxide (SO_2), nitrogen oxides (NOx), ammonium gas and Volatile Organic Compounds (VOC).

Agriculture is a significant source of precursors for the secondary formation of particulate matter[68]. Whilst both red meat production and poultry production show no significant long-term trend in increased production[74] there are concentrations of activity in some areas, such as dairy farming in Pembrokeshire and Carmarthenshire and poultry production in Powys and Anglesey. This concentration could result in local air quality pressure.

Any increase in the number or concentration of composting or intensive farming activities around human habitation could increase the risk of adverse health impacts from bioaerosols[75].

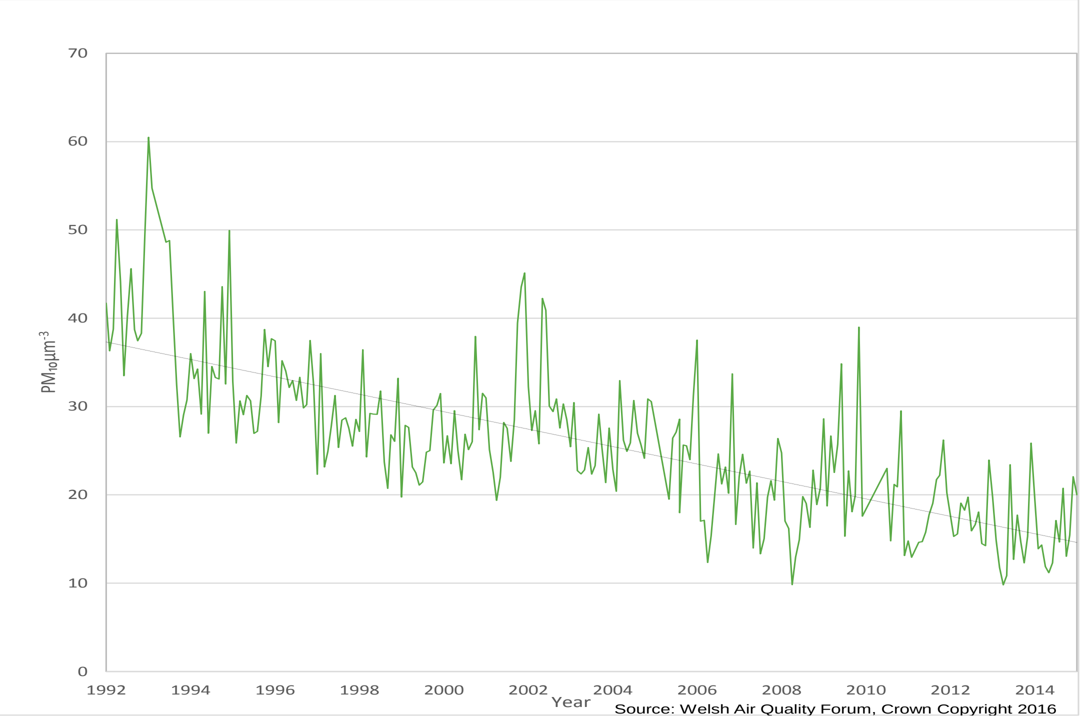

Figure 10 Reduction in PM_{10} Pollution Trends in Cardiff Centre since 1992, produced by calculating monthly mean values from daily and hourly higher time resolution data[76].

Nitrogen oxides

Nitric oxide (NO) and nitrogen dioxide (NO_2) are known as nitrogen oxides (NO_x) because they are rapidly inter-converted during the day. NO_2 is split by UV light to produce NO and an oxygen (O) atom, which combines with molecular oxygen (O_2) to produce ozone (O_3). During the day, therefore, NO, NO_2 and ozone exist in a quasi-equilibrium which depends on the amount of sunlight. Eventually NO_2 is oxidised to nitric acid (HNO_3) vapour which is absorbed directly at ground level and is converted into nitrate-containing particles, or dissolves in cloud droplets.

At night, different oxidation processes convert NO_2 to nitrates. Nitric acid is absorbed on contact with surfaces (e.g. cloud droplets, soil, vegetation) but other nitrogen oxides are removed slowly and may travel hundreds of kilometres before converting to nitric acid or nitrates and deposited. The UK exports about three-quarters of its emissions of NO_x[77].

Emissions of NO_x have declined by 48% since 1990, mainly due to the fitting of three-way catalysts in road transport vehicles. The decrease in nitrogen dioxide has slowed down and recent figures (2012-2013)[67] show a slight increase due to the increase in coal-fired power generation. This increase should not be significant in the long term.

The total emissions of nitrogen oxides (NO_x) for Wales in 2013 was 91,000 tonnes from all sources. This was 9% of the UK total[67].

The highest concentrations of NO_2 are in large urban areas and adjacent to the motorway network, reflecting the contribution traffic and urban activity make to poor air quality. Typical annual mean concentrations in these areas can be in excess of 19 $\mu g/m^3$ NO_2 (roughly equating to 10 ppb)[78]. The annual mean limit for NO_2[79], to protect human health, is 40 $\mu g/m^3$ and this was exceeded at five roadside locations in Wales in 2015[80].

Sulphur dioxide

Sulphur dioxide (SO_2 expressed as SO_x) has long been recognised as a pollutant because of its role, along with particulate matter, in forming winter-time smog. Studies indicate that SO_2 causes nerve stimulation in the lining of the nose and throat leading to irritation, coughing and a feeling of chest tightness, which may cause the airways to narrow.

The UK is currently on track to meet the Gothenburg Protocol target in 2020. Emissions will need to be reduced by a further 26% of the 2013 emission total to meet this target[81].

Since 1970, SO_2 emissions have declined by 94%. In 2013, Wales SO_2 emissions were 39,000 tonnes (10% of the UK total). Over 80% of the reduction seen since 1990 (Figure 11) is due to reductions from heavy industry and the fitting of Flue Gas Desulphurisation (FGD) equipment at Coal fired power stations[67].

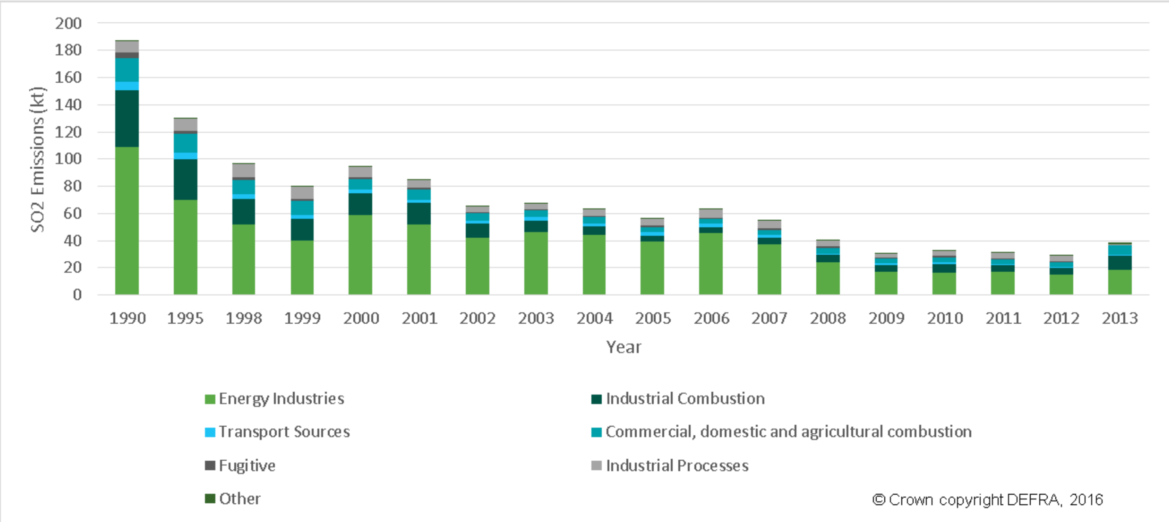

Figure 11 Wales Sulphur Dioxide (SO_2) Emissions by Source Sector[67]

Fuel combustion accounted for more than 83% of Wales SO_2 emissions in 2013. The main source was the combustion of solid fuel, which has a high sulphur content compared to other fuels. The introduction of low sulphur fuels for vehicle use has reduced the amount of SO_2 in the urban environment[67].

CASE STUDY

Reducing SO_2 emissions aids recovery of sausage beard lichen

The spectacular sausage beard lichen *Usnea articulata* was lost from mid Wales by the early 20th century and was then only found at fewer than 15 sites in Pembrokeshire and Gower. Over the last 10 years we have discovered more than 90 new populations, in Pembrokeshire, Carmarthenshire, Ceredigion, Breconshire and Glamorgan. They extend as far east as the Onllwyn and Merthyr Tydfil areas, where historic pollution would have meant that very few lichens could grow at all, and have also been noted on the coalfield between Llanelli and Cross Hands. Most of these new records have been made by observant NRW staff going about their daily business, rather than targeted surveys. It is thought that slightly reduced SO_2 pollution in Pembrokeshire allowed the remaining colonies to bulk-up and begin sending aerial fragments eastwards to colonise other parts of South Wales. The now cleaner air in these other areas has allowed the lichen to survive and then spread onwards.

The main industrial sources of SO_2 emissions in Wales are split between four sectors, with 26% coming from oil refining[a], 20% from electricity production for residential purposes, 19% from iron and steel production and 17% from residential sources[67].

The increases between 2012 and 2013 were due to increased coal burning at power stations and increased iron and steel production. The downturn in the iron and steel industry, the closure of an oil refinery and the UK government’s policy of phasing out coal fired power stations, will mean a decrease in these emissions over time.

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[a] These are based on 2013 figures: the picture has now changed as a result of the closure of anoil refinery.

Additional treatment of gases rich in sulphur (sour gases) and the introduction of new limits on sulphur emissions in 2016 at an oil refinery will also result in a decrease in the overall emissions in Wales.

Ecosystem impacts of Nitrogen and acid air pollution

When the amount of atmospheric deposition of these pollutants exceeds the critical loads, it is considered that there is a risk of harmful effects to sensitive receptors such as habitats or plants. Approximately 7,800km^2 of habitats in Wales are considered to be sensitive to acid deposition, and 6,800km^2 sensitive to nitrogen deposition (eutrophication), with much of this area sensitive to both.

The excess deposition above the critical load is referred to as the *exceedance*. Decreasing pollutant deposition below the critical load is seen as a means of preventing the risk of damage. Where exceedance remains, reductions in the magnitude of exceedance may also benefit sensitive habitats and could favour some species to return, especially those where conditions are only just unsuitable. Atmospheric Nitrogen deposition at or just below critical loads may combine with terrestrial sources (e.g. from diffuse water pollution) to cause significant enrichment impacts.

The biggest adverse effect of NO_x emissions on ecosystems is through their contribution to total nitrogen deposition[78]. Vulnerable habitats include upland heath and grassland, woodland, freshwater wetlands, mountain, moorland and heaths, and coastal margins. Direct effects of gaseous NO_x may also have a negative impact in areas close to sources (e.g. roadside verges).

Evidence from monitoring to date shows that emissions of SO_2 from Wales' largest emitters is not having an adverse effect[82]. This is due to dispersion characteristics and subsequent low ground level concentrations. The role of SO_2 in secondary particulate formation and the contribution to acid rain means that continued reductions are desirable and are driven by the implementation of the Industrial Emissions Directive[83].

The critical level for all vegetation types from the effects of NO_x has been set to 30 µg/m^3. There is substantial evidence to suggest that the effects of NO_2 are much more likely to be negative in the presence of equivalent concentrations of SO_2, thus lowering SO_2 emissions from all sources remains important.

In Wales, the area of habitats with exceedance of critical loads for eutrophication has decreased by less than 10% (98% to 90.3%) between 1995 and 2013, but the magnitude of the average exceedance has declined by 44%, from 15.8 kg N ha^{-1} year^{-1} in 1995 to 8.9 kg N ha^{-1} year^{-1} in 2013[84].

In Wales, the percentage area of habitats with exceedance of acidity critical loads (see NO_x) has decreased from 90% in 1995 to 74% in 2013. Over the same time period the magnitude of the average acidity exceedance has reduced by 65% (from 1.36 keq ha^{-1} year^{-1} to 0.45 keq ha^{-1} year^{-1} [84].

Future reporting
New critical loads are currently being developed. Aiming to prevent biodiversity declining below a defined critical threshold, they will have considerable potential for application at the national, regional and site-specific scales. Using site-specific data would allow determination of which species are most at risk at a particular site, and assessment of the possibility of mitigating some of the effects of nitrogen pollution through appropriate management. Critical loads and exceedances based on this biodiversity metric will provide a more realistic assessment of the combined effects of nitrogen and sulphur on biodiversity in UK habitats or designated sites.

Ammonia
Ammonia (NH_3) contributes to a number of different environmental issues including acidification, nitrification and eutrophication. It also acts as a precursor to secondary particulate matter, therefore contributing to health impacts. The atmospheric chemistry of NH_3 means that it can react with other chemicals to produce particles which can be removed from the atmosphere by rain, or to produce other ammonium compounds, which can be transported long distances. As a result, NH_3 emissions can impact at a highly localised level, as well as contributing to effects from long-range pollutant transport[77].

Although emissions of ammonia have declined by 21% since 1990 (Figure 12), it remains an issue. The level has plateaued in recent years and is expected to rise slightly in future. In 2013 25,000 tonnes of ammonia was released in Wales, with 84% of this from agricultural sources.

The biggest single contributor of ammonia from agriculture is manure management. The application of manure to land contributed 77% of the total agricultural ammonia release in 2013[67]. Cattle farming (dairy and non-dairy) is the dominant agricultural contributor.

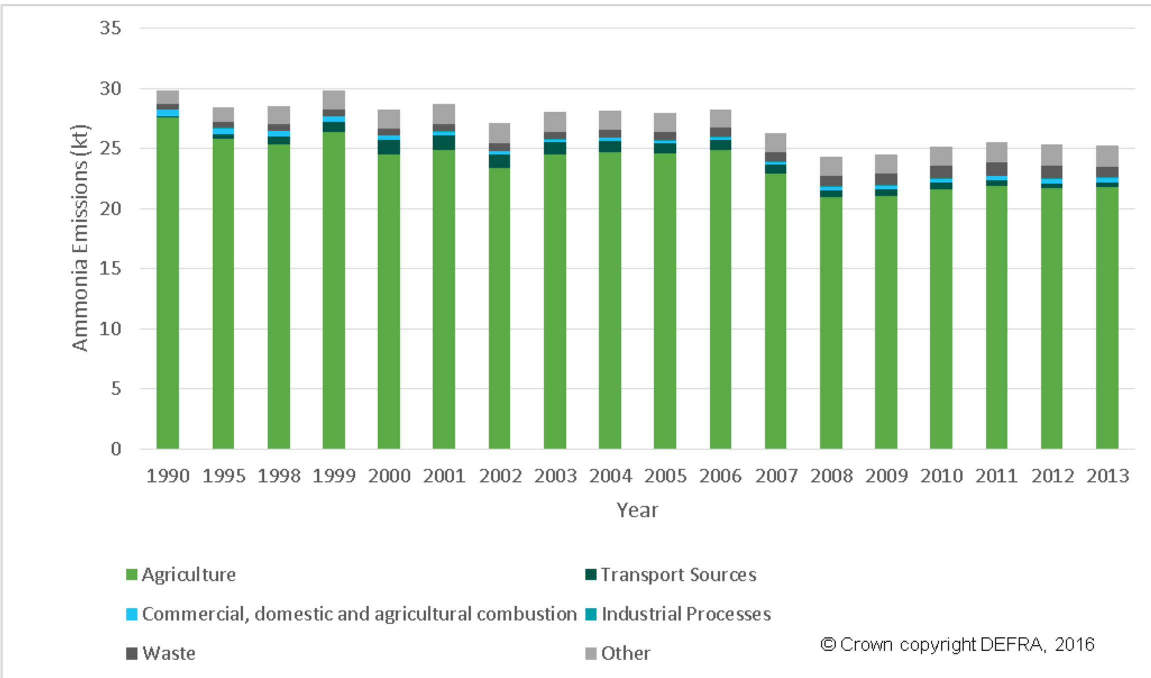

Figure 12 Wales Ammonia (NH_3) Emissions by Source Sector[67]

Ozone
Many of the precursor gases that lead to ozone formation are released in urban areas, e.g. from vehicle and industrial pollutants such as nitrogen dioxide. Ironically, ozone concentrations are generally much lower in the urban environment, with the maximum concentrations present in rural areas due to the reaction with sunlight.

Three sites in Wales exceed the Air Quality Standards[79] objective for ozone (daily mean 100 µg/m^{-3} on more than 10 occasions).

Ozone (O_3) is a secondary pollutant (i.e. it is not directly emitted into the atmosphere). It forms when sunlight reacts with other pollutants such as oxides of nitrogen and volatile organic compounds (VOCs). At high concentrations ozone impacts upon human health by adversely affecting lung function and respiration. It also directly damages crops and reduces yield, and degrades a number of building materials. It has damaging impacts upon many plant communities. The critical thresholds of ozone for effects on crops, forests and semi-natural vegetation are widely exceeded across the UK[77].

Peak ozone concentrations have declined over the past 30 years[77]. However, over the same period, background concentrations have been steadily increasing across northern Europe by about 0.2 µg/m^3 annually[77].

Concentrations can vary widely from year to year depending on environmental conditions. In the stable, high pressure conditions of summer 2003 concentrations were very high[77]but in cool, wet and windy summers concentrations are much lower. There has also been a slight seasonal shift in the ozone climate which has seen summer peaks reduce but winter and spring concentrations increase[77]. The daily ozone climate in Wales is also affected by altitude. In lowland areas there is a marked diurnal pattern with highest concentrations building during the day but dropping away at night. In upland areas, such as Snowdonia, concentrations are much more stable day and night.

CASE STUDY
Ozone, the Dr Jekyll and Mr Hyde of pollutants – 'Good Guy/Bad Guy'

Ozone is found in two main zones around our planet. In the stratosphere (above cloud level) it provides a shield that blocks harmful UV rays (the 'good guy'). In the troposphere (the lowest atmospheric level, generally below the tops of clouds down to ground level), ozone causes all the issues discussed above – damaging plants and buildings etc. (the 'bad guy').

During the 1980s and 1990s there was a lot of concern about stratospheric ozone depletion ('the ozone hole'). There is now evidence that this is repairing due to the banning of certain chemicals such as chlorofluorocarbons (CFCs). Unfortunately, evidence is also emerging that the chemicals used to replace CFCs, hydrofluorocarbons (HFCs), also have a deleterious effect on stratospheric ozone, and are a greenhouse gas. NASA have estimated that by 2050 HFCs may contribute as much as 20% of what CO_2 contributes to global warming.

There is increasing interest in the role that ozone plays in affecting climate change. Ozone's impact on climate is mainly related to temperature: the more ozone in a given volume of air, the more heat it can retain. Therefore, the more ozone in the troposphere, the warmer it can get, thus ground level emissions of ozone contribute to climate change.

Non-methane volatile organic compounds

Some organic compounds can differ widely in their chemical composition but are often grouped under the label of Non-methane volatile organic compounds (NMVOCs) as the majority display similar behaviour in the atmosphere. NMVOCs are emitted to air as combustion products, as vapour arising from petrol and solvent use, and from numerous other sources. Interest in NMVOC emissions has grown as their role in the photochemical production of ozone has been appreciated. The diversity of processes which emit NMVOCs is huge, covering not only many branches of industry, but also transport, agriculture and domestic sources[85].

The two largest sources of NMVOC emissions in Wales (Figure 13) are the use of solvents and other product use (43% of 2013 emissions), and extraction and distribution of fossil fuels (18% of 2013 emissions). 13% of the NMVOC emissions arise from combustion sources, the most significant of which is road transport. Natural emissions of NMVOCs are not included in the UK emission figures. Total VOC emissions for Wales in 2013 was 48,700 tonnes[67].

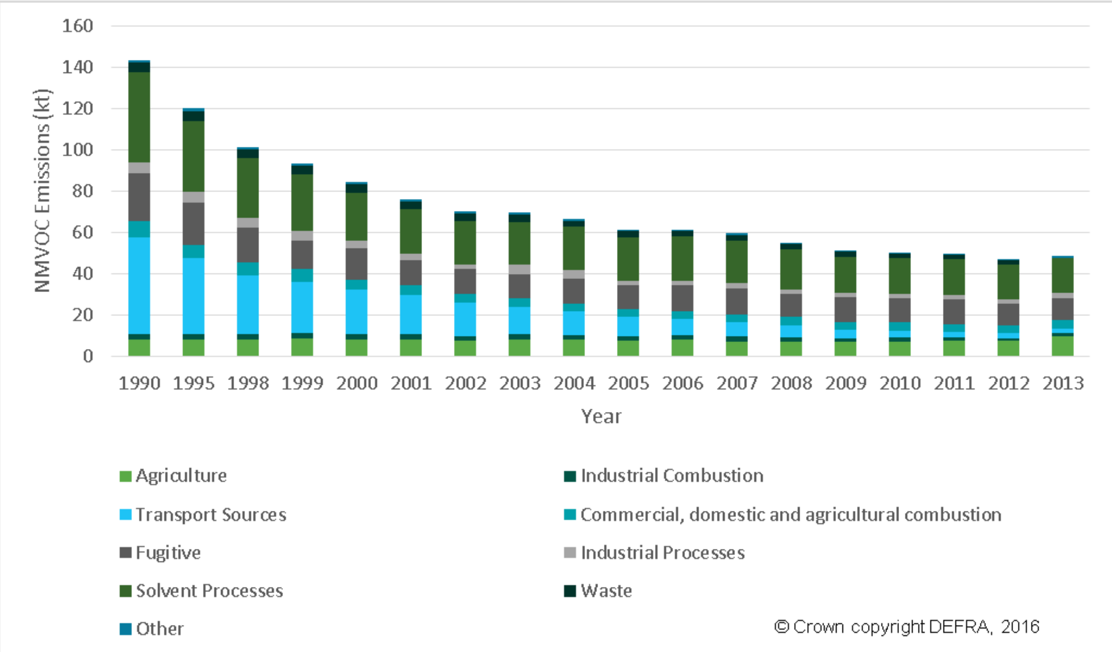

Figure 13 Wales Emissions of Non-Methyl Volatile Organic Compounds by source sector[67]

Carbon monoxide

Carbon monoxide (CO) arises from incomplete fuel-combustion and is of concern mainly because of its effect on human health and its role in ozone formation in the Earth's lower atmosphere. It leads to a decreased uptake of oxygen by the lungs and can lead to a range of symptoms as the concentration increases. Road transport, in particular vehicles with petrol engines, is the largest source of carbon monoxide emissions, although domestic fires, the iron and steel sector, and industrial fuel combustion are also significant[77].

Since 1970 combustion-related emissions from the domestic and industrial sectors have decreased by 90% and 49% respectively due to the decline in the use of solid fuels in favour of gas and electricity[67]. The banning of stubble burning[86] in 1993 in England and Wales caused a sudden decline in emissions from the agricultural sector. Over the period 1970-2013, emissions have decreased by 79%.

Emissions from road transport decreased by 91% between 1990 and 2013 as a result of EU-wide emission standards (Figure 14). Road transport contributed around 70% of carbon monoxide emissions in 1990 compared to less than 30% in 2013[67].

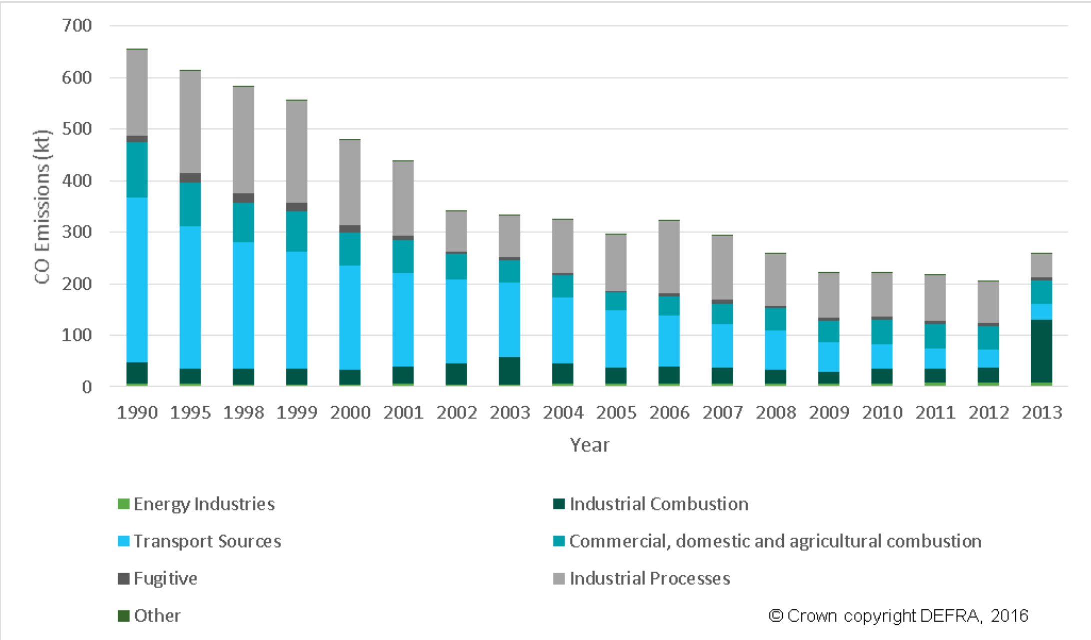

Figure 14 Wales Emissions of Carbon Monoxide by source sector[67]

In 2013, 260 kilo tonnes of carbon monoxide were released in Wales mainly from industrial, domestic and transport sources. There are no direct health effects from carbon monoxide at the background concentrations found currently in Wales[67] although, being an ozone precursor, there are secondary impacts from its release.

Lead

Exposure to high levels of lead concentrations in ambient air may result in toxic biochemical effects on humans (e.g. adverse effects on the kidneys, gastrointestinal tract, the joints and reproductive systems, and acute or chronic damage to the nervous system), as well as affecting intellectual development in young children. Emissions of lead have declined by 90% since 1990 (Figure 15). In 2013, the amount of Lead released in Wales was around 0.01 tonnes[67].

Leaded fuel was totally phased out at the end of 1999, so industrial processes (in particular the combustion of coal, and production of iron, steel and nonferrous metals) now account for the vast majority of lead emissions in Wales (81% in 2013)[67]. Regulating lead emissions from industrial sources, to meet the current legislative requirements, will help improve human health and ecosystems.

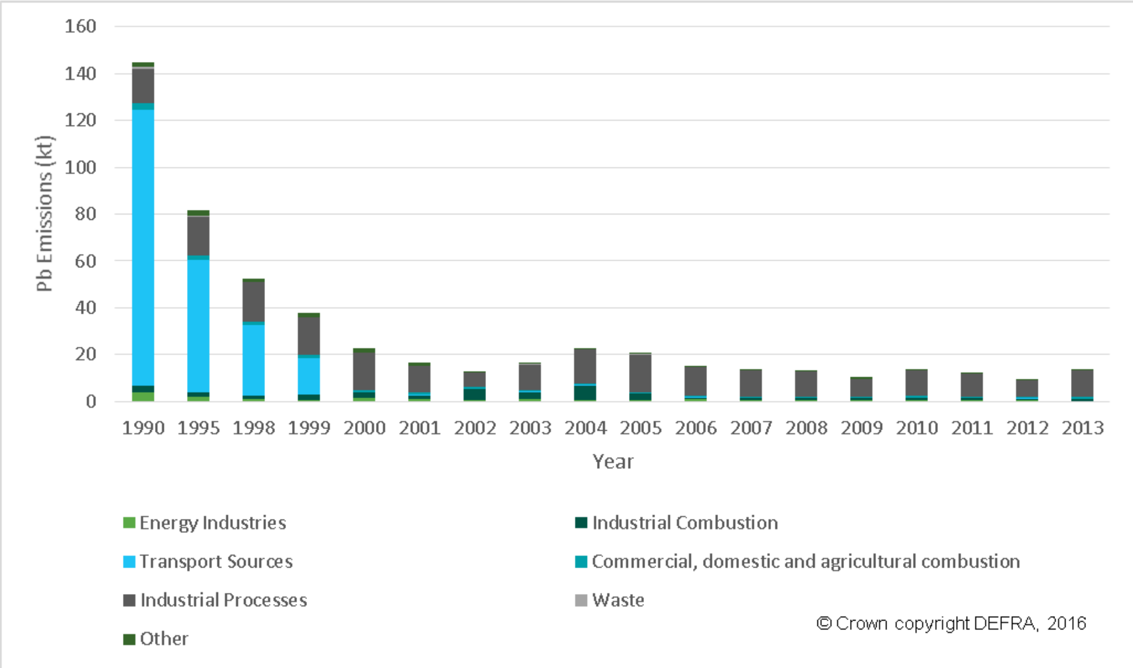

Figure 15 Welsh Emissions of Lead in air[67]

Concentrations of lead rose between 2012 and 2013 in Wales, although the quantity of lead released to the atmosphere is now less than 100 kg a year in Wales and is not thought to be an issue in general terms. A study carried out in 2012[87] showed that even at sites surrounding large industrial complexes concentrations were well below the required values[79].

Dioxins and furans

Dioxins (polychlorinated dibenzo-p-dioxins) and furans (polychlorinated dibenzofurans) are often simply referred to as 'dioxins'. They are a type of toxic organic micro-pollutant, and are mainly produced as by-products of industrial processes, but can also result from natural processes such as volcanic eruptions and forest fires. They are formed due to incomplete combustion. Dioxins can arise from any thermal process where chlorine is present in any form. Emissions of dioxins have declined by 83% over the period 1990 to 2013[67]. The main sources of dioxins in 2013 were domestic combustion of coal and wood, steelmaking, and the small scale burning of waste material, e.g. on garden bonfires. There may be increased amounts if there are large increases in the use of domestic burners and illegal waste burning[68].

One of the largest sources of dioxins emissions in the past has been waste incineration. However, emissions from this source have fallen by 97% between 1990 and 2013, driven by the introduction of emission limit values and other control standards. Municipal Solid Waste (MSW) incinerators not meeting these requirements closed in the period leading up to December 1996, and emissions from the sector were significantly reduced from then on. Emissions from plants burning MSW or incinerating other wastes contributed less than 2% of UK dioxin emissions in 2013.

Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are a large group of persistent, organic compounds that accumulate in people and animals and which have toxic and carcinogenic effects. Lung cancer is most obviously linked to exposure to PAHs through inhaled air[68]. These pollutants can bio-accumulate and be passed up the food chain, thus having health impacts as well as environmental impacts.

Benzene [a] Pyrene (B[a]P), a by-product of incomplete combustion, is used as a 'marker' for PAHs. The main sources of emissions of B[a]P in the UK are from domestic coal and wood burning, industrial processes (e.g. coke production) and fires (e.g. accidental, bonfires etc.)[77].

In 2013, an exceedance was reported in the South Wales Zone[b]. The level of 1 ng/m^3 of ambient air was exceeded due to domestic sources at one location (coal burning) and industrial emissions at another. Further detailed modelling was able to show that for the main source of B[a]P, an exceedance of the air quality standard was unlikely[88].

Nickel

Inhalation of nickel can cause irritation to the nose and sinuses and can also lead to the loss of sense of smell. Long-term exposure may lead to asthma or other respiratory diseases. Cancer of the lungs, nose and sinuses as well as the larynx and stomach has been attributed to exposure to nickel[77].

Emissions of nickel have declined by 57% since 1990. In 2013, two zones in Wales were reporting exceedances (the only UK exceedances). Both zones are affected by the same sources. . The implication of this finding is that many small manufacturers using nickel could be contributing to poor air quality; however, without local monitoring it is unlikely to be noticed[89].

Radioactivity

Radioactivity enters the environment (both air and water) from natural sources and industrial processes (Figure 16). Regulated, routine discharges of small quantities of radioactive waste to the air from industrial sources are made from a range of nuclear (most commonly power stations) and non-nuclear[c] facilities in the UK. Wales has three nuclear sites and a number of non-nuclear facilities, predominantly in the medical sector, that use radioactive materials and dispose of radioactive wastes. These are regulated by the environment agencies, including NRW, for activities in Wales.

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[b] For the purpose of EU compliance reporting against EU Directive 2004/107/EC, the UK is divided into 43 zones termed agglomeration (large urban areas) and non-agglomeration zones. In 2013 two of the 43 zones in the UK were reported to have exceeded the target value for nickel (one agglomeration and one non-agglomeration zone). The affected zones were Swansea Urban Area (AZ) and South Wales (Non AZ).

[c] 'Nuclear' relates to sites with a Nuclear Site Licence which usually relates to power generation whilst 'non-nuclear' relates to any other site, such as medical and industrial uses of radioactive elements.

The Radioactivity in Food and the Environment (RIFE) annual report focuses on discharges from human activities, not naturally occurring sources, and reports on an extensive programme of food, dose rate and environmental monitoring in the terrestrial and marine environment.

The 2014 monitoring programmes found that radiation doses from authorised releases of radioactivity to people living around nuclear licensed sites were well below the UK national and European dose limit of 1 millisievert[d] per year[90].

Measurements of naturally occurring radioactivity, such as radon gas in homes, are undertaken by Public Health England. Measurements are compared with the UK Action Level set at 200 Becquerels per cubic metre (Bq/m^3). As of July 2012 radon measurements had been completed in around 17,700 Welsh homes, with 1,900 homes identified with a radon concentration at or above the Action Level. For the majority of cases remediation was successful in reducing the radon level to below the Action Level[91].

The UK average dose from natural radioactivity is 2.2 millisieverts per year, with a range across different geographical locations from 1.5 and 7 millisieverts per year[92].

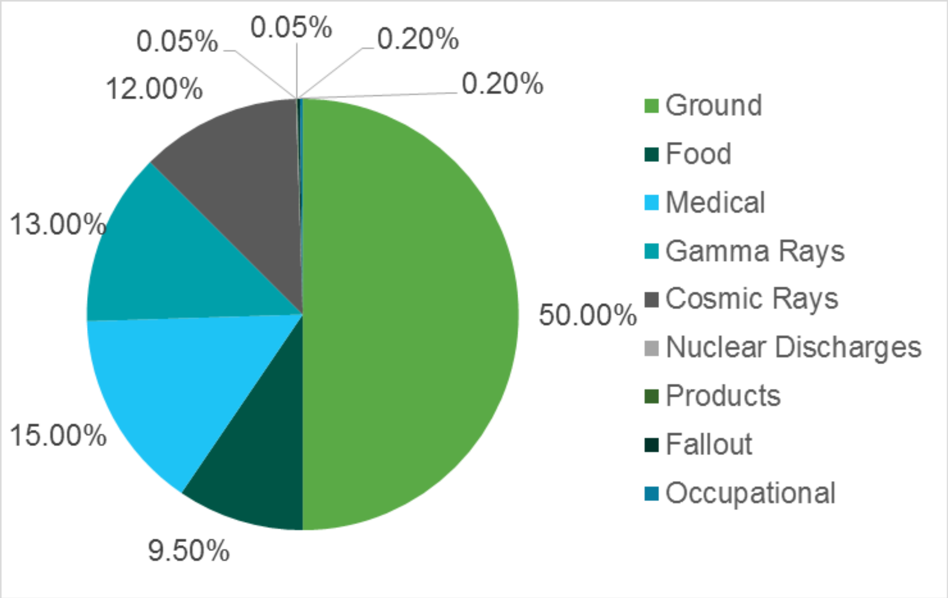

Figure 16 Annual average dose of radioactive substances to the UK population[92].

Radioactive elements decay and emit radiation, a form of energy that can cause damage to living tissues, increasing the risk of cancer[92]. Any exposure to this type of radiation is a potential risk to health. The exposure to people and the environment from manufactured sources, however, is extremely small.

Radioactivity, whether naturally occurring or manufactured, can be taken up by plants and animals with the result that it can enter the food chain.

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[d] The rate that radiation is released from a source is measured in Becquerels. The estimate of effects on a body from a received dose of radiation is measured in Sieverts.

CASE STUDY
Regulated nuclear sites in Wales[90]

- Trawsfynydd nuclear power station in North Wales ceased power generation in 1993 and is undergoing decommissioning. The total dose from all pathways and sources (air, water, food) of radiation from the site have decreased. Dose estimates from 2004 to 2014, for all sources at this site, range from 0.012 to 0.032 millisieverts per year.
- Wylfa nuclear power station on Anglesey ceased power generation in December 2015 and will start defueling (removal of the nuclear fuel from the reactors) in 2016 as part of a long decommissioning programme. Radioactive discharges to air and water, reported in RIFE 20[90], decreased mainly due to the end of power generation from one of its two reactors in 2012. Dose estimates from 2004 to 2014, for all sources, range from <0.005 to 0.011 millisieverts with a downward trend, compared to the regulatory dose limit of 1 millisievert.
- The third nuclear site, in Cardiff, previously a manufacturer of radionuclides, ceased operation in 2010. Discharges from the site have continued to decline since this time and are now below the detection limit of 0.005 millisieverts.

Trends

As can be seen from the information and graphs above, the improvement in air quality seen since 1990 has levelled off and in some cases the recent trends show a slight reversal. The levels of pollutants released from all sources are expected to continue to fall as abatement technology improves. However, there will be local increases in air pollution from urbanisation, road traffic and intensification of agriculture.

3.3. Water Resources and Hydrological Processes – Freshwater and Marine

Water is central to our way of life. We rely on considerable quantities of water to produce resources, transport our goods, provide recreational benefits and grow our food. However, too much water in our river systems, during high rainfall events, create risks to property and life through flooding.

This section looks at water as a resource, using evidence we hold on the impacts of high or low flows of water in the hydrological system on other ecosystems, and wellbeing. It discusses the key issues drawn from an analysis of trends and future pressures.

Extent and Condition – Water Resources

The recently completed LIFE Natura 2000 Programme identified that changes to hydraulic conditions had an impact on or were likely to have an impact on, 45 of 112 (40%) protected sites in Wales. Much of the habitat degradation seen within Natura 2000 rivers and their floodplains is linked to historical and current changes. Many wetland sites suffer from barriers which can affect their natural hydrology (e.g. historic railway/tram tracks on Fenn's, Whixall, Bettisfield, Wem and Cadney Mosses SAC), and altered water flows which, as well as impacting on hydrology, can also lead to nutrient-rich water being diverted on to sites. Intensive land drainage, agricultural changes and peat cutting can cause water to drain away from peat bogs and lead to them drying out. This reduces the ability of wetlands to control flood water and function as a carbon store. The upland and lowland lakes of Wales designated under the Natura 2000 network are impacted by drainage, water abstraction and changes in water levels which affect their habitat condition.

Currently we are in the process of changing around 10 abstraction licences in Wales where there are significant risks that abstraction could damage important conservation sites, including Natura 2000 sites and Sites of Special Scientific Interest (SSSIs). Following previous investigations, around 60 abstraction licences in Wales have already been changed to protect Natura 2000 sites. Where changes could not be implemented immediately we are working with licence holders to ensure solutions are in place as soon as technically feasible.

As part of the implementation of the Water Framework Directive (WFD) a programme of investigations has been targeted at water bodies failing their objectives, in order to identify the main pressures and develop solutions. This information is summarised in the updated River Basin Management Plans. In total 29 water bodies have been identified as failing WFD objectives due to changes to flow and water levels resulting from human activities.

Trends – Water Resources

Water availability
The current system of allocating water for abstraction through Abstraction Licences was introduced back in the 1960s. It has proved an effective mechanism for managing water resources over the last 50 years, but is unlikely to be able to cope in its current form with the challenges posed by climate change and future population

growth. In addition, some water abstractions which can pose a significant risk to water status are currently exempt from requiring a licence.

There are currently around 1,200 abstraction licences in Wales, but there are around another 500 abstractions that are above the volumetric limit of 20m^3 per day but which are currently exempt from licensing. These abstractions are mainly used for navigation purposes, dewatering of quarries or some types of irrigation, or are in exempt areas for groundwater abstraction. Through the New Authorisations project, the Welsh Government intends that these currently exempt activities will be brought into the abstraction licensing system.

Whilst Wales is perceived to be water-rich, we are already facing challenges. For example, in 7% of our water bodies water is only reliable for new consumptive abstractions for 30% of the time.

In 2011 the Environment Agency published *The Case for Change – current and future water availability*[93]. The report sets out how the availability of water resources in the future may be adversely affected by pressures associated with climate change (UKCP09[94]), population increase, and changes in people's behaviour. By the mid-2050s the population of Wales is expected to increase by 10%, to approximately 3.4 million people[95]. The report was updated in 2013 but its conclusions remain largely unchanged. Whilst recognising that quantifying water availability is complex, a number of catchments across Wales are predicted to experience significant unmet demands under many of the scenarios investigated.

To help address the implications of these future pressures, Welsh Government and the Department for Environment, Food and Rural Affairs (Defra) are currently working to reform the abstraction management system in Wales and England. In January this year the Welsh Government published its response Defra's consultation *Making the most of Every Drop, Reforming the Abstraction Management System*[96]. The response document sets out how the abstraction management system will evolve to meet the challenges set out above, whilst still protecting the environment. The reformed abstraction management system is likely to be implemented in the early 2020s.

Soil sealing

Our towns and cities are experiencing increasing rates of soil sealing as we build on green spaces. This results in increased surface water run-off and associated diffuse pollution, and changes to soil moisture, groundwater levels and flows in receiving streams. When rainwater drainage enters sewers it puts increasing pressure on the existing infrastructure.

CASE STUDY
Impact of impermeable developments[97]

Figure 17 Impermeable surfaces in a Cardiff suburb

The image on the left shows a Cardiff suburb in 1984. The grey areas are impermeable surfaces and the drainage of the site is designed to accommodate run-off from a 1-in-30 year return period storm. On the right is the same suburb in 2009. It shows (in red) the 20% increase in impermeable area through home extensions, conservatories and paving of gardens. Despite this increase, the drains remain unchanged. Due to these changes, and the increasing rainfall predicted from our changing climate, sewer flows in Wales are projected to increase by over 1% a year. Applying Sustainable Drainage (SuDs) techniques to new developments will not address flooding on existing sites. To do this, SuDs techniques need to be implemented on existing sites or the risk of surface water and sewer flooding will inevitably rise.

Climate change

Analysis carried out to support the *Water Resources Strategy for Wales*[98] shows how potential changes in rainfall, predicted as a result of climate change, could affect average river flows across Wales, throughout the year, by 2050. By 2050 river flows in winter may rise by 10-15%. However, river flows in the summer and early autumn could reduce by over 50%, and as much as 80% in some places. These patterns would result in a drop in the total annual average river flow of up to 15%.

In many Welsh rivers flows are particularly vulnerable to climate change because they tend to rise and fall quickly in response to rainfall. The impacts of lower river flows will extend beyond water resources. For example, reduced flows and associated changes to water quality and temperature could impact on fish migration and spawning, reducing the quality of inland fisheries in Wales. Increased flows during winter may also increase pressure upon sewerage and drainage systems and diffuse pollution.

Climate change may affect groundwater. By 2025 it is likely that groundwater recharge will decrease, resulting in decreased dry weather river flows and a general lowering of groundwater levels. This may have impacts on base-flow to rivers and wetlands in dry periods, and small domestic and agricultural water supplies.

Extent – Hydrological Processes

Hydrological processes are a key influence on marine ecosystems because they create conditions for life and supporting systems. This includes transport systems for food (both for human consumption and within the ecosystem), waste, nutrients, sediments, front creation and so on. The waters of the Welsh inshore are strongly influenced by oceanographic processes, with influxes of water from the Celtic Sea and north from the continental shelf current. The *Wales Marine Evidence Report*[99] describes the hydrological processes in Welsh waters in detail.

Condition – Hydrological Processes

Tidal range, tidal currents and sea levels
Tidal ranges on spring tides are generally high along the Welsh coast but vary significantly, from less than 4 metres within Cardigan Bay to approximately 12 metres in the Severn Estuary[100]. Surges due to variations in atmospheric pressure can significantly raise or depress the water surface with implications for coastal erosion, sea defence integrity and coastal flooding.

During mean spring tides, tidal currents vary from 0.5 m/s to a peak of more than 2 m/s[100].

Waves
Much of the Welsh coastline is open to the prevailing south-westerly winds, and exposed locations can be subject to severe wave attack. Waves, therefore, make an important contribution to coastal evolution and are the primary driver for longshore sediment transport[100].

Temperature
The UK's position at the junction of two marine biogeographic regions, where cooler water from the north meets warmer water from the south, contributes to marine diversity. South Wales in particular experiences this overlap[101]. A large tidal range and strong tidal currents mean that most of Welsh waters are mixed, although some seasonal thermal stratification occurs in deeper areas[102].

Current sea surface temperatures in winter are 9-11^{o}C, and in summer are 16-18^{o}C[102].

Salinity
In addition to the thermal stratification described above, saline stratification also occurs in shallower estuarine areas[100].

The Atlantic Ocean is the main influence on salinity, with rainfall and evaporation having a much smaller effect. Locally, variations are experienced due to the influx of freshwater from rivers via estuaries. Generally salinity varies between 34 and 35.6 salinity units[102].

Coastal processes and management
Almost 28% of the coast has some form of artificial protection[103,104] whilst 23.1% of the Welsh coast is considered to be eroding[105], with the potential to affect people, properties and infrastructure. In addition, both erosion and coastal protection have the potential to affect protected sites, although allowing dynamic processes to take place is usually considered to be positive.

Flooding is not only a pressure on communities and built structures but also causes impacts on the environment as was seen in the 2013-14 winter storms[106].These storms caused £8.1 million of damage to flood defence structures, in addition to the financial costs associated with the approximately 300 properties that were flooded. It is estimated that £2.96 billion of damage to properties was avoided as a result of protection from defences[107].

Developments affecting hydrological processes
The gradual development of marine renewable technologies may already be contributing to changes in hydrological processes. For example, some effects of offshore wind turbine structures include reduction in tidal currents, increases in tidal amplitude, and increases in vertical mixing which reduces seasonal stratification[108].

Trends – Hydrological Processes

Tidal range, tidal currents and sea levels
Sea level around the UK increased by approximately 1-3 mm per year during the 20th century[109]. There is variance is sea-level change around the UK partly due to vertical land movement from isostatic rebound following the last Ice Age, with the south of the UK sinking while Scotland is rising.

Based on a medium emissions scenario, relative sea level rise projections for Cardiff, compared with a 1990 baseline, indicate a rise of approximately 10 cm by 2020, 22 cm by 2050 and 44 cm by 2095[110].

Waves
A review of storm frequency and intensity was undertaken following the winter 2013/14 storms[111]. This review found that whilst there did not appear to be an increase in storm frequency, the intensity of strong winter cyclones had increased since 1871. It was concluded that a more comprehensive study of storms affecting the UK is needed to explore these findings in more detail, but that the current evidence does suggest an increase in storminess[111, 112].

Simulations run as part of the UK Climate Projection 2009 (UKCP09) investigations suggest that, in the future, the mean annual and winter maxima of significant wave heights are generally expected to increase to the South West of the UK, including the Welsh coastline[110].

Temperature
Since the 1980s the sea surface temperature of the seas around the UK have risen at a rate of about 0.2–0.6°C, and seven of the warmest years in UK coastal waters since records began in 1870 have occurred in the last decade[113].

Whilst based on limited modelled outputs, sea-surface temperature increases of 2.5-4°C are projected for the Celtic Sea and Irish Sea for the period 2070-2099[110].

The changes to temperature and salinity are expected to have effects on mixing and stratification[114]. There is therefore significant potential for the climate change to lead to an alteration in patterns of ocean circulation through the Irish Sea including Welsh waters.

Salinity
Trends in the salinity of UK marine waters are less apparent, although the evidence suggests a freshening to a minimum in the 1980s-1990s followed by a subsequent increase in salinity[110, 115, 116]. However, in contrast to the relatively large increases in temperature predicted for the Celtic Sea and Irish Sea by the late 21st century (2070-2098), salinity changes in these regions are expected to be less than the rest of the UK.

In estuaries, sea-level rise will increase the extent of saline intrusion and shift the position of tidal limits upstream[109].

Coastal processes and management
The trends in hydrological processes which include sea-level rise and increased storminess are likely to increase the likelihood and consequences of coastal flooding and erosion. For example, over the next 100 years, 2,126 properties are expected to be at risk from coastal erosion. However, if Shoreline Management Plan policies, which integrate the protection of habitats and people, are implemented this will significantly reduce to 145[117].

These trends will also affect other assets such as coast paths, roads and railways, and also historic coastal landfill sites, which could become a serious source of pollution.

Shoreline Management Plans for the coast of Wales set the preferred policy for sustainable management of the shoreline position over the next 100 years and take sea-level rise into account. If these plans are implemented, they predict a decline in extent of intertidal and coastal habitats (mainly intertidal sand and mud and saltmarsh) due to coastal squeeze[, 118, 119, 120].

Developments affecting hydrological processes
Welsh waters are recognised for their potential contribution to renewable energy through tidal range, tidal stream and wave energy devices[100]. These developments will support efforts to reduce carbon emissions and mitigate the effects of climate change, but could also have effects on hydrological processes in addition to the climate change effects described above.

Developments in the marine area have the potential to alter or diminish the available tidal current and wave energy. For example, it has been demonstrated that tidal stream turbines which extract even a small amount of energy from a tidal system can lead to a significant effects on flows and sediment dynamics[121, 122].

Large scale developments (in particular tidal barrages and tidal lagoons) also have the potential to alter tidal range, on either a local scale or, for some developments, on a much wider scale. Some models of possible tidal barrage developments in the Severn Estuary have predicted increases to mean high water levels of 0.2 to 0.3m along the Welsh coast as far as the Llŷn peninsula, and increases as far as the east coast of Ireland[123].

Summary

The combined effects of climate change and developments in the marine environment could lead to significant changes in hydrological processes in Welsh waters, with consequential effects on sediment transport, seabed, coastal and estuarine morphology, and the associated habitats and species. These changes will also influence consideration of measures for coastal management and adaptation.

3.4. Soils

Extent

Soil in Wales is strongly influenced by climate (and altitude), vegetation, land use and the underlying sediments or rocks. This gives rise to 10 major soil groups (of which peat is one), all of which are present in Wales. In the widespread upland and lowland areas, soils are a mixture of acidic, well drained soils and slowly permeable soils that have impeded drainage.

Welsh soils are relatively unusual in a global context[124]. There is a scarcity of high quality agricultural soils, with those considered to be the best and most fertile accounting for no more than 7% of Wales' land area.

Of the total extent of peat soils (soils with surface organic/peaty layer of≥45 cm thick) (90,995 ha, equivalent to 4.3% of Wales' land area), 75% is in upland areas and 25% is in lowland areas[125]. Organo-mineral soils, which have an organic (peaty) surface layer <0.4 m thick cover an additional area of 359,200 ha (17.3%)[126]. Over 80% of soil carbon stores in Wales are associated with upland and grassland soils[127].

Soils provide Wales' largest terrestrial ecosystem store of carbon, estimated at 410 million tonnes. Forest soil carbon stocks for Wales are estimated at 57 mt[128]. Peat soils are particularly rich in carbon, containing around 157 mt over only 4.3% land area of Wales[129]. These soil carbon stocks are larger under conifers compared to those under broadleaves.

The total concentration of different elements in the soil – its geochemistry – has implications for both human, animal and plant health. Their distribution and concentrations[130] can help determine whether, and the degree to which, soil may have been contaminated by human activities.

In Wales, soils have been contaminated by past and present industrial processes or activities. Where waste products or residues remain, these can sometimes pose an environmental hazard but they can also support rare flora and fauna. The extent of soils impacted by contamination to a level where it could pose a risk to human health and the environment (including brown field sites) is unknown.

There is currently no statutory soil monitoring programme in Wales or the UK, and there is a general lack of information on the national extent of, state and threats to soils[131].

Condition

Peat soils

Most organic soils (peat soils) support ecosystems that are sensitive to pressures from human activities; hence these soils are susceptible or vulnerable to degradation, including carbon loss though oxidation and erosion[132]. Only 30% of the Welsh peat soil area is considered to be in 'good condition'[125] Around three quarters of peatland are thought to have been impacted by one or more land-use activities. It is thought there are at least 3,000 km of drainage ditches on peatland in Wales, with two thirds in the uplands and one third in the lowlands (excludes ditches in a forestry context).

There are 18,100 ha of deep peat in a forest land-use context with just under 11,000 ha of this under tree cover and 1,200 ha of this under active restoration.

Welsh peatlands are currently estimated to be generating anthropogenic emissions of around 400 kt CO_2-equivalents per year (equating to 7% of all Welsh transport-related emissions) as a result of degradation from land use activities. This compares to an estimated natural 'reference' condition of approximately 140 kt CO_2-eq. yr^{-1} [125].

Erosion

It takes approximately 500 years to form 2.5 cm of topsoil under normal agricultural conditions[133], and therefore soil should be treated as a finite and essentially non-renewable resource[134]. Shallow soils are generally less resilient to the impacts of erosion compared to deeper soils.

Various forms of land use and land management can result in: soil erosion; loss of soil condition, fertility and biodiversity; decreased carbon storage; lower water-retention capacities; disruption of gas and nutrient cycles; and reduced degradation of contaminants[134]. Soil sealing (e.g. by roads, buildings, garden paving etc) can lead to increased surface run-off and degradation or destruction of soils.

These impacts in turn affect the ability of soils to deliver the vital functions and services required by society[127, 135, 136, 137]. There is a general lack of information on how much of Wales' soils are affected by development, soil-sealing and erosion.

Compaction

Around 10-15% of grassland fields (England and Wales) are thought to be affected by severe soil compaction and poor soil condition[138]. Poor soil condition is not restricted to 'improved' grasslands as more 'semi-improved' grassland soils are in poor condition. This indicates that poor soil structural condition may hinder plant species diversity in some cases and enhance it in others.

Soil moisture, texture and structure also determine whether rainfall infiltrates soil or runs off of it, which is important for regulation of surface water flows and flooding. Soils containing low levels of organic matter are generally more susceptible to compaction. A study carried out at the Pontbren group of farms showed that infiltration rates were up to 60 times higher in tree-planted areas compared to adjacent grazed areas[139].

Nitrogen & phosphorous

The dominant source of nitrous oxide (N_2O), accounting for >90% of N_2O emissions in Wales[124], is from agricultural soils. Raised soil nitrogen levels have been connected to changes in plant species in semi natural habitats[140]. Around 90% of sensitive habitat soils receive nutrient nitrogen deposition in excess of their critical loads for eutrophication, i.e. an excess of nitrogen as a nutrient[141].

NRW surveys report that 44% of the samples obtained from agricultural land contained phosphate levels above the optimum level, which can cause problems with water quality, indicating there is scope for improvement with nutrient management[142].

Acidification
Compared to Great Britain as a whole, Welsh soils are more acidic than in other countries across most Broad Habitat types. The most acid soils in Wales in 2007 were those beneath upland coniferous woodland (pH 4.14), whilst soils beneath enclosed farmland Broad Habitats were the least acid[140]. It is estimated that 74% of acid-sensitive habitat soils receive acidic deposition in excess of their buffering capacity[141].

Soil biodiversity
Macrofauna such as burrowing animals and earthworms are important factors in soil nutrient cycling, fertility and structure. Soil mesofauna – those animals that are under 2 mm in size – are just as important, particularly for their role in soil fertility, breaking down organic matter. There is no direct evidence for the condition of biodiversity in Welsh soils[131].

Soil contamination
The UK Soil and Herbage Pollutant Survey[143] indicates that concentrations of copper, lead, mercury, nickel, zinc and tin are higher in urban and industrial soils than rural soils, in the main reflecting inputs from industry and transport. Countryside Survey results indicate that concentrations of heavy metals in rural soils are generally below regulatory limits[144]. Zinc poses the most significant risk to soil organisms, due to the sensitivity to zinc of soil microorganisms responsible for nitrogen fixation (rhizobia)[145]. Concentrations in grassland soils probably reflect sewage sludge applications, while concentrations in organic soils suggest retention of pollutants from atmospheric deposition[144].

Sites identified as Contaminated Land under Part 2A of the Environmental Protection Act (1990) pose an unacceptable risk to human health and the environment. The most common contaminants found on these sites were benzo(a)pyrene, lead and arsenic, all of which were identified at over 60% of the sites.

Soil concentrations of polychlorinated biphenyls (also known as PCBs) in urban and industrial areas of the UK are about 1.5 times those of soils in rural areas[143]. Concentrations of total polycyclic aromatic hydrocarbons (or PAHs) and benzo(a)pyrene in urban and industrial soils are around 5-7 times those in rural areas. Across the UK, concentrations of dioxins in urban and industrial soils are 2-3 times greater than rural soils.

Trends

Soil loss and erosion
The total urban area of Wales is increasing[146] but it is unknown how much of this increase has resulted in loss or degradation of soils. Soil erosion has increased and soil formation has been affected due to various human impacts[147]. An estimated 2.2 million tonnes of topsoil is eroded on an annual basis in the UK[148]. With low rates of

soil formation, any soil loss above 1 tonne per hectare per year can be considered irreversible over a time span of 50-100 years[149].

Information on erosion of soils in Wales is very limited. 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 management activity)[127] where the risk is not well managed, especially when combined with high rainfall events. Soil quality has deteriorated over time[127]. The rate of change of soils in relation to compaction and degradation in terms of structure is unquantified.

Dissolved organic carbon (DOC) concentrations in upland waters draining peaty soils are high and have risen across the UK in the last 20-30 years[150,151], suggesting that soil carbon stocks may be destabilising. The National Soil Inventory (NSI)[152] reports losses in topsoil carbon for England and Wales over the same period, but does not discriminate for Wales specifically. NSI data reported that the largest rate of decline in organic matter in topsoils in England and Wales was in peat soils, bog and upland heath[153]. However, the Countryside Survey and GMEP report no significant change overall in soil carbon from 1978-2007 for topsoils in Wales, and also indicate no change in soil carbon in improved grassland systems in Wales between 1978 and 2013. It is not known whether arable systems in Wales are maintaining soil carbon levels. At the UK scale they are known to be in decline[154].

Soil monitoring by GMEP indicates no significant change in soil nitrogen concentration across Wales as a whole between 1998 and 2007 or between 2007 and 2013[124]. There has been a 7.7% reduction (1995-2013) in the area of sensitive habitat soils where critical loads for nitrogen have been exceeded[141]. Overall trends in reduction are thought to be due to reduced nitrogen fertiliser use (particularly in grasslands) and reduced numbers of livestock[124].

GMEP data also indicate a stabilisation of the decline in soil phosphorus levels seen in the Countryside Survey across all broad habitats. Overall there has been a decline in phosphorus on improved land, but this is consistent with declines in fertiliser use since the 1980s and actually moves the levels closer to those that should be maintained for sustainable management. However, applying excess nutrients is still occurring as indicated in areas where nutrient levels exceed crop and land capacity, resulting in potential loss to the environment in the form of pollution.

In general, on a national scale, the pH of soils has been increasing across Wales as soils recover from acidification from atmospheric deposition, and data from the GMEP survey in 2013 are consistent with that. There is no evidence on trends in relation to soil biodiversity. However, European-wide evidence suggests that intensively managed systems are at greater risk of loss in soil biodiversity[155] and many studies report soil biodiversity declines as a result of the conversion of land to agriculture and from agricultural intensification[156, 157].

There has been little or no decline in elevated levels of soil contaminants from industry and transport[158]. There were 111 Contaminated Land sites in Wales which have been identified under the Part 2A regime (introduced in 2001) of the Environmental Protection Act 1990[159] (See Chapter 3, Section 3.4). Under this Act there is thought to be still around 9,330 potentially contaminated sites that have yet to be investigated by local authorities. Remediation has been completed at 97 of these sites and has commenced for one additional site. Remediation of 93% of the soil contamination sites in Wales are mainly dealt with through the planning process but around 3% of contaminated sites are dealt with under Part 2A and a similar amount under voluntary action.

The concentrations of polychlorinated biphenyls (PCBs) in UK soil have fallen approximately 800-fold since the mid-1970s, reflecting changes to industrial production restrictions[158]. Soil dioxin levels have dropped by approximately 70% since the 1980s[143], indicating that soils are maintaining a capacity to detoxify and degrade organic pollutants[158].

Climate change-related risks are threatening the many services that soils provide (Table 7), notably those that relate to soil biota, soil organic matter, and soil erosion and compaction. Declines in soil carbon in arable soils, increases in the area of some high risk crops (e.g. maize) and the degraded condition of peatlands suggests that the vulnerability of soils in Wales is increasing. Future climate projections suggest that climate, in combination with the other pressures, will lead to a major increase in risk due to the effects from higher temperatures, more intense rainfall and increased aridity, depending on location and soil type.

The risk of water-driven soil erosion is expected to be higher with projected increases in the frequency and intensity of heavy rainfall events, but there are no Wales-only studies available. The extended growing season may provide opportunities for longer outdoor grazing in winter, which increases the risk of soil compaction by livestock. Autonomous land management responses to changing climate (e.g. cultivation of steeper slopes; expansion of maize cropping) may increase erosion risks further in the future. Due to higher temperatures and reduced soil moisture, soil is likely to experience decreases in organic matter, with adverse consequences for crop production, soil biodiversity and carbon storage. Soils of wetland habitats, such as peat bogs and fens, are particularly sensitive to changes in the soil wetness regime; the degraded condition of the majority of these habitats increases the vulnerability of their soils.

It is predicted that climate change will not significantly change the average annual duration of soil wetness (i.e. field capacity days) or potential soil moisture deficits until 2080 although there is likely to be a shift in seasonal distribution of the field capacity period leading to drier autumns and wetter springs.[160]. More frequent droughts may mean, however, that soils may experience prolonged periods of high soil moisture deficit more often. Only soil carbon in organo-mineral and peat soils shows a marked response to climate change. Maintaining the carbon content of these very soils, however, is a key priority in limiting overall greenhouse gas emissions in Wales, and in managing water resources in the face of inevitable climate change. There is little hard evidence on the vulnerability and resilience to climate change of different soil types in Wales[131].

While much uncertainty surrounds the impacts of climate change on soil biota and soil functioning[161], any changes in the abundance of soil organisms and the structure of the soil food web will significantly influence soil functioning[162] and human health[163] Changes in climate are expected to affect the abundance, diversity and activity of soil life[161], with implications for the decomposition of organic matter and hence carbon storage, nutrient cycling and other soil-related ecosystem services such as crop production.

Climate change also increases the risk of landslides (from heavy rainfall events) and ‘shrink-swell’ subsidence (from soil moisture fluctuations), impacting on e.g. transport networks, infrastructure and housing. Drying of soils will compromise their capacity to buffer and withstand climate extremes such as heat waves[164], thereby impacting on human health, and the protection of cultural heritage[165]. Organic/peat soils are particularly vulnerable to wildfires. Projected increases in soil moisture deficits would be expected to lead to a large increase in the number of fires and area affected. Modelling suggests that wildfire risk will increase by 30-40% in the Brecon Beacons, Pembrokeshire Coast and Snowdonia National Parks by the 2080s. Sea level rise scenarios indicate a further flooding and loss of coastal zone habitat and their associated soil resources, together with the many ecosystem services they provide.

Table 7 Changes in soil function in response to climate change

Soil response to climate change	Key soil/landscape areas impacted	Type of response in Wales
Change in soil moisture, hydrological response and flooding of soils.	Slowly permeable soils.	Duration of field capacity period not significantly changed across Wales in 2020 and 2050 but start and end date shifted (later onset of return to field capacity in Autumn).
	Change in water regime of wet organic (peat) or organo-mineral soils.	Potential soil moisture deficits (PSMD) are similar in 2020 to the baseline but increase by 2080.
	Other soils that may have restricted storage capacity.	Some evidence for a small reduction in the period of waterlogging in slowly permeable soils by 2080.
	Change in water-holding capacity in organic soils.	As saturation period has not changed this could imply that there is limited hydrological buffering to events, increasing the susceptibility to run-off and flooding.
	Soils on sloping ground.	Change in grade of agricultural land due to shift in climatic drought criteria.
	Shrink-swell (clay) soils in urban areas and infrastructure routes.	Human health impacts from less buffering of air temperature by soil (moisture) during extreme weather ie heatwaves. Landslides e.g. earthworks/embankment failures causing disruption to rail and road networks. Few soils cause shrink-swell subsidence and earthwork failures in Wales combined with low PSMD.
	Organic (peat) and organo-mineral soils.	Extreme events (drought): Increase risk of wildfires – peat loss and hydrophobicity (increased water run-off).
	Slowly permeable, waterlogged soils, including peats; coastal soils; grassland soils.	Soil protection of cultural heritage. Degradation of waterlogged soils in response to fluctuating rainfall pattern and lower water tables may expose some previously buried archaeological remains to air, impacting on

Soil response to climate change	Key soil/landscape areas impacted	Type of response in Wales
	 Coastal soils.	preservation. Pollen record in peaty soils lost by oxidation in upper peat layers. Sea level rise resulting in loss or damage to archaeological remains. Higher river volume and increased frequency of flooding increasing soil erosion in heritage sites in estuarine areas. Poaching and machinery pressure damaging archaeological sites. Coastal flooding from sea-level rise – soil loss and salinization impacts on soil function.
Change in soil carbon dynamics.	Organic (peat) or organo-mineral soils.	Declines in soil carbon related to climate change alone are small, although upland areas will experience greater amount of C loss through Particulate Organic Carbon, Dissolved Organic Carbon and CO_2. However, the UK CCRA17 Evidence Report[166] has identified climate change risks to natural carbon stores and carbon sequestration, emphasising that upland and lowland deep peat soils represent Wales' largest terrestrial store of carbon
Change in soil erosion risk by water.	Fine sandy and silty soils; peat soils.	Grassland systems less vulnerable to erosion.
Soil biodiversity responses.	Potentially all soils but focus on soils with maximum change e.g. organic (peat) or organo-mineral soils.	Change in biological response as a result of drying previously saturated soils.
Grassland productivity-induced change in soil structure e.g. increased grazing pressure impacts of livestock causing soil compaction.	Soils of improved and permanent grassland systems.	Increase in grazing window means greater pressure on soils from livestock (compaction and associated erosion).

3.5. Geodiversity

Geodiversity is the variety of rocks, minerals, fossils, landforms, sediments and soils, together with the natural processes which form and alter them. Geodiversity provides many of Wales' natural resources, strongly influences our landscape, biodiversity and culture, and is internationally important for geoscience research.

For a relatively small country Wales has some of the most varied geology in the world.

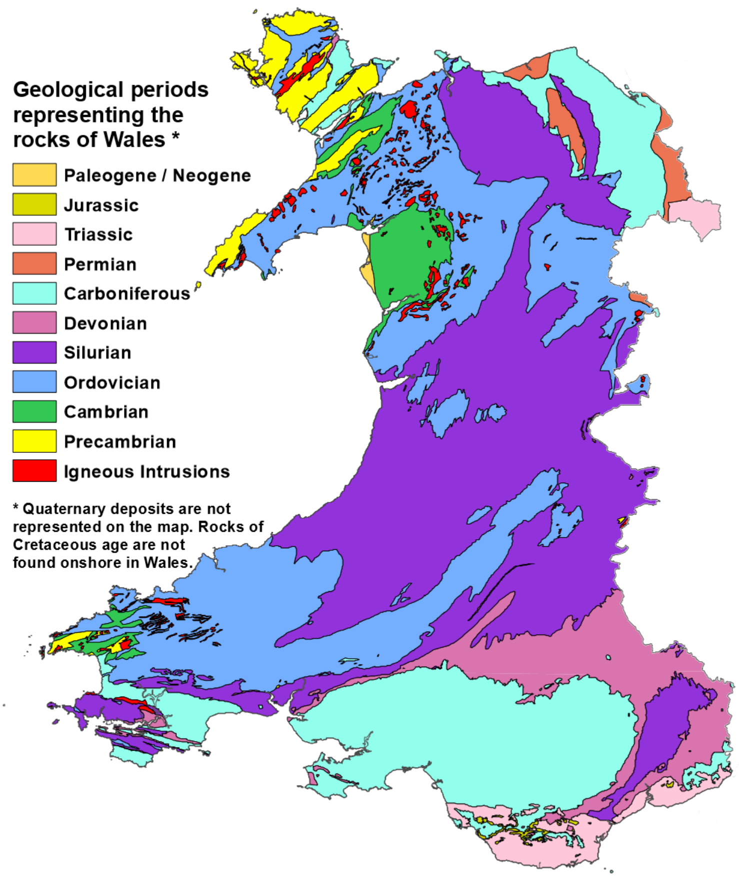


Figure 18 The geology map of Wales highlights the diverse nature of the underlying geology. Each colour represents rocks from the different geological periods. Contains British Geological Survey materials © NERC [2016].

Extent

The rocks and landforms of Wales provide evidence from Earth's early history through the last Ice Age to the present day, covering 1.4 billion years. Within Wales and the adjacent seas, elements of all the major geological systems are to be found. The colours of a geology map (Figure 18) show at a glance how the rocks vary around the country. Every rock type shown on the map has its own distinct landscape. For example, the extensive Precambrian rocks on Anglesey and Llŷn, the Ordovician volcanic rocks of Snowdonia, the Silurian mudstones of mid-Wales, the limestone scenery of the Gower, or the Jurassic cliffs of the Vale of Glamorgan. On top of all this, the glaciation of Wales has shaped the landscape through erosion and deposition of glacial deposits.

Wales has attracted geologists since the pioneering work of Victorian times when they named some of the divisions that define the international geological timescale – for example, the Cambrian, named after the Latin name for Wales, and the Ordovician and Silurian periods, which are named after Celtic tribes. These are standard geological terms used globally and this rich legacy continues to attract geologists from all over the world to study the geology, including globally recognised reference sites.

Geotourism

Two UNESCO Global Geoparks, GeoMôn and Fforest Fawr, cover 1,483 km^2 of Wales and are designated as areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable geotourism[167]. Other areas of Wales, such as the Wales Coast Path, National Parks and Areas of Outstanding Natural Beauty (AONBs), are underpinned by geodiversity and promote the varied landscape that attracts millions of tourists and contributes significantly to the Welsh economy.

Protected Sites

Geodiversity sites include geological Sites of Special Scientific Interest (SSSIs), Regionally Important Geodiversity Sites (RIGS) or any geodiversity heritage feature which is visible and accessible for education, scientific research and/or public amenity (Figure 19).

Some 500 geological features (Geological Conservation Review[168,169] (GCR) sites) found within 300 SSSIs in Wales cover 48,815 ha. These sites display sediments, rocks, fossils, landforms and geomorphological processes that make a special contribution to our understanding and appreciation of Earth history and climate change, and are manifested in numerous ways. They may be working or disused quarries, mine spoil, road or rail cuttings, soft or hard coastal cliffs, active landforms such as sand dune systems or meandering rivers, or fixed landforms such as glacial cwms or drumlins.

RIGS in Wales cover some 20,000 ha and were selected to supplement the SSSI network, but also include areas of educational, aesthetic and historical interest.

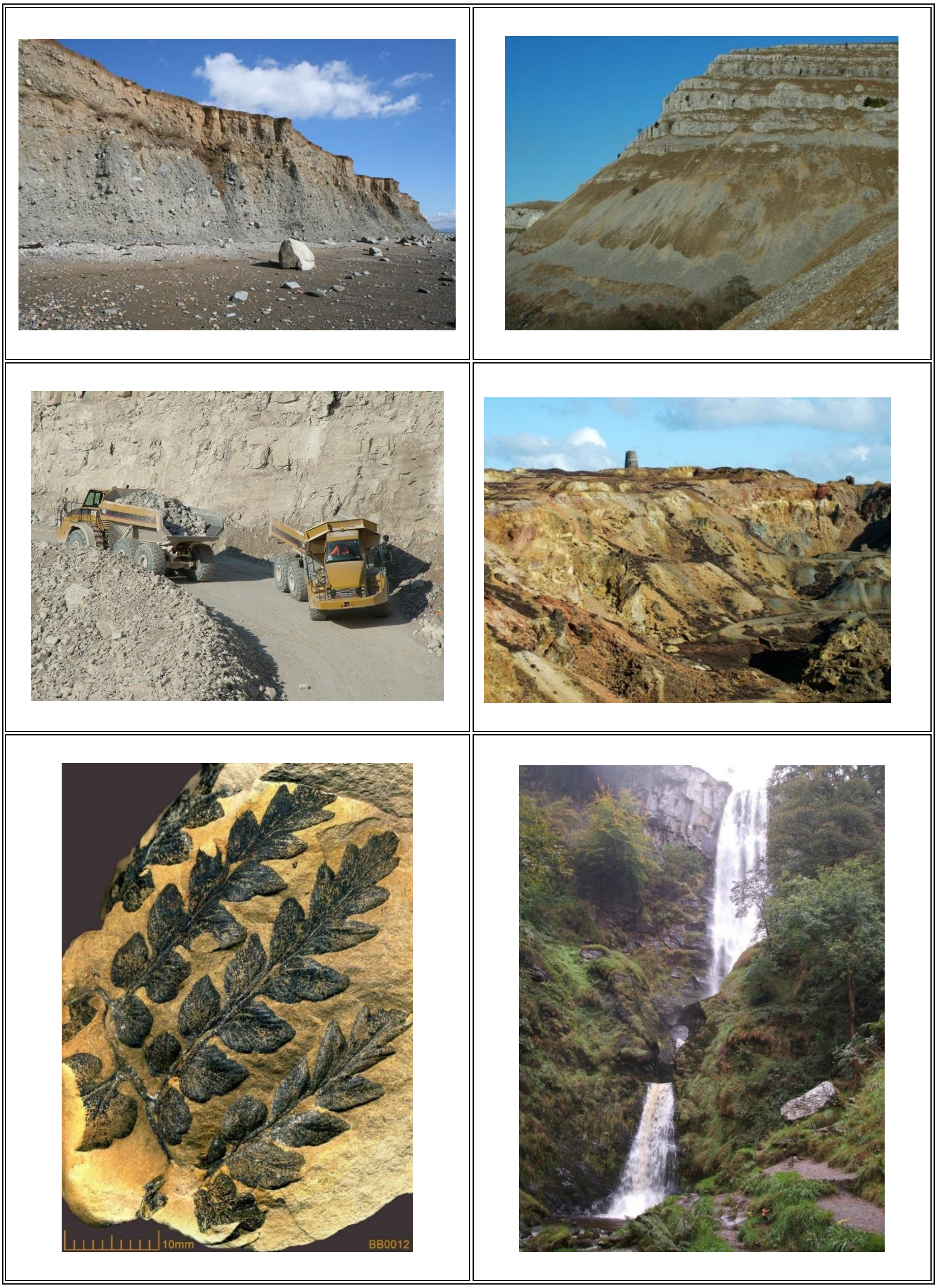


Figure 19 Protected geodiversity sites vary widely in their nature and include working quarries, abandoned mines, coastal cliffs, fossil-rich sites and the highest waterfall in Wales.

Minerals

Wales' geological formations provide a rich variety of materials which are economically important for construction and industry (See Chapter 3.5 in SoNaRR). Mineral resources are finite and not evenly distributed (Figure 20), being limited to a particular outcrop or deposit, and their exploitation is also governed by demand and accessibility to markets. For example, the limestone aggregates industry is focussed in north-east and south Wales. In contrast, sand and gravel extraction is largely limited to north-east Wales and dredging in the Bristol Channel. High-specification aggregates such as sandstones for road construction or igneous rocks for rail ballast are highly localised.

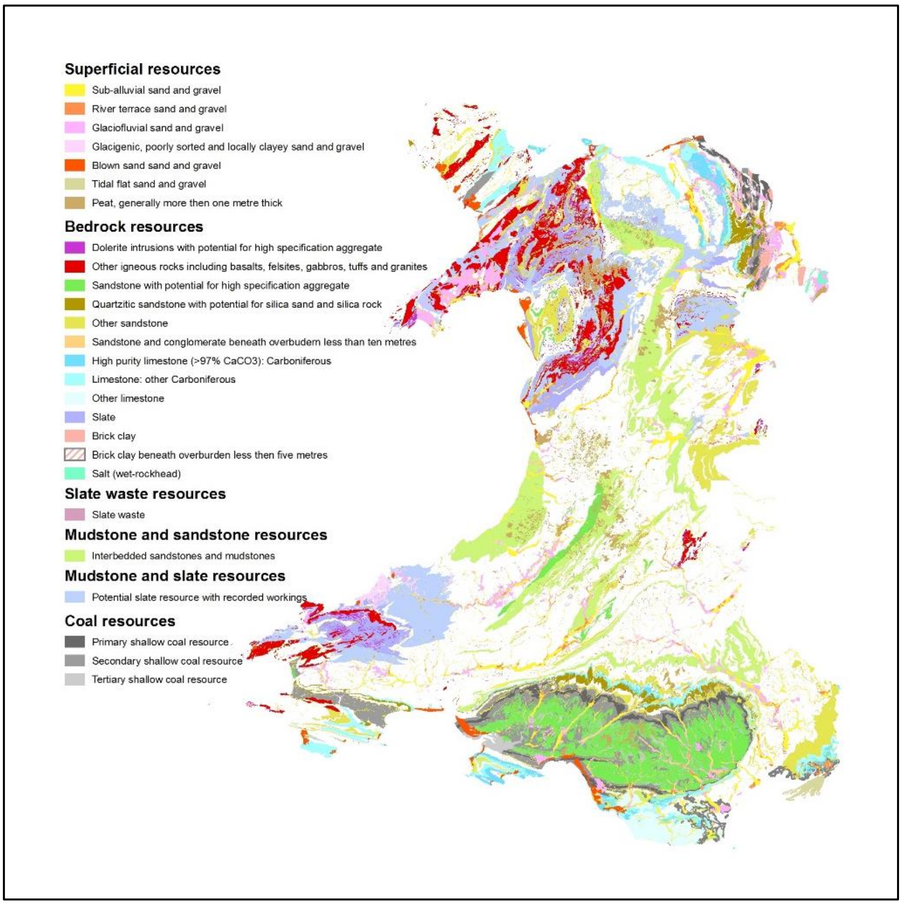


Figure 20 The mineral resource map of Wales[170]. Contains British Geological Survey materials © NERC [2016].

Geological hazards

The complex geology and geomorphology of Wales give rise to a variety of geohazards (

Table 8). Limestone, for example, is water-soluble and locally may be affected by the development of sinkholes and springs. Its inherent permeability is also linked to the transfer of radon gas. In contrast, strata associated with former coal and metal mining may be locally susceptible to subsidence, landslip, pollution and contaminated land.

Table 8 Geohazards in Wales

Natural	Anthropogenic
Mass movement/landslide Soluble rocks and karst Compressible ground Shrink-swell Radon Flooding	Quarrying Shafts & underground workings Minesites Contaminated land Ground instability

Condition

Geotourism

We need to monitor the development of geotourism and the added benefit of geodiversity to the tourism economy.

Sites

All geological and geomorphological sites are subject to a range of developmental and climate change pressures. These can include new buildings, new development and vegetation obscuring rock exposures, or erosion of fragile landforms. The most recent monitoring data available for each site records 93% of the SSSI features considered as visible and accessible and therefore considered in favourable condition.

There are few data currently available for the condition of RIGS in Wales, but a monitoring and recording scheme is being put in place by RIGS groups and Local Record Centres.

Minerals

In 2015 the Welsh Economic Research Unit of Cardiff Business School reported that the mineral products industry is a key employer in Wales. In 2013-2014 the industry provided direct employment to round 3,800 people at more than 200 sites, generating sales of £650m[171].

Trends

Geotourism

There is an increasing appreciation of the importance of geodiversity within Welsh tourism and geoconservation sectors. The monetary contribution of UNESCO Global Geoparks to the Welsh economy is increasing. UNESCO estimate the annual economic benefit from each of the Welsh Geoparks is £2.7m[172].

Protected sites

Many geosites are slowly deteriorating, both through natural processes (encroaching vegetation, erosion etc.) and human activity (development pressures, illegal activity), making them less usable and useful for research, education and training

NRW is working with a range of partners including the Welsh UNESCO Geoparks and National Museum Wales to develop a Geodiversity Charter to take this forward.

Geological hazards assessment
Some of the geological hazards may change as a response to climate change, e.g. coastal erosion, landslides, or pollution from former mine sites.

CASE STUDY
SSSI clearance work prior to international conference

Figure 21 Geological SSSI before site clearance before (left) and after (right)

Trefawr Track forms part of a network of sites in and around Crychan Forest in mid-Wales. The sites were first selected to represent the Silurian in the type Llandovery area. Described by Murchison in the 19^{th} Century, these rocks attract geologists from around the world. Trefawr Track was one of the key sites visited by the International Subcommission on Silurian Stratigraphy during their 2011 field meeting. A mechanical digger did the initial clearance work, but critical parts of the exposure needed debris removal by hand to avoid damage. Such painstaking operations are labour-intensive and demand specialist geological supervision.

3.6. Mountains, moorlands and heath

This section covers some of the most iconic semi-natural habitat components of the Welsh uplands, including blanket bog (upland only), dwarf-shrub heath (upland and lowland) and the very confined montane habitats of our highest upland regions. It also includes upland and lowland areas of bracken-dominated vegetation and rock exposures, and upland examples of fen and flush. Acid grassland, the most extensive upland habitat, is included in the grasslands section, but it is widely associated with all of the mountain, moorland and heath habitats. Coastal and dune heathlands are included under coastal habitats.

The dominant environmental factors at play in the Welsh uplands include a significant excess of rainfall over evapo-transpiration and seasonally low temperatures, though in a European context the Welsh uplands are oceanic in character.

Extent

The habitats of mountain, moor and heath cover a total area of 261,824 ha in Wales, of which 219,000 ha (>83%) occur in the uplands (defined here as land lying above the upper limit of agricultural enclosure). The most extensive elements are (in rank order) dry heath, bracken and blanket bog, with upland fen, marsh and swamp collectively accounting for 43,500 ha (this is split into its three components of marshy grassland, fen and flush - See Chapter 3.6).

This habitat suite is well represented in the SSSI series, with elements of it occurring as features on 118 SSSIs over a total area of 70,130 ha. The most numerous individually qualifying features are dry heath and wet heath (83 and 54 SSSIs respectively), natural inland rock exposures (30 SSSIs) and blanket bog (28 SSSIs).

The total upland area recorded by the Habitat Survey of Wales is 401,500 ha (19.3% of total Welsh land area)[173]. Much of this upland area is only of moderate height (c. 300-600 m) and would be regarded as sub-montane in character, with only c. 20,670 ha lying above 600 m[174] and meeting the definition of montane[175]. Habitats outside the mountains, moor and heathland definition – some 182,500 ha in total – include unimproved acid grassland (108,100 ha) and planted conifer woodland (43,700 ha).

Mountain, moorland and heath habitats are widespread in Wales, though distinct trends in distribution occur. In terms of the most extensive upland stands, dwarf shrub heath forms more than 20% of the cover of the Snowdonia mountains, north-central moorlands, western hills and border moorlands biogeographical groupings defined by Yeo & Blackstock[176], and is relatively less abundant in the southern uplands and south-central moorlands. Blanket bog is widespread, but the least modified examples form less than 5% of all areas in Figure 22, with the exception of the north-central moorlands: modified examples (including areas dominated by purple moor-grass *Molinia caerulea* and hare's-tail cotton-grass *Eriophorum vaginatum*) are much more prevalent in the south-central moorlands and southern uplands. Acid flush is widespread and forms 4% or more of all the biogeographical groupings with the exception of the comparatively drier border moorlands. Inland rock habitats are best represented in the Snowdonia Mountains, occurring as minor components (4% or less) of the area of the remaining biogeographical units. Montane heath extends to little more than 100 ha, with Welsh examples defining the southern UK limit of the distribution of this habitat.

The most extensive lowland areas of this habitat suite are represented by dry and wet heath (8,900 and 3,600 ha respectively) and bracken (30,100 ha). An important characteristic of lowland stands is the relatively smaller size of individual habitat patches compared with upland areas; for example, dry heath shows a trend from 9.9 ha for lowland stands through 18.6 ha for the upland fringe (including ffridd) and 25.7 ha in the uplands[173]. This reflects the extent of modification and fragmentation (through habitat loss) of habitats in the lowlands.

Some of the most important habitats of the ffridd are included in this habitat suite, notably bracken and heathland.

Some 60% of the Welsh deep (=/>0.5 m) peat resource occurs within the mountain, moorland and heath habitat suite, with most of it represented by blanket bog. Significant areas of deep peat occur elsewhere in the uplands, chiefly in conifer plantations, acid grassland, heathland and improved grassland. Lowland peatlands are covered in the freshwater section.

The inland rock resource in Wales is dominated by acid/neutral rock exposures (8,600 ha), reflecting the character of the dominant rock types of Wales. Exposures of basic rock (mostly limestone) amount to just 460 ha, including important exposures of limestone pavement associated with outcrops of Carboniferous Limestone in north and south Wales.

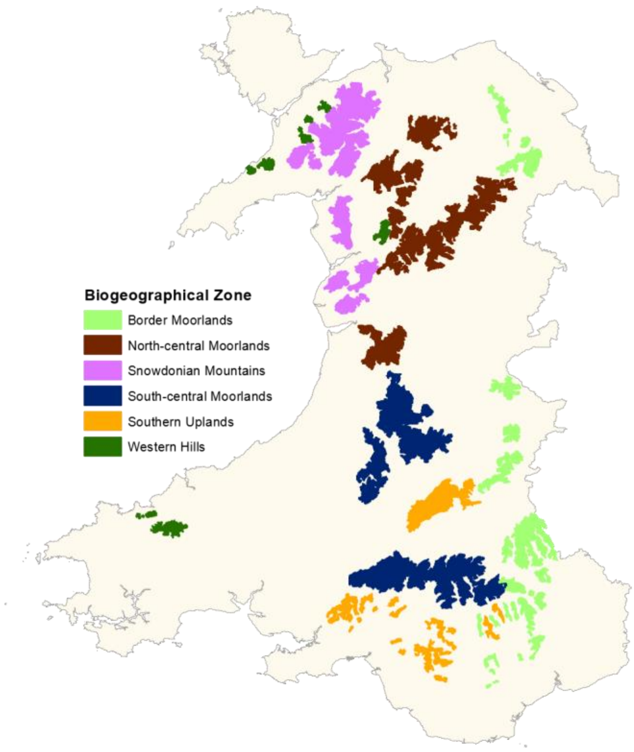


Figure 22 The six biogeographical zones defined for habitats in the Welsh uplands[176]

Condition

The condition of SSSI features corresponding to the mountain, moorlands and heath habitat suite is summarised in Chapter 3.6. The condition of the most extensive semi-natural habitats ranges between 63% and 73% unfavourable. These data are based on expert judgement collated during 2003 as opposed to systematic formal condition assessment. The main causal factors of poor condition resulting from land management are grazing (both excessive and insufficient), drainage, burning management, and invasive non-native species, including conifer seeding[177]. All montane habitats are currently judged unfavourable.

Large areas of habitats with a significant presence in the uplands are subject to atmospheric nutrient nitrogen critical load exceedance[178], (see Chapter 2). Ozone concentrations in the uplands remain at levels above the AOT40 threshold (the accumulated amount of ozone over the threshold value of 40 ppb) during the early summer, though AOT40 exceedance declined between 2006 and 2008[178] Twenty-five of the 47 grassland species tested were sensitive to ozone[179] and DEFRA[180] found a negative relationship between ozone and species richness in heathlands and bogs. (see section 3.1).

Table 9 Proportion of the key mountain, moorland and heathland broad habitats affected by exceedance of nitrogen deposition critical loads in Wales.

Habitat type	% area of Wales affected by atmospheric nutrient nitrogen critical load exceedance
Bog	100
Dwarf shrub heath	99.4
Montane habitats	100

The overall assessment of the conservation status of the 15 Annex I habitats associated with mountains, moorlands and heaths is either bad or inadequate (See Chapter 3.6 in SoNaRR)[181]. For many habitats this assessment relates mainly to condition, with habitat area judged as stable for 11 of the habitats, but unknown or declining for 4, with the most extensive of these (blanket bog) judged as declining. Only half of the area of the upland Annex I habitats (70,112 ha) has been subject to standardised Phase 2 survey to date, with the majority focussed in Special Areas of Conservation (SACs).

Almost three quarters of heathland features within SSSIs were judged as being in poor condition in the last comprehensive review[177]. For dry heath, typical indicators of unfavourable condition include closed canopy, lack of bare ground, lack of structural diversity and the dominance of *Ulex gallii*, with the latter of particular relevance in the lowlands. Scrub and bracken encroachment and invasive non-natives, particularly rhododendron[182], are also common. Indicators of over-intensive management, such as the reduction of the ericoid canopy and low diversity of both ericoids and associated species, is more common in the uplands, although localised heavy grazing in the lowlands can also reduce floristic and structural diversity[183]. However, lack of grazing and succession have been identified as pressures on lowland dry heath associated with coal spoil[184]. Lack of grazing is also a significant factor for wet heath in the lowlands and ffridd, with overgrazing more significant in the uplands.

Poor condition in blanket bog ecosystems manifests typically as graminoid or ericoid dominance, coupled with a reduced cover of Sphagna, with causal factors including past over- or undergrazing, fire history and drainage. Extensive areas of *Molinia* domination are a particular feature of blanket bog in central and south Wales, and the situation on the Elenydd plateaux may be unparalleled elsewhere in Britain[185], and certainly in Wales[178]. Hummock-hollow patterning is decidedly rare in Welsh blanket bogs; the extent to which this reflects drainage and peat cutting impacts or biogeographical factors is unclear.

At least 3,000 km of drainage ditches are estimated to occur on Welsh peatlands (excluding afforested areas), with approximately two thirds in the uplands and thus within this habitat suite[178]. A recent NRW analysis of drain blocking activity by all partners across Wales suggests a minimum of 742 km of drainage ditches on peat had been dammed up until May 2015. Comparison of this data-set with the drainage map produced from analysis of aerial photographs suggests the latter correctly predicts the location of 75% of ditch sections.

A recent assessment of the condition of upland peatlands in the Brecon Beacons National Park suggests widespread degradation over 50% of the resource and more localised degradation over the remainder[186].

Peat erosion is almost entirely confined to upland peatlands within the mountains, moorlands and heathlands broad habitat. There are at least 184 locations with signs of peat erosion across Wales, with bare peat amounting to an estimated 70 ha[187]. The actual figure may be closer to 120 ha if GMEP[178] estimates are upscaled to the total estimated extent of deep peat in Wales. Severe erosion, including loss of peat down to bedrock, is relatively localised and is most widespread in mid and south Wales. The overall extent of erosion in Wales is of relatively modest scale, and greatly reducing its extent to increase the resilience of blanket mires to climate change is feasible.

The environmental constraints of the upland zone in Wales place a limit on the range of non-natives that are considered to be problematic. Rhododendron, New Zealand willowherb *Epilobium brunnescens* and the seeding in of conifers influence the condition of several mountain, moorland and heath habitats (see section 2.2.5). Rhododendron is established in more than 2,000 ha across Snowdonia National Park, and affects Atlantic oak woodland, heathland and blanket bog[182].

Trends

In terms of historic trends, significant areas of mountain, moorland and heath habitats have been replaced by other land-cover types, notably acid and improved grassland and conifer woodland. Conifer woodland is estimated to occupy 8,690 ha of deep peat (primarily in the uplands)[188], much of which would originally have been blanket bog with smaller areas of flush and fen; some rare examples of raised bog in the uplands or upland fringes have been planted or heavily influenced by conifer plantations. The area of upland bog restored following plantation is steadily increasing as a result of NRW activity on sites prioritised for this measure[189], and also through the wind energy programme.

Detailed upland vegetation maps[174] indicate the important role of long-term anthropogenic pressure as one of the factors limiting the distribution of certain key upland habitat elements in Wales, with many critical gaps in distribution within the ecological range. There is a striking discord between the extent of chasmophytic (rock-dwelling habitats) and the estimated theoretical extent of c. 5,000 ha inferred from slope data: this probably reflects lack of survey data as much as habitat loss, and further underlines the need for targeted ongoing survey. Set against this is the evident potential for creating a much better connected upland landscape[190] which is more resilient to climate change.

A summary of the long-term degradation of the Welsh blanket bog resource[191] shows the least modified blanket bog estimated as representing only 40% of the blanket peat resource. Data relating to change in the condition of blanket bog over the last 30 years indicate no overall change[178], though most recently a significant increase in *Sphagnum* cover has been noted between 2007 and 2013/14, based on a relatively limited sample size. There has been a slight increase in the area of blanket bog since 1990[178].

The extent of bare peat appears to be declining, based on subjective assessment. The apparent decline reflects reductions in stocking density and the success of measures to reduce burning. Spontaneous recovery of exposed peat faces and flat areas where peat has been redeposited has been observed, especially on afforested sites with very limited or no grazing. Some of the most severe areas of erosion, particularly in south Wales, have expanded. Areas of active erosion with little or no sign of recovery are a priority for restoration.

It's estimated that the Berwyn has lost around 44% of heather-dominated moorland habitats (including heath and blanket bog) between 1947 and 1980[192], and similar losses are reported for the Clwydian Range and Llantysilio Mountain[193]. These changes probably reflect agricultural intensification coupled with wider grazing and burning issues. Over the longer term, more substantial declines have occurred, particularly with respect to wet heath. For example, for the Llŷn Peninsula a 95% decrease in wet heath was recorded between the 1920s and 1980s compared to a 50% decrease in dry heath[194]. These trends are likely to apply to other lowland areas in Wales.

More recently, a sample-based survey of the Snowdonia National Park[195, 196] has estimated a loss of 14% of upland fringe dry heath since the Phase I Habitat Survey of Wales programme was completed in 1997, with overgrazing by sheep as a contributory factor in the degradation of heathlands. Analysis of the Article 17 database for Natura 2000 habitats confirms grazing as the pre-eminent land-use activity affecting feature condition across many of the Annex I habitats included in mountain, moorland and heath.

An assessment of trends in the long-term condition of two montane habitats[174] (low alpine grassland and montane heath) shows a marked decline in habitat condition between the 1950s and 1990s, and this has been attributed to overgrazing, atmospheric deposition and visitor pressure. There are indications of improvements in condition since 2003, which may reflect reductions in grazing stock numbers and improving air quality.

Significant areas of this habitat suite are included in Glastir Entry and Glastir Advanced agri-environment schemes. For example, 41,531 ha of habitat on peat (much of it upland) has been included in the Glastir Entry scheme to date, with another 22,585 ha included in Glastir Advanced[197]. Agri-environment measures continue to be effective in helping to protect some of the most extensive mountain, moorland and heath habitats, with encouraging trends in condition noted for blanket bog and heathland and less strongly for flush and spring[198, 199].

Assessment of change in the extent and condition of mountain, moor and heath in the wider countryside (Figure 23) as a whole (i.e. including non-designated land) indicates a recent decrease in the extent of dwarf shrub heath and bracken and no change in acid grassland extent. There has been no change in habitat condition since 1990. These results indicate a halt in the historic decline of this habitat suite but no evidence of expansion or improvement of condition since 1990[178]. Payments through agri-environment schemes are likely to have contributed to the maintenance of current conditions despite ongoing pressures from eutrophication from air pollution and climate change but at a national scale overall improvement has yet to be realised. Modelling work simulating the potential benefit of a range of management interventions including bracken cutting which is relevant for this habitat suite highlighted a potential lag time of 1 to 2 decades for species to respond to management interventions and the need for consistency in payment schemes if benefits are to be realised[200].

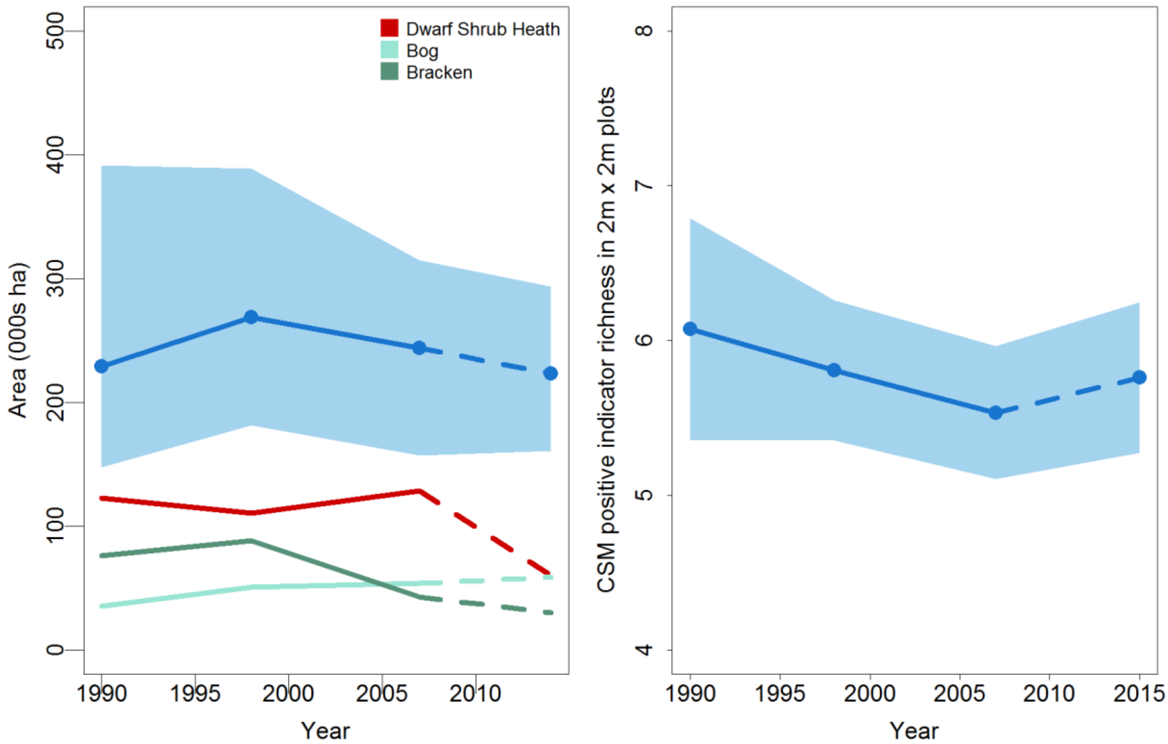


Figure 23 Ongoing trends in a) extent of mountain, moor and heath including extent of a selection of habitats which contribute to this habitat suite and b) trends in habitat condition. Habitats included in the overall extent assessment are bracken, dwarf shrub heath, inland rock, flush, montane, purple moor grass and blanket bog and other bog. Habitat condition is assessed by the richness of Common Standard Monitoring positive plant indicator species. The solid blue line indicates average value for a year with 95% confidence limits indicated by the shaded blue area. The dotted line connects GMEP results to comparable historic survey data (Countryside Survey 1990 - 2007).

Table 10 National estimates of Broad Habitat extents from GMEP and CS – '000 hectares

Broad Habitats	1990			1998			2007			GMEP 2013/14/15			Direction of significant changes 1998-2007
	Area Estimate	Lower estimate	Upper estimate	Area Estimate	Lower estimate	Upper estimate	Area Estimate	Lower estimate	Upper estimate	Area Estimate	Lower estimate	Upper Estimate	
Total MMH	229.2	151.7	395.61	268.6	188.1	399.1	244.1	159.3	312.5	223	160.9	290.1	
Bracken	76.1	52.2	142.6	88.3	38.1	141.7	42.6	26.1	65.0	30.2	17.51	46.7	
Dwarf Shrub Heath	122.6	47.9	262.4	110.7	55.6	185.9	128.3	65.0	181.4	60.1	26.3	105.2	2007-GMEP
Bog	35.2	5.9	39.1	50.6	21.5	87.9	53.8	23.4	81.1	58.7	29.5	95.0	1990-98
Montane	0	0	0	0.1	0.01	0.3	0.08	0.08	0.21	3.1	0	9.3	2007-GMEP
Inland rock	7.8	2.5	17.0	7.5	2.8	12.4	7.2	3.3	12.5	3.5	1.1	6.8	

3.7. Semi-natural grasslands

Extent

Grassland makes up nearly two thirds of the land cover of Wales[201]. The great majority is agriculturally improved, but semi-natural grassland types cover around 9% of the land area (c.192,000 ha), excluding upland marshy grassland which is discussed in the mountains, moorlands and heaths section.

Just over 78,000 ha of the semi-natural grassland is listed as Priority Habitats (as listed in the Environment (Wales) Act 2016, interim Section 7), more than 90% of which is in the lowlands[201,202]. Upland acid grassland remains relatively common in the uplands and ffridd, and is apparently stable in its extent[203], reflecting the long-standing and dominant use of the uplands as a grazing resource.

A total of 7,900 ha (around 10% by area) of all Priority Grassland Habitat is protected on SSSIs in Wales, although the proportion is substantially higher for some types of grassland (Table 11).

Table 11 Percentage coverage of grassland Priority Habitats on SSSIs in Wales. Data derived from a digital (GIS) overlay of grassland Priority Habitat areas and SSSI boundaries in 2012.

Grassland Priority Habitats	% on SSSI in Wales
Lowland Meadows	55
Lowland Dry Acid Grassland	5
Lowland Calcareous Grassland	57
Upland Calcareous Grassland	74
Purple Moor-grass and Rush Pastures	11
Calaminarian grassland	89
ALL	**10**

Eight forms of European protected grassland (listed on Annex I of the European Habitats Directive) occur in Wales, three of which – Calaminarian grasslands of the Violetalia calaminariae; Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels; and Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae) – have more than 10% of their UK resource in Wales. Areas of the Annex 1 grassland habitats in Wales are shown in Table 12. About 50% (by area) of Annex I grassland types form recognised ‘qualifying features’ on SSSIs in Wales. The area of Annex I grassland is considered favourable for just two of the eight types[204].

Welsh Government estimate that 21,400 ha of lowland grassland habitat are currently included in Glastir agri-environment scheme options, with 12,100 ha covered by Glastir Entry management options and 9,300 ha by Glastir Advanced.

Condition

In the UK's latest assessment of the condition of grassland Annex 1 habitats (2013), 92% of grassland SAC features were considered to be in unfavourable condition[204].

Aside from the SACs, recent data on the condition of grassland habitats on SSSIs are largely lacking. A review of the condition of SSSI features in 2003[205] estimated that just 43% of assessed lowland grassland features were in favourable condition, with neutral and calcareous grasslands being particularly poor (only 37% and 31% favourable respectively), and more than three quarters of grassland features in unfavourable condition were considered to be declining rather than recovering (See Chapter 3.7 in SoNaRR). Undergrazing was the most frequently reported factor affecting lowland semi-natural grassland (47% of SSSI features), but overgrazing was the key factor for upland grasslands. Monitoring of SACs in the early 2000s also highlighted undergrazing as the main 'adverse activity' affecting lowland grassland condition[206].

Very little is known about the condition of the 90% of semi-natural grassland which lies outside statutory protected sites in Wales.

Trends

The extent of semi-natural lowland grassland has declined enormously since the 1930s. There was a decline of some 97% between 1930 and 1984 in England and Wales[207], and an estimated 91% loss of all semi-natural lowland grassland, and 97% loss of dry grassland habitat, in Wales[202] (See Chapter 3). Losses were particularly severe from 1945 until the 1980s, due largely to agricultural improvement[208].

The rate of loss of lowland grassland habitat is thought to have slowed in recent years[202, 208]. This is in part due to improved levels of statutory site protection, as well as the inclusion of sites in agri-environment schemes and the application of the Environmental Impact Assessment (Agriculture) (Wales) Regulations. However, there is evidence that grassland habitat is still being damaged or destroyed[202,208, 209]. A re-survey of non-protected lowland grassland habitat in Wales in 2004 found a 25% loss of sites over an average 8 year period[202]. By comparison, an assessment of 52 grassland SSSIs[202] found that none had sustained significant damage or loss. A similar pattern was found in England[210] recording an overall loss of 47% of semi-natural grassland extent over a 32-53 year period, but a much smaller decline in grassland habitat on SSSIs (9%) compared to on non-protected sites (73%). These studies show the benefit of site protection in decreasing the rate of grassland habitat loss.

In the UK's latest (2013) submission[211] to Europe for the Habitats Directive, all eight of the Annex I grassland habitats found in Wales were considered to be in an 'unfavourable bad' conservation status (Table 12). Three of these habitats declined in extent in the UK over the 2001-12 period and in Wales one showed a decrease in area of more than 1% per year[204]. The most frequently cited (existing) pressures and (ongoing) threats are listed in Table 13. They include long-standing issues such as agricultural improvement and grazing (the latter largely expressed as undergrazing in the lowlands and overgrazing in the uplands), and more recent phenomena such as atmospheric nitrogen deposition, which causes both eutrophication and acidification of grasslands[212, 213], and climate change, which may negatively impact grassland habitat in a variety of ways, including excessive drying of wet grasslands and general decline in species intolerant of drought conditions. The effects of fragmentation of grassland habitats are particularly significant for plant and animal species which are unable to move between habitat patches, despite an increased need to do just that because of other pressures, including climate change.

Table 12 Summary of the conservation status of grassland Habitats Directive Annex I habitats in Wales[204].

Annex I habitat name	Surface area (ha) - Wales	Proportion (%) of UK surface area in Wales	Short-term trend direction – Wales (area)	Short- term trend direction – UK (area)	Overall conservation status - UK
Alpine and subalpine calcareous grasslands	1.7	0.2	↔	↔	*Unfavourable Bad*
Calaminarian grasslands of the *Violetalia calaminariae*	49.3	15.0	↓	↓	*Unfavourable Bad*
Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels	65.0	22.6	**?**	↔	*Unfavourable Bad*
Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*)	10.7	0.7	↑	↔	*Unfavourable Bad*
Molinia meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)	515.6	14.3	↓↓	↓	*Unfavourable Bad*
Semi-natural dry grasslands and scrubland facies: on calcareous substrates (*Festuco-Brometalia*)	741.0	1.5	↔	↔	*Unfavourable Bad*
Siliceous alpine and boreal grasslands	84.0	0.1	↔	↔	*Unfavourable Bad*
Species-rich *Nardus* grassland, on siliceous substrates in mountain areas (and submountain areas in continental Europe)	137.5	2.7	↔	↓	*Unfavourable Bad*

Table 13 Pressures/threats highlighted for grassland habitats in Wales during the most recent submission for European Habitats Directive reporting[204].

Pressure/threat	Number of times cited as medium or high (out of 8 habitats)
Atmospheric nitrogen pollution	6
Grazing issue (including undergrazing and overgrazing)	5
Agricultural improvement (including fertiliser use and drainage)	5
Habitat fragmentation	4
Forest/tree planting	3
Invasive non-native	2
Climate change	2
Building development	2
Recreational pressures	2
Other	4

Assessment of change in the extent and condition of semi-natural grassland in the wider countryside as a whole (i.e. including non-designated land) indicates a recent increase in extent in semi-improved neutral grassland but no change in upland acid grassland extent or condition since 1990 (Figure 24). New data also indicates a halt in the decline of plant species richness in habitat land which is dominated by semi-natural grassland[203]. Modelling work for some important grassland species emphasised the lag time of 1 to 2 decades for many species to respond to changes in management interventions to help restore the condition and extent of semi-natural grasslands and the need for consistency in payment schemes if benefits are to be realised[214].

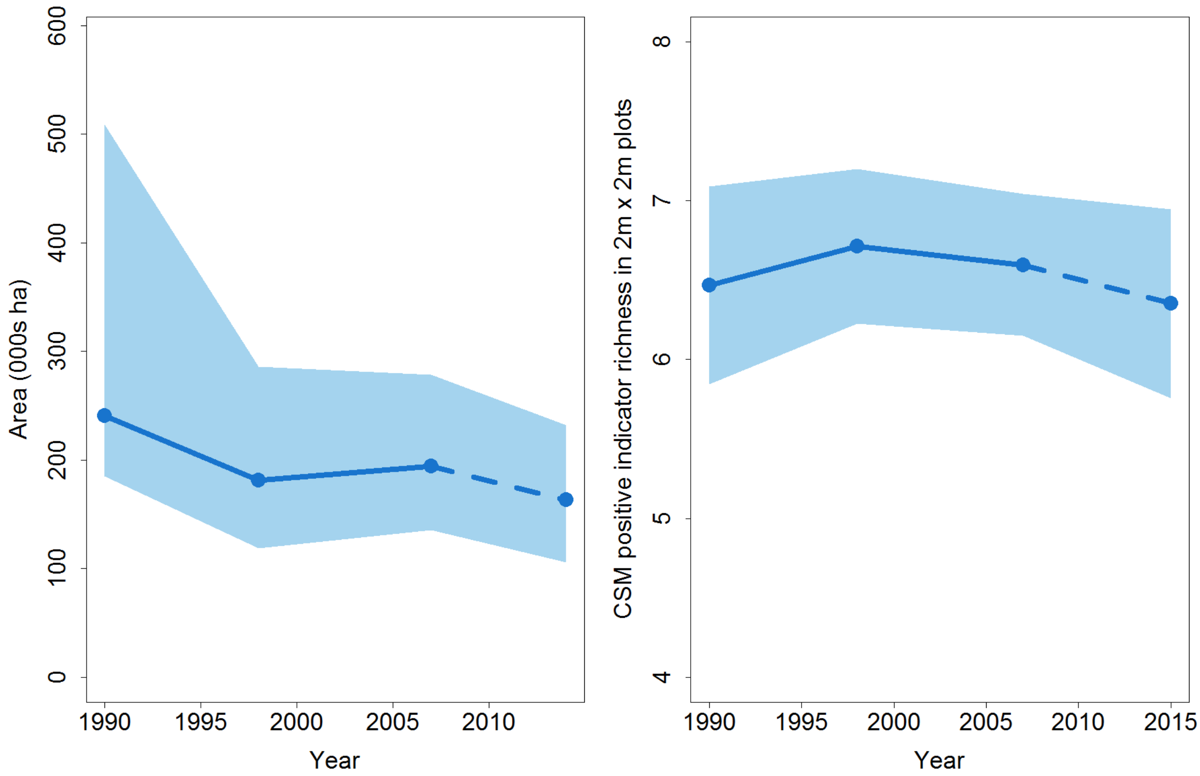


Figure 24 Ongoing trends in upland acid grassland a) extent and b) habitat condition. Solid blue line indicates average value with 95% confidence limits indicated by the shaded blue area whilst dotted line connects GMEP results to comparable historic survey data (Countryside Survey 1990 – 2007).

3.8. Enclosed Farmland

Definition and Extent

Enclosed farmland is a difficult concept to define[215]. It comprises those agriculturally improved grasslands, arable fields, horticultural lands and orchards which are bounded by hedges, walls, fences and other field boundaries, but excludes the ffridd as well as all enclosed semi-natural grasslands.

The total area of enclosed farmland in the UK National Ecosystem Assessment[216] was estimated to cover 804,000 ha. Improved grassland accounted for 731,000 ha and arable land covered 73,000 ha. This estimate was based in turn upon the relatively limited number of sample squares in the Countryside Survey of 2007[217] and hence has a broad confidence interval.

By contrast, the total area of permanent grassland identified in the Welsh Agricultural Survey is 1,068,814 ha, whilst enclosed semi-natural grasslands have been estimated to cover some 25-30,000 ha[218]. This suggests that the area of agriculturally improved permanent grassland may lie between 1,038,814 ha and 1,043,814 ha.

Arable and horticultural cropping cover 89,035 ha whilst grasslands under 5 years old account for another 157,501 ha. Adding these figures to the estimates for improved permanent grassland suggests that the total area of enclosed farmland in Wales could be as high as 1,285,350-1,290,350 ha. However, this approach involves making significant assumptions about how much of the permanent grassland in the Welsh Agricultural Survey[219] has actually been enclosed.

A third approach involves using the Habitat Survey of Wales[220]. Adding the area of lowland improved grassland in the Habitat Survey (1,012,700 ha) to the area of arable land (60,100 ha) produces an estimate of 1,072,800 ha for the total area of enclosed farmland. This has been rounded down to ‘around one million ha’ on the basis that a proportion of the lowland improved grassland will be located in the ffridd which is covered by the mountains, moors and heaths section.

For the purposes of SoNaRR we have chosen to use the estimate derived from the Habitat Survey of Wales. Although this pre-dates the Welsh Agricultural Survey it was based on a field-by-field assessment. In addition, the Habitat Survey method involves making fewer assumptions than the estimates derived from the other two sources, as well as representing something close to the mid-point in the range.

Condition

Welsh agricultural land is dominated by grass. Land use is determined by a wet but mild climate, relatively poor soil quality, relatively high altitudes and severe slopes.

Around 80% of the agricultural land in Wales has been designated under the Less Favoured Area Directive[221]. Such land is characterised by less fertile soils with limited agricultural potential and below average economic returns[222].

The combination of climate, topography and soils means that livestock rearing for meat and milk form the backbone of the agricultural industry. The much smaller cereal, horticulture, poultry and pig sectors are proportionally more significant in suitable locations. For example, cereal growing occupies 2.6% of the agricultural area in Powys, but 8.4% in Pembrokeshire[223].

Agricultural land, including commons, covers 1,842,900 ha[224]. Although rough grazings play a major role, especially within the sheep sector, the bulk of Welsh agricultural production takes place on enclosed farmland. This accounts for 54% of the farmland area, but is often better drained with more suitable soil, fertilised, and planted with agriculturally productive species. Rates of productivity per ha are therefore often much higher.

Recent data indicate overall plant species-richness has increased in improved land, and is stable in arable land since 2007. Plant species thought to reflect overall condition in both habitat types have remained stable225.

The amount of new planting of hedgerows has decreased and there is evidence of a large increase in frequency of cutting (Figure 25). Diversity of woody species in hedgerows has not changed significantly and there has been a decrease in the structural condition of hedgerows since those reported by Countryside Survey in 2007, from 44% in good condition to 31%[225], perhaps reflecting inappropriate management.

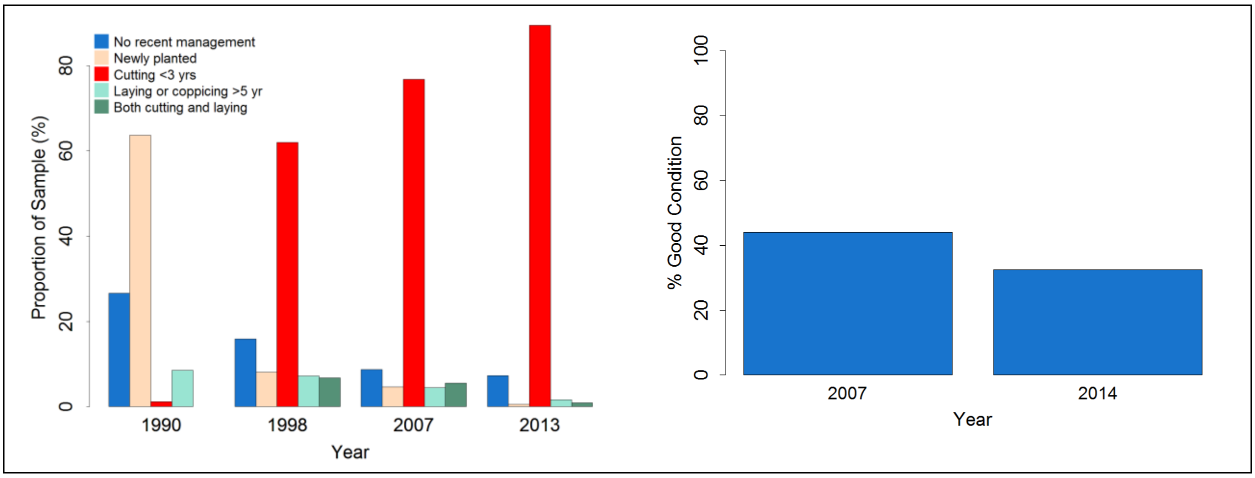


Figure 25 a) Trends in the percentage of new hedgerows and those in active management[217, 225] and b) Change in hedgerow structural condition between 1997[217] and 2014[225].

Cattle and sheep account for 41% of the value of Welsh agricultural output, with milk and milk products contributing a further 31%[223]. Mixed cattle and sheep farms accounted for some 55% of Welsh holdings with specialist beef (6%), specialist sheep (28%) and dairy (11%) making up the remainder. Of the 9.7 million sheep in Wales, nearly 50% are lambs under one year old. The dairy herd comprises 246,000 animals[226] or just under 23% of the total number of cattle and calves[224].

Poultry and egg production accounted for 7.5% of the value of Welsh agricultural output[224]. Some 96% of the current population of 7.85 million birds are concentrated on 133 holdings; each of which holds more than 10,000 birds.

Trends

Agriculturally improved grasslands, characterised by various strains of rye-grass and clover, now predominate throughout much of Wales, with an estimated total coverage of 1,027 million ha[220]. During the latter part of the 20th century these highly productive grass crops largely replaced semi-natural pastures and hay meadows. In addition, much of the land formerly devoted to hay cropping is now used for the production of silage. This is used for stock feed over the winter period, together with concentrates and forage crops such as oats, barley and maize[215].

Within the improved grassland category, those less than five years old (new leys) have increased by 37% from 115,000 ha in 2005 to 157,000 ha in 2015[224].

The number of sheep and lambs in Wales peaked at 11.8 million in 1998 before declining to 8.2 million in 2009. Numbers then increased steadily to 9.7 million in 2014 before falling back to 9.5 million in 2015. The number of breeding ewes now stands at 4.7 million – a decline of 15% since 1999[224]. More lambs are now being produced from fewer ewes, with progressive increases in lamb carcase weights. Such productivity gains over the period 2004-12[227] have been accompanied by changes in the utilisation of enclosed farmland and associated semi-natural habitats, with the former now undergoing more intensive management[228].

Cattle numbers peaked at 1.6 million in 1975, but had declined to 1.1 million by 2015. The current numbers of breeding female beef cattle (208,600) are more than 20% less than in 2004[225]. [224]

The number of dairy farmers has fallen by 30% (from 2,500 to 1,758) over the last decade[226] By contrast, the size of the dairy herd increased by 3% (from 238,386 to 246,331) over the same period[224].

CASE STUDY
The scale of poultry rearing and its impact

Recent work by NRW has demonstrated that large intensive poultry units can have fewer effects on air quality than much smaller, less intensive units.

Work in Powys[229] has examined the cumulative and in-combination effects of clusters of poultry units on the environment. These clusters tend to arise around animal processing units. Powys contains many hundreds of poultry units, with over 200 additional applications since 2008.

The NRW study looked at 14 poultry units utilising a worst-case precautionary approach; 13 of these had fewer than 40,000 birds each (below the threshold required for a permit under the Environmental Permitting Regulations or EPR) whilst the larger farm (80,000 birds housed in two sheds) was regulated under the EPR.

Conventional thinking suggests that the larger unit containing more birds would have bigger adverse effects, but preliminary investigation showed that the smaller,

CASE STUDY
The scale of poultry rearing and its impact

non-regulated poultry units had a greater impact on local ammonia concentrations than the regulated intensive farming unit. The fact that a 12,000 bird free-range farm can have a larger environmental impact in terms of local ammonia concentrations than 80,000 birds housed indoors appears counterintuitive.

A key difference is that the controls on the emissions from the intensive unit result in greater control of pollutants, thus reducing the concentration of ammonia in the environment. Ammonia is a form of nitrogen and can both directly and indirectly adversely impact sensitive plant species.

The NRW study also shows the kinds of effects that the number and type of farms in one particular area can have. Large poultry units may have less impact on local air quality than many smaller free-range units. However, ammonia emissions from both larger and smaller units can have significant ecological impacts if they are located too close to sensitive features e.g. on protected sites.

Note that this study relates only to Powys[229]. Different results could occur in other areas depending on the nature of the local environment.

Table 14 Climate Change Risk Analysis for Enclosed Farmland

Risks Associated with Climate Change	Observed Changes	Potential Impacts in relation to enclosed farmland	Other interactions
Changes in land capability and flexibility.		Over 1 million hectares of high-grade agricultural land across the UK are projected to be at high risk (1 in 75 years or greater) by the 2050s under a 4ºC climate change scenario. Potentially significant changes in land capability classification grades (based on current modelling which are likely to occur as a result of climate change). The existing model is heavily driven by sensitivity to drought[230].	Potential impacts on land capability are significantly affected by water availability. It remains unclear how such predictions will manifest themselves as farming systems will adapt (by using of irrigation drought resistant grasses etc). In addition, there may be an inherent oversensitivity to drought in the existing land capability classification system[230]
Reduced water availability for agriculture.		Increase in areas experiencing water deficits during the summer months. Location and extent of cropped areas could change and as a result there could be changes in enclosed farmland.	
Increase in waterlogging/flooding of agricultural land.	Crop losses due to flooding have been significant recently[231].	Wetter winters could increase prevalence of waterlogged soils, especially if these occur in conjunction with more rainfall in spring or autumn.	Additional drainage could alleviate water logging, however, this might exacerbate the effects of reduced water availability during summer months.

Risks Associated with Climate Change	Observed Changes	Potential Impacts in relation to enclosed farmland	Other interactions
Loss or asynchronisation of pollinator species.	Ranges of both bumblebees and solitary bees have contracted[232] although this may not be directly related to climate change.	Reduced fruit/seed production of crops reliant on pollinators may lead to changes in crop types on enclosed farmland.	Ongoing trend towards more intensive use on enclosed farmland including greater use of agrochemicals, re-seeding, increased stocking rates, habitat loss and fragmentation are the main factors resulting in the loss of pollinators. The effects of these may be exacerbated by climate change[228]. Changes in the selection of crop types may exacerbate decline in pollinators. Counter-measures are possible. For example, plants need to be grown that support pollinators outside the flowering period of the main target species for pollination.
Changes in crop yields productivity and impacts on livestock productivity.	Average length of growing season in England and Wales has increased by around 60 degree-days over the period 1914 – 2000, with a substantial increase in the last decade of the 20th century[230]. Lack evidence on the effect of climate change on beef and sheep system dynamics.	Limited knowledge regarding effects of climate change on soil-climate-crop-interactions together with subsequent impacts on crop and livestock production. Limited knowledge regarding the viability of likely adaptions in farming systems. Subsequent impacts on enclosed farmland are unknown, but concluded that 3M	Limited understanding of how to optimise sward composition in the context of climate change, the forage being grown and resulting interactions with animal productivity. Effects of heat stress can be reduced by providing access to drinking water and shelter[234].

Risks Associated with Climate Change	Observed Changes	Potential Impacts in relation to enclosed farmland	Other interactions
	Impacts of climate change on highly productive grass species are reasonably well understood, but little knowledge of impacts on permanent pastures and more marginal grasslands, together with subsequent effects on the livestock industry. Opportunities to grow alternative forage crops and diversify existing grassland swards. Heat stress in dairy cows can significantly affect milk yields and fat and protein content as well as causing animal welfare issues. Cattle behaviour can be negatively affected by cold and wet conditions. This could result in lower productivity, with reductions in time spent lying down and eating[235 236].	ha could become unprofitable for agriculture by 2060[233].	Impact of cold weather conditions can also be alleviated by providing shelter and dry surfaces[234, 235, 236].
Increase in frequency and	During the period 2009/10 - 2012/13 there were over 200,000 wildfires in Great	There is substantial year-on-year variation and the length of the existing record is insufficient to	Most fires start on permanent pastures (in particular on semi-natural grassland, heathland,

Risks Associated with Climate Change	Observed Changes	Potential Impacts in relation to enclosed farmland	Other interactions
magnitude of wildfires.	Britain. It is unknown how many of these affected enclosed farmland directly (fire damage) or indirectly (subsequent management changes due to fire affecting on parts of the farming system).	show any trends. However, the UKCP09 climate change projections show a consistent trend towards drier summers and more frequent droughts. This would be expected to lead to more frequent and severe wildfires.	moorland, scrub and bracken) before spreading to woodland or enclosed farmland. The management of semi-natural permanent pasture has the capacity to directly affect the likelihood that enclosed farmland will be impacted by fires.
Risk to agriculture from pests pathogens and invasive species.	The incidence of disease caused by endemic liver fluke *Fasciola hepatica* has increased[237];	Increased risk of incursion by exotic animal diseases, especially Bluetongue, and Schmallenberg which are carried by insect vectors. The likelihood these diseases becoming established within the UK is increased under a warmer climate. Changes in climate may result in existing crop pests having a greater impact e.g due to increased overwintering, changes in population growth rates and development seasons[238]. Plant health is predicted to suffer as a result of climate change[239].	Changes in populations of pests, pathogens and invasive species may not have a direct impact on enclosed farmland. Indirect effects may arise as a result of the management undertaken to alleviate or control such species e.g. through increased use of pesticides.
Impacts of extreme weather events.	Unexpected heavy snows in the spring of 2013 caused higher rates of calf and cow mortality	The impact of climate on enclosed farmland is most evident under extreme weather. The predicted	

Risks Associated with Climate Change	Observed Changes	Potential Impacts in relation to enclosed farmland	Other interactions
	than in the previous three years as well as resulting in fewer lambs per ewe[240].	increase in extreme weather events is therefore likely to lead to a significant increase in existing risks.	

3.9. Woodlands

The term ‘woodland’ means different things to different people, and is often used interchangeably with the term ‘forestry’.

Extent

In the centuries following the last Ice Age, much of Wales developed into woodland – the so called ‘wildwood’. The clearance of native forests started many thousands of years ago and only in the last 80 years has the decline in woodland cover been halted and partially reversed, although this was mainly through the planting of non-native conifers on marginal sites. Over the last two decades and since the introduction of the Broadleaves Policy to Great Britain in 1985, much has been done to create new native woodland cover including the provision of targeted grant aid to both plant new woodlands and bring neglected native woodlands into management[241].

Wales has 306,000 ha of woodland with 38% comprising the Welsh Government Woodland Estate[242] (WGWE). Wales is one of the least wooded countries in Europe, with woodland covering only 14.8% of the land area compared to the EU average of 38%[242]. Since 2001, the estimated area of conifer woodland in Wales has decreased by 18,000 ha, while the estimated area of broadleaf woodland has increased by 35,000 ha[242]. The classification of woodlands in Wales is provided in Chapter 3, section 3.9.

There are also 15.3 million trees in Wales outside woodlands[242]. More than half of these trees are growing along linear features like hedgerows, riverbanks and roadsides, while the rest are found in orchards, parks, wood pastures and urban areas.

The amount and type of new woodland planting in Wales changed between1971 to 2015[242] (see Chapter 3, section 3.9). Rates of new planting were significantly higher in the 1970s and new planting was almost exclusively with conifers. In contrast, planting rates in the last two decades have been much lower, and have predominantly been with broadleaves. New planting is influenced by government policy and the availability of grant funding[243]: after the Second World War, government policy resulted in the planting of large areas of non-native coniferous plantations, whereas now public funding supports mixed or native broadleaf planting for carbon and biodiversity benefit. There is concern that the focus on low density broadleaf planting will impact in the medium and long term on the productive capacity of Welsh woodlands for timber production and carbon sequestration[244, 245, 246].

The composition of woodlands in Wales is an important measure in relation to the benefits that can be derived from them but also in terms of their resilience to future climate change. Table 15 summarises the main tree species diversity by river basin district in Wales in 2012: together, the three river basins cover the whole of Wales.

Table 15 Predominant tree species by river catchment in Wales[242]

Catchment	Dominant tree species
Dee River Basin District	The most common woodland trees are Sitka spruce *Picea sitchensis* (27%), birch *Betula spp.* (12%), and hawthorn *Crataegus monogyna* (10%).
Severn River Basin District	The most common woodland trees are Sitka spruce (17%), oak *Quercus spp.* (11%), and hawthorn (10%).
Western Wales River Basin District	The most common woodland trees are Sitka spruce (30%), oak (11%), and ash *Fraxinus excelsior* (8%).

Condition

Overall management

Forest Research are due to publish a report on forest condition in 2017, derived from the National Forest Inventory[247], which will be based on age and structural diversity, tree species composition, deadwood, regeneration factors and threats to woodland biodiversity such as the impact of browsing damage by animals and the presence of invasive non-native species. Until this report is available, an overall proxy for woodland condition is the amount of woodland in Wales that is managed to the UK Forestry Standard (UKFS) for sustainable forest management. The total area of woodland in Wales *known* to be managed to the UKFS has increased from 123,000 ha in 2001 to at least 203,000 ha in 2014[242]. The total area managed to the UKFS is likely to be higher.

Biodiversity

All woodlands, including 20th century coniferous plantations, provide habitat for a wide range of flora and fauna[248] but some woodland types are more significant than others from a biodiversity perspective. Semi-natural broadleaved woodlands in Wales comprise six of the interim Section 7 list habitats of principal importance and support 39% of interim Section 7 species of principal importance.

They also include seven habitats listed under Annex I of the EC Habitats Directive 1992. The overall conservation status of these seven woodland habitats is regarded as unfavourable, although there is a trend of increasing favourable management with local recovery in response to SSSI management agreements, National Nature Reserve (NNR) management and a wide range of targeted restoration projects. The percentage of both area and number of woodland features in SACs which are in favourable condition has declined between 2002 and 2012[249]. The LIFE Natura 2000 Programme data shows that inappropriate or inadequate woodland management and the negative effects of deer are having (or likely to have) an impact on 44 out of 123 different Natura 2000 habitat or species features (36%), on 47 out of 112 Natura 2000 sites across Wales (42%)[249].

Woodland processes work over very long time-scales, which means that favourable condition status may not be achieved for a long time, even if appropriate management is in place and condition improving. In relation to SSSIs, the rapid assessment of SSSI features in 2003[250] suggested that the condition of SSSI woodlands in Wales by site was 31% favourable and 69% unfavourable; of the unfavourable sites for which there were data, 54% were classed as recovering.

Key to the value of woodlands for biodiversity is the management regime. Outside of the WGWE, it is estimated that 147,000 ha of woodland in Wales (around 40%) is under-managed or in no management at all: these woodlands are typically native, mostly small and fragmented, and often on farms. In Wales there are nearly 22,000 woodlands identified as being smaller than 2 ha and a further 10,000 woodlands between 2 ha and 10 ha[251]. In general a lack of management results in closed canopy woodlands with little age-structure diversity, an under-developed shrub and ground flora, and a lack of regeneration and fewer opportunities for biodiversity. Inappropriate management includes overgrazing, which has a significant effect on the ground flora of woodlands and on the regeneration of shrubs and trees. This can be caused by wild deer and also domestic cattle and sheep. Established trees can also be affected through fraying by deer and bark stripping by deer and sheep.

Habitat change, particularly fragmentation, is a significant pressure affecting the condition of native woodland in Wales. The fragmentation of woodland habitat into smaller isolated patches poses one of the key threats to forest biodiversity[252], as it reduces the total amount of habitat area (and particularly core habitat) and increases patch isolation. Intensification of and changes in land uses surrounding woodland patches may exacerbate the effects of isolation for many woodland species. Semi-natural and extensive habitats are considered to be more conducive, or permeable, to species movement, while intensive land uses are regarded as less permeable, thereby reducing connectivity and effectively increasing ecological isolation. Many forest species have evolved within a highly connected and extensive habitat, and fragmentation has inevitably had a major impact on them. Without remedial measures those with high habitat area requirements (e.g. pine marten *Martes martes*) will become extinct rapidly, while wider biodiversity (e.g. ancient woodland flora) exhibit a slow attrition. There are concerns that climate change may further compound these effects.

The LIFE Natura 2000 programme thematic action plan for woodlands recognises that the current fragmentation threatens woodland biodiversity on Natura 2000 sites and recommends increasing the size and connectivity of woodlands through new planting. As 40% of Wales' woodlands are estimated to have little management, this diversity is missing from a significant proportion of woodlands. Single species plantations also lack the diversity of species and structure that increase the biodiversity value and resilience of woodland.

Natural regeneration of native woodland is important for genetic health and local adaptation. It is also useful for measuring the health of our non-native plantations to ensure continuity of woodland conditions and the flow of benefits from woodland ecosystems. Regeneration is negatively impacted by browsing and grazing pressures from domesticated and wild animals. Wild deer are now more common and widespread in Wales than at any time in recent history[253]. Management to reduce their impacts is key to prevent population and range increases. Two deer species present in Wales are non-native and have the potential to impact native biodiversity, through hybridization (Sika deer *Cervus nippon* with native red deer *Cervus elaphus*) and different habitual behaviour (Reeves Muntjac deer *Muntiacus reevesi* are a solitary species that easily adapt to different habitats).

Woodland condition and timber quality is highly affected by damage from grey squirrel *Sciurus carolinensis*, an invasive non-native species (INNS) which is widespread across Wales in both rural and urban situations. Grey squirrel bark stripping behaviour often prevents trees reaching maturity, significantly reduces timber quality, and provides entry pathways for pests and pathogens. Grey squirrels can alter the species composition of woodlands through preferential damage to particular species and prevent investment in management of quality broadleaf stands. *Rhododendron ponticum* is well established in many woodlands in Wales and impacts upon woodland condition reducing flora, fauna and regeneration potential through shade and chemical changes to woodland soils[254]. It can prevent safe woodland management without prior expensive removal. It is also a virulent sporulating host of *Phytophthora ramorum.*

Productivity
At least 60% of the woodlands in Wales are actively managed, mainly for timber production but also other management objectives including recreation, wildlife and conservation. The most recent data indicate that the total GVA of the forestry sector in Wales is £499.3 million[242]. This figure relates to forestry and logging, the manufacture of wood and products of wood and cork, and the manufacture of paper and paper products. Woodland condition is linked to timber quality and production and therefore potential GVA. Timber production from the private sector in Wales has gradually been increasing as planting over the past 50 years has reached productive age (Table 16).

Table 16 Softwood timber production in Wales, by sector, 2005-14[255]

Year	Public sector	Private sector	Total
	Volume harvested (green tonnes)		
2005	673	266	939
2006	612	326	938
2007	584	382	966
2008	556	333	889
2009	717	321	1,038
2010	644	429	1,073
2011	689	501	1,190
2012	663	611	1,274
2013	693	695	1,388
2014	722	739	1,461

The forecasted availability of softwood and hardwood timber in Wales to 2061, on the WGWE and from woodland in other ownership, is presented in Chapter 3, section 3.9. There is forecasted to be a significant drop in softwood timber availability over the next 30 years but this can be compensated for by smoothing out production levels, bringing more woodland into management, and creating new woodland that is capable of producing utilisable timber. Forecast data also show an increase in the availability of hardwood timber presenting market development opportunities, though concerns remain over the quantity and quality of products that could eventually be derived from this increasing resource.

Carbon sequestration

Woodland condition (and extent) is linked to carbon sequestration potential[256] (i.e. carbon stocks held in woodland biomass, soils and wood products, plus the carbon abatement opportunity due to product and fuel substitution). Carbon sequestration from Welsh woodlands is estimated to be about 1,419,000 tonnes annually[242.]

Forestry is predicted to remain a net sink for atmospheric carbon. Whilst the social value of net carbon sequestration by Welsh woodlands is double the market value of wood production per hectare[248], carbon sequestration remains a largely non-market benefit and there is little incentive for landowners and managers to increase provision or maintain existing storage. Appropriate new woodland creation would have a positive impact on total carbon stocks held by Welsh woodlands.

Tree health

Woodland condition has been heavily affected by increasing pressure from pests and pathogens, with outbreaks of two quarantine diseases affecting tree species in Wales (*Phytophthora ramorum* and *Chalara fraxinea*) since 2010 (Table 17). There are also a small number of non-quarantine pests and diseases known to be affecting tree species in Wales, such as a small outbreak of *Phytophthora lateralis* in South Wales in 2012[242].

Table 17 Current Tree Health Issues and Future Threats[257, 258]

Main current concern	Established threats	Examples of emergent threats to Protected Zone Status
Genera *Phytophthora* (Greek for ‘plant destroyer’) and its impact on forest ecosystems.	Red Band Needle Blight (caused by the fungus *Dothistroma septosporum*) affecting pines.	*Xylella fastidiosa* is a disease-causing bacterium that affects a wide range of important woody plants and broadleaved trees.
Phytophthora ramorum affecting mainly larch *Larix decidua* but also a wide range of tree and shrub species.	Acute Oak Decline (AOD) affecting both of Britain's native oak species (currently isolated stands in eastern Wales).	Asian & Citrus longhorn beetles affecting deciduous trees especially *Acer spp*.
Chalara fraxinea affecting ash both in woodland and the wider environment.	Green spruce aphid *Elatobium abietinum* affecting spruces but mainly Sitka spruce.	Oak processionary moth *Thaumetopoea processionea* already present in England.
	Large pine weevil *Hylobius abietes* affecting newly planted trees.	Bark beetles *Ips typographus, Ips amitinus* and *Ips duplicatus* affecting spruce especially with milder, wetter winters.
	Great spruce bark beetle *Dendroctonus micans*	Gypsy moth *Lymantria dispar*, a defoliator of

Main current concern	Established threats	Examples of emergent threats to Protected Zone Status
	affecting spruce. Various *Phytophthoras* including*, P. lateralis, P.cinnamomi, P pseudosyringge* and *P.cambivora* affecting a wide range of plant species.	important woody plants and broadleaved trees. Chestnut blight *Cryphonectria parasitica* affecting sweet chestnut *Castanea sativa*.

Phytophthora ramorum is the most significant tree disease to affect woodlands in Wales in recent years. It has caused the widespread death of larch, a significant timber-producing tree species, and is a potentially serious threat to other trees and plants. The long-term prognosis for larch in Wales is of concern, particularly as tests have shown that sporulation on infected European, Hybrid and Japanese larch far exceeds other hosts such as rhododendron, sweet chestnut and bilberry *Vaccinium myrtillus*. As at 25th November 2015, approximately 8,582ha of larch[259] in Wales has been found to be infected with *Phytophthora ramorum* (Table 18) and larch is no longer used for restocking on the WGWE. The distribution of *Phytophthora ramorum* in Wales is shown on Chapter 3, section 3.9.

Table 18 Area of woodland affected by *Phytophthora ramorum*, 2010 to 2015[259]

Sites taken under Notice	2010	2011	2012	2013	2014	2015 (to 25/11/15)	Total
Private Sites (ha)	18	65	356	903	249	271	1,862
Public Sites (WGWE) (ha)	817	442	1,117	2,981	161	1,202	6,720
Total (cumulative)	835	1342	2,815	6,699	7,109	8,582	8,582

Chalara dieback of Ash was first confirmed in the UK in February 2012 when it was found in a consignment of infected trees sent from a nursery in the Netherlands to a nursery in Buckinghamshire, England. In October 2012 it was also found in the wider environment in woodland in the east of England and South Wales. It is potentially a very serious threat, having caused widespread damage to ash populations in continental Europe, including estimated losses of 60-90% of Denmark's ash trees. There is no reason to believe that the consequences of its entering the natural environment in Britain would be any less serious. Experience on the continent indicates that it kills young ash trees very quickly, while older trees tend to resist it for some time until prolonged exposure causes them to eventually succumb. In 2015, the disease was located at 100 individual sites across Wales[260]. The disease is now clearly established and sporulating in the wider natural environment across the country, albeit at low levels, and not restricted to new planting sites as previously thought. The majority of new cases have been found in roadside hedgerows and natural regeneration.

CASE STUDY The impact of tree disease on hedgerows
• The aggressive species of Dutch elm fungal disease emerged in Britain in the late 1960s, imported on elm logs from Canada. By 2010 it was considered some 60 million elm trees had been lost to the disease. • Elm is still a common component within hedgerows, but it no longer grows to its full height as regular new infections continue to occur. • *Chalara* (ash die-back) is now a major environmental threat. Welsh hedgerows contain a large proportion of ash, both in the shrub layer and as standard trees. Loss of ash trees will create gaps in hedgerows as well as removing a significant proportion of mature trees from the landscape. This is also likely to have a major impact on the other species that depend on ash trees.

Trends

Trends in woodland extent, condition and state, where known, are summarised in Table 19. Additional information about observed and predicted trends due to climate change are summarised in

Table 20. Climate change has wide-ranging implications for woodlands in Wales, in terms of the way they are managed, the suitability of different tree species, and the benefits derived from them, but also in relation to Wales' carbon footprint and the role woodlands play in climate change mitigation and adaptation.

Table 19 Summary of trends in woodland condition and extent (adapted from[242])

Woodland measure	Desired trend	Apparent trend	Comment
Area of woodland in Wales	↑	↑	Rates of new woodland creation are low, and very dependent on public funding. WG aspires to increase woodland cover to 20% of Wales by 2030, but this is unlikely to be achieved without significant intervention.
Diversification of woodlands	↑	-	WG commitment to increase the diversification of Welsh woodlands to improve woodland condition and resilience. Diversification likely to be improving slowly, due to increased planting of broadleaves relative to conifers. Genetic diversity measure yet to be developed. National Forest Inventory (NFI) Woodland Condition survey data due 2016/17.
Sustainable woodland management	↑	↑	Proxy indicator of woodland condition (area managed to UKFS)
Carbon balance	↑	-	Work is currently underway to calculate the carbon balance for the WGWE.

Woodland measure	Desired trend	Apparent trend	Comment
Extent of pests and diseases (tree health)	→ or ↓	↑	Risk of pests and diseases is likely to increase in the future due to predicted changes in weather patterns and climate. Diversification of woodlands is key to improving resilience.
Condition of native woodland	↑	→ or ↑	NFI reporting 2016/17 will provide more data on woodland condition across Wales but not necessarily significant below country level.

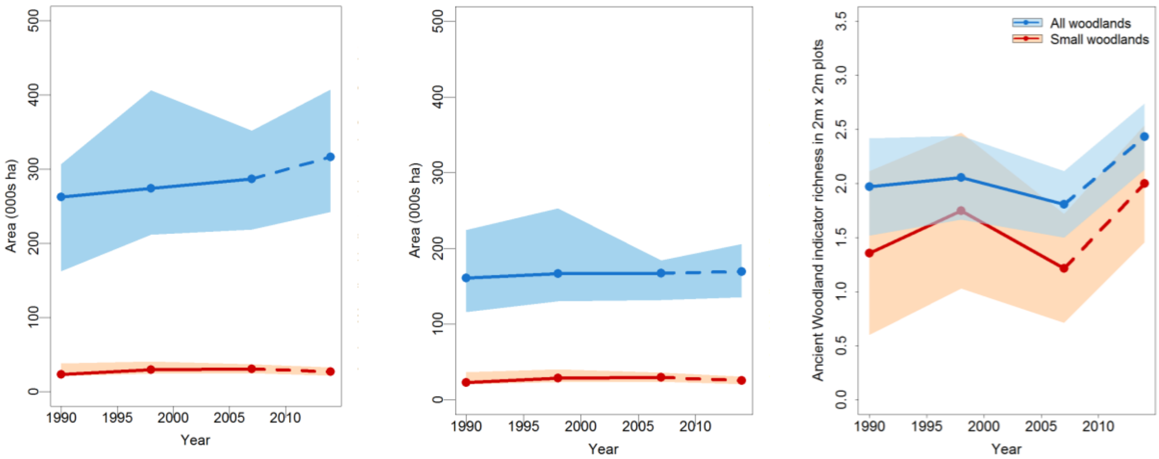
Table 20 Summary of observed and predicted trends in woodland extent and condition in Wales due to climate change (adapted from[261, 262, 263, 264, 265])

Trend (impact)	Observed changes to date	Predicated changes based on climate change projections
Impact on forestry from pests, pathogens and invasive species.	Since the 1990s red-band needle blight (caused by the fungus *Dothistroma septosporum*) has become widespread in Britain, mainly on Corsican pine *Pinus nigra*, less so on other pines. This could be due to increased rainfall in spring and summer, coupled with the trend towards warmer spring temperatures.	Increased risk from pests and diseases. Pest and disease ecology will change with the climate; for example, more frequent green spruce aphid attacks may reduce Sitka spruce growth in west, east and south Wales. Milder winters will increase the size of overwintering populations. Longer and warmer growing seasons may increase the development rate of insects and, for some, the number of generations per year. In addition, warmer conditions and increased CO_2 will encourage development of more foliage for food – often shortening time to maturity.
Impact on tree growth and woodland productivity	Woodland Ecological Change Network sites – observing earlier flushing and lack of pre-chilling of seed in warmer winters, which is impacting on the ability to germinate and the decline in pollinators in spring.	There will be a change in tree species suitability. There could be increased growth rates of some species, particularly in west Wales where the climate becomes warmer and soil moisture does not become restricting. Soil moisture and increased occurrence of droughts will increasingly become a limiting factor. This will affect a number of species, including Sitka spruce in some areas. The epidemiology of tree diseases will change. For example, wetter and milder winters followed by droughty summers may predispose Oak and other broadleaved species to root pathogens such as *Phytophthora cinnamomi.* A longer and warmer growing season is likely to lead to increases in tree growth rates for some species, particularly in cooler and wetter areas such as western Wales. However, growth stimulation from higher CO_2 concentrations are reduced

Trend (impact)	Observed changes to date	Predicated changes based on climate change projections
		when nutrients are limited, as occurs in a high proportion of Welsh forests due to the large areas of peaty soils.
Impact on soils from increased aridity and changes in rainfall patterns	Likely, but incomplete evidence. Presents increased risk from forest management operations through unpredictability of rainfall intensity and changes in seasonality.	More waterlogged soil conditions are likely to occur. Drought stress will become more critical when winter waterlogging is followed by summer drought, making trees more susceptible to pests and disease outbreaks. Some tree species are particularly unsuited to sites with seasonally fluctuating water tables from very wet to dry conditions, especially beech *Fagus sylvatica* and Douglas fir *Pseudotsuga menziesii*.
Impact on forestry from change in frequency and/or magnitude of extreme weather and wildfire events	In dry summers there is evidence of increasing forest-fire frequency and an increase in the area of woodland damaged by forest fire. The leafing date of oak has advanced by 2–3 weeks since the 1950s in response to increased temperatures and there is some evidence that this is having a negative impact on woodland flora, particularly vernal species. Wind damage to forests is a major problem to forestry in UK and across Europe where wind and snow storms cause approximately half of all damage to forests. Wildfire data has begun to be systematically collected in Wales and land management actions identified[264]. Warmer and drier springs have seen a vast	Extreme weather events such as storms and high winds and summer droughts and fires could become more frequent. Predicting future changes in storm tracks is highly uncertain. However, warmer autumns, with consequent later leaf loss, are likely to increase the risk of damage in deciduous species. Wind damage may also increase with higher levels of soil wetness, as waterlogging reduces rooting depth and consequently tree stability. Climate modelling suggests that fire risk will increase by 30-40% in our three National Parks by the 2080s. Increased tree mortality from droughts and from pests and diseases may in turn increase wildfire risk through increased fuel availability. The growing season is predicted to lengthen. Some species of tree will have earlier bud-burst and later dormancy, giving more frequent and prolonged late season (lammas) growth which may reduce timber quality. In theory, earlier leafing will increase net primary productivity through extending the growing season. However, earlier leafing may have negative impacts on the wider

Trend (impact)	Observed changes to date	Predicated changes based on climate change projections
	increase in grass and forest fires before fresh growth begins. In Spring 2015 there were 513 deliberate fires in Rhondda Cynon Taff, though wetter and cooler conditions in Spring of 2016 shows a markedly lower incidence.	woodland ecosystem through affecting the synchrony between different trophic levels (for example, oak, winter moth caterpillar *Operophtera brumata* and blue tit *Cyanistes caeruleus*), or through reducing the amount of light available for characteristic woodland ground flora specialists such as bluebell *Hyacinthoides non-scripta*, wood anemone *Anemone nemorosa* and sanicle *Sanicula europaea*.
Impacts on woodland flora and fauna	A repeat survey of 103 British woodlands (1970, 2001) detected a long-term decline in woodland specialist richness. This is thought to be mainly due to the deterioration of woodland quality and reduced management, although changes in the timing of seasonal events (such as earlier tree-leafing) may also have had adverse implications for ground flora and other woodland species due to phenological mismatches	Mammal numbers, including deer and grey squirrel, are likely to increase. Milder winters with fewer frost days will reduce winter mortality, increase the recruitment of young, and increase damage to trees through browsing and bark stripping. The fragmentation of woodland and other habitats may be enhanced as species may need to move to find more suitable climatic conditions. However, due to connectivity issues, some woodland species will have limited ability to move to new climatic spaces.
Impacts on carbon sequestration	There is some evidence of enhanced tree biomass growth across Europe in recent decades, but this may be attributable to non-climate related factors (enhanced N deposition; recovery from S deposition; forest management changes)	Climate change may have direct impacts on the ability of soils and vegetation to sequester and store carbon. A longer growing season and increased CO_2 concentrations in the atmosphere could increase sequestration rates by trees, but expected future changes in tree growth are subject to considerable uncertainty as they will be influenced by a range of climate-related risks such as drought, pests and pathogens, and wildfire.

An overall increase in the area of woodlands is due to increases in the area of conifer woodland, with no increases seen in the area of broadleaf woodland over the last 15 years. There was an increase in the amount of small (<0.5ha) broadleaf woodlands across Wales (1984-2007) which has since stabilised with no recent increase from 2007 to 2015 (Figure 26)[266]. Condition, as assessed using the number of Ancient Woodland Indicator plant species, shows a recent improvement for broadleaf woodlands although this appears very dynamic over time (Figure 26)[266]. An increased canopy density, associated with reduced management levels, reduces the light levels required by many species and may be limiting the expansion of some species[266]. However, shade favours other groups of species. Modelling work for some important woodland species indicates that management intending to ensure improved condition and biodiversity of these habitats incurs a lag time of 1 to 2 decades for ground flora to respond to changes[267]. Evidence from the BTO/JNCC/RSPB Breeding Bird Survey[57] shows a recent rise in the Woodland Bird Indicator. This is due to increases in several generalist and oak woodland-specialist species[268]. It is unlikely to reflect the impact of increased coniferous woodland cover in Wales but may reflect the increase in small broadleaf woodland areas.



(a) (b) (c)

Figure 26 a) Ongoing trends in the extent of all large conifer and broadleaf woodlands (blue) and small broadleaf woodlands (red). b) Ongoing trends in the extent of Welsh large (blue) broadleaf and small (red) broadleaf woodlands. c) Ongoing trends in the condition of broadleaf large (blue) and small (red) woodlands[e].

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[e] *The selection of Ancient Woodland Indicator species for Welsh woodlands is subject to an ongoing process of consultation with NRW. Thus the composition of the list is likely to change in the future. Solid blue and red lines indicate average value with 95% confidence limits indicated by the shaded blue or red areas whilst the dotted line connects GMEP results to comparable historic survey data (Countryside Survey 1990 -2007)[e]*

3.10. Freshwater

Freshwater habitats are here defined as inland running waters (rivers and streams), and standing waters (lakes and ponds) above the tidal limit and with water which would not be classified as saline. These habitats drain terrestrial catchments and are closely associated with significant areas of wet terrestrial ecosystems such as floodplain wetlands, wet woodland, reedbed and swamp. Water quality and flow in freshwater habitats is therefore intimately connected with the condition of the surrounding terrestrial habitats.

Extent

Rivers
This term refers to all water flowing in an identifiable channel for most of the year. 'Rivers' and 'streams' are regarded as a continuum within a catchment-level network. Both longitudinal connectivity (ability to migrate up and downstream) and lateral connectivity (maintenance of the natural flood cycle and connection to floodplain habitats) are crucial to river ecology[269]. Naturally, most running waters flood during wet periods, and the sustainable management of floodplains and flooding is an important challenge for Wales.

Estimates of river length depend strongly on the scale of mapping and the definition of a stream. The Water Framework Directive (WFD) dataset covers only the more significant rivers and streams, and provides a structured estimate of Welsh river length of 7,711 km, divided into 15 separate types (Table 21, Figure 27). However, a more detailed estimate indicates that Wales has approximately 24,000 km of river and stream[270], with the difference mainly accounted for by small headwater streams not mapped on the WFD dataset.

The WFD typology covers a range of different catchment altitudes, sizes and geological types (Figure 27), which provide a spatially comprehensive overview of the range of river types within Wales. Wales consists primarily of neutral to slightly acidic catchments (5,100km / 66%), which are located mainly in the north and the west. Calcareous catchments (2611 km / 34%) occur mainly in south-east and north-east Wales. Organic (peaty) catchments are very rare (6 km / < 1%), though it is probable that the WFD dataset underestimates the true extent of this river type. These general patterns tend to be reflected by the biological communities, which include aquatic plants, invertebrates and fish[271, 272, 273.]

The WFD typology does not capture all of the key aspects that contribute to river biodiversity. Examples of these types of habitats include the headwater flushes where rivers originate; geological features such as gorges and waterfalls; groundwater influence; surrounding vegetation; and meandering, low-gradient sections.

Table 21 Length in km in Wales of different WFD river types as defined by the UK WFD typology[274]. Low altitude catchments have a mean altitude <200m; mid-altitude catchments have a mean altitude of 200-800m. Dominant geology has been determined using GIS.

Dominant Geology	Catchment Size	Mid Altitude Catchment	Low Altitude Catchment
Siliceous	Extra Small (<10km^2)	42	248
	Small (10-100km^2)	2623	1154
	Medium (100-1000km^2)	823	140
	Large (1000-10,000km^2)	10	54
Calcareous	Very Small	0	156
	Small	1099	747
	Medium	340	96
	Large	175	0
Organic	Small	6	0

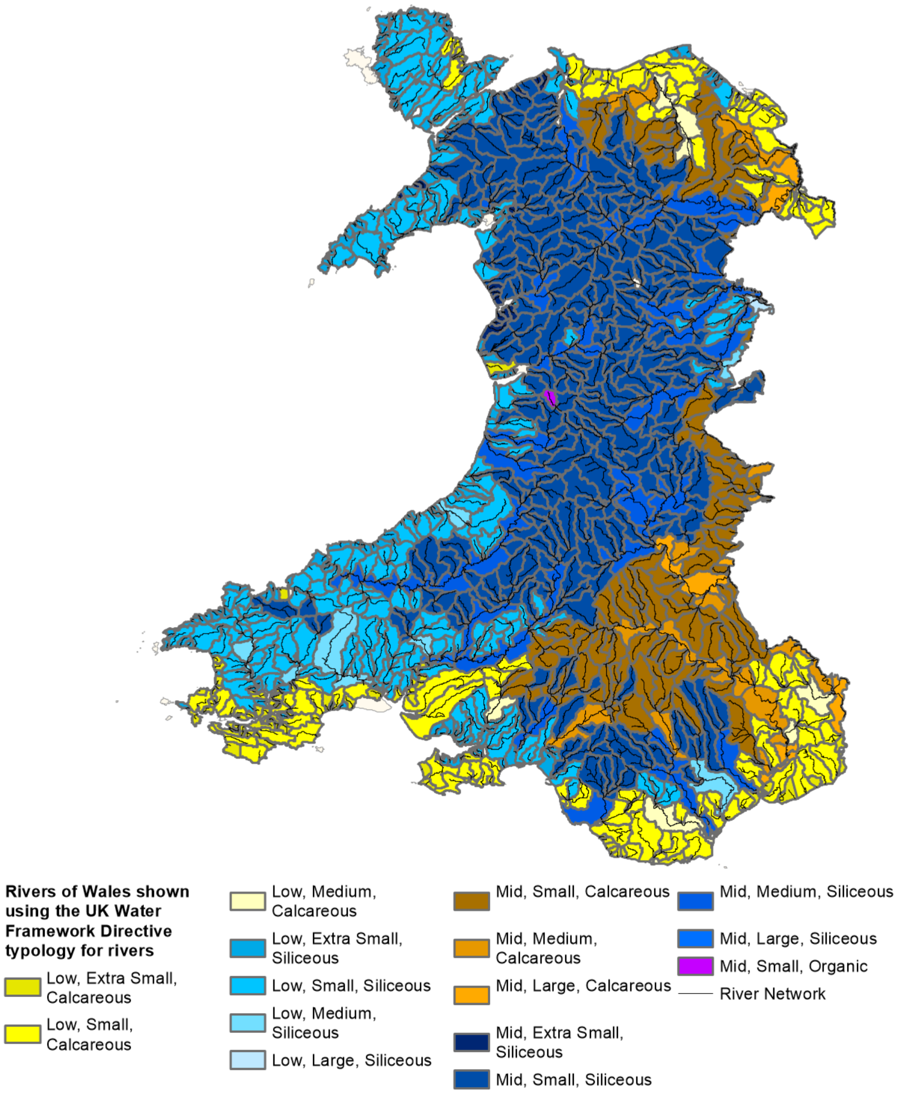

Figure 27 Rivers of Wales shown using the UK Water Framework Directive typology for rivers.[274]

The varied and relatively unmodified nature of Welsh rivers is reflected in the level of protection they are provided[275]. Parts of nine major river systems (Wye, Usk, Tywi, Cleddau, Teifi, Eden, Glaslyn, Gwyrfai and Dee) are designated as Special Areas of Conservation (SAC) under the Habitats Directive, for both river habitat species and a range of species including fish, invertebrates, otter and aquatic plants. The total length of river SAC in Wales is about 1,550 km, with an emphasis on larger rivers. Headwater streams receive less direct protection but may receive indirect protection by virtue of being included within a terrestrial protected area.

All of these SACs are also protected as SSSI under the Wildlife and Countryside Act, which can provide specific protection for some habitats and species not specifically protected by the Habitats Directive.

Lakes

Standing waters are commonly divided into lakes and ponds, although it is generally accepted that these represent a continuum. The Great Britain Lakes cut-off of 1 ha[276] has been used as the dividing line between a 'lake' (1 ha or more) and a 'pond' (less than 1 ha). Although this definition is unsatisfactory, it probably provides a reasonable approximation of the distribution of the respective habitats at a strategic level.

There are 558 lakes in Wales, totalling 8,143 ha[277], with a mean area of 14.4 ha. It was estimated[277] that 185 of these, constituting more than half of the total resource by area (4931 ha) were artificial and likely to be heavily impacted as ecosystems; these also had a higher mean area (27.6 ha) compared to natural lakes (12.5 ha). The total catchment area of lakes in Wales is 304,116 ha (14.7% of the land area of Wales).

The distribution of lake types generally mirrors that for rivers (Figure 27) and is reflected by different ecological communities at a British[278, 279] and regional scale[277]. The distribution and extent of Biodiversity Action Plan (BAP) lake types in Wales[277] is shown in

Table 22 and Figure 28. A significant proportion (185 / 4,931 ha) of Welsh lakes are artificial in origin (e.g. constructed public water supply reservoirs, industrial lagoons, quarry lakes). These are very variable in nature; some are heavily polluted and potentially hazardous, whilst others function much like natural lakes and provide a wider range of ecosystem services than their original purpose.

Most of the larger lakes in Wales are artificial or modified for public water supply. Of 27 lakes over 50 ha in area, 22 are artificial reservoirs.

Table 22 Number and combined area of different Biodiversity Action Plan lake types in Wales[277].

Category	Nº of Lakes	Area (ha)
Low alkalinity, clear	157	1392.2
Low alkalinity, peaty	15	52.4
Moderate alkalinity	21	618.2
High alkalinity, nutrient-poor	11	91.1
High alkalinity, nutrient-rich	33	799.9
Unknown Type	129	811.1
Unlikely to match a BAP Category	185	4391.4
Destroyed	12	31.6

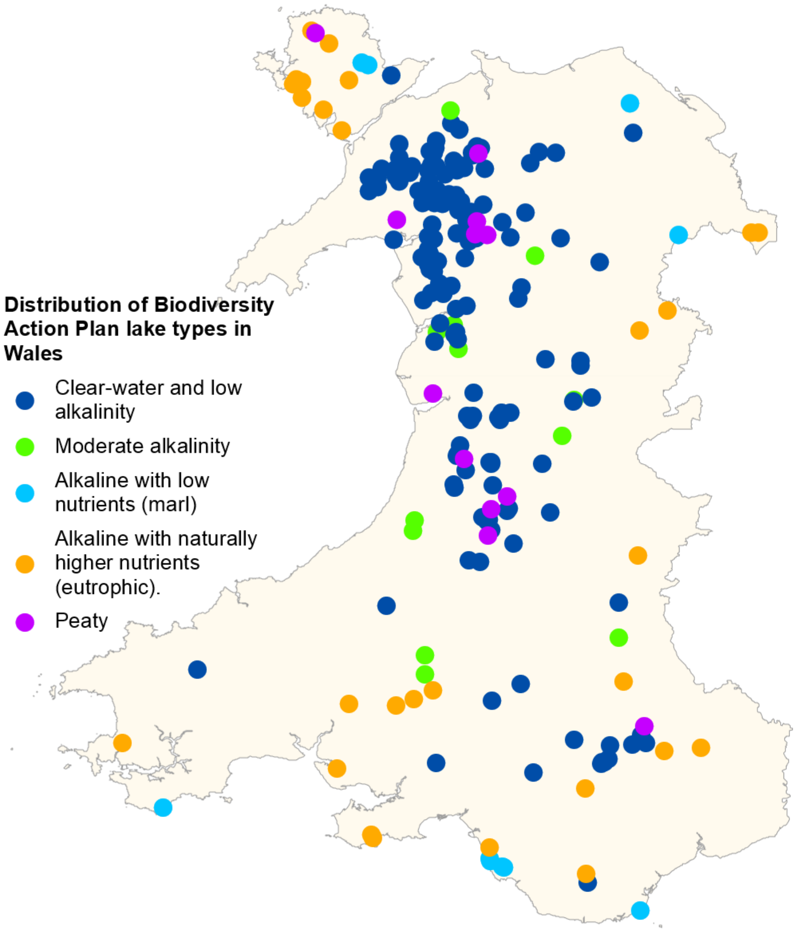

Figure 28 Distribution of Biodiversity Action Plan lake types in Wales[277].

Ponds

There is no comprehensive inventory of ponds in Wales, and it is unlikely that one will be developed because of the relatively high turnover of this habitat due to natural succession. The most comprehensive and recent review of pond status in Wales[280] identified important areas for ponds based on a series of criteria linked to the presence of rare species and/or assemblages indicating good condition, but the review also highlighted significant data gaps. Using a pond definition of 1 m^2-2 ha, it was estimated[280] that there were about 36,000 ponds in Wales based on multiplying mean pond density for the UK by the land area of Wales. By contrast, a smaller number of 27,600 was estimated using extrapolated Countryside Survey (CS) data and the CS definition of a pond (25 m^2-2 ha)[281].However, at least some of the difference between these estimates may be accounted for by the difference in size categories used.

There is no accurate estimate of the total area of ponds in Wales. The data from CS[281] suggest a total area of about 5,000 ha, with lower and upper 95% confidence intervals of 1,349 and 7,504 ha respectively. Unlike lakes and rivers, there is no systematic typology for ponds although certain pond types are either specifically or incidentally protected.

Groundwaters
Groundwater is the water stored in soil and rocks. It provides base flow to springs, rivers and wetlands and supplies up to 10% of drinking water in Wales. In rural areas, groundwater may be the only viable water source for isolated properties. Approximately 80,000 people in Wales rely on these private water supplies.

The geology of Wales is such that there is relatively little natural storage of water in aquifers to support and maintain river flow in drier periods.

Wetlands
Wales has a rich and varied terrestrial lowland wetland resource which includes most of the main ecological types found in north-west Europe[282].

Lowland raised bogs occur widely throughout Wales, with over 40 sites recognised to date and other sites awaiting confirmation through survey[283]. They are of high conservation value: 28 are included within SSSI designations, 12 make up part of a Natura 2000 site, and three are designated as Natura 2000 sites in their own right (namely Cors Caron, Cors Fochno and Fenns' & Whixall Mosses).

In total there are around 6,200 ha[282] of lowland fen and swamp (including reedbeds) within Wales. Sites are generally less than 5 ha in extent and, though many of the larger systems are included within SSSIs, very many sites remain without any form of designation. This category includes examples of fens in basins, floodplains and valleys (topogenous fen) as well as examples on hillslopes fed by lateral water movements (soligenous fens, including flushes and springs).

Inland floodplains extend over a total area of 38,248 ha in Wales, with coastal floodplains contributing another 25,292 ha. Collectively these areas constitute an important component of the coastal & floodplain grazing marsh Section 7 habitat, although in reality this is an amalgam of two distinct landscape types supporting multiple habitats[284]. There are 258 coastal and inland floodplains associated with 87 river systems in Wales; over 60% of their total area is concentrated within just 10 river systems, with the Severn (13,500 ha), Dee (4,700 ha), Elwy (3,800 ha), Tywi (3,600 ha), Teifi (3,200 ha) and Dyfi (3,100 ha) representing the top six ranked rivers in terms of total floodplain extent. Only a further nine rivers support a floodplain extent of more than 1,000 ha and the vast majority (72 rivers) support substantially less, with a median area of just 124 ha dispersed over a mean of 3.02 floodplain sites per river (minimum 1, maximum 14 for the rivers Conwy and Wye) with a median area of 124 ha. These figures confirm that extensive areas of floodplain are generally scarce in Wales.

Condition

The WFD requires us to define and assess the ecological, chemical and overall status of surface and ground water bodies, including rivers, canals, lakes, estuaries, and coastal waters. A broad suite of biological, physical and chemical elements are monitored and assessed against standards to produce an ecological, chemical and overall status for each water body. For groundwater, quantitative rather than ecological status is assessed, and dependent wetlands form part of the overall assessment. The overall status (2015) for river lake and groundwater bodies is shown in Table 23.

Table 23 Wales summary of overall status assessments in the second cycle for rivers (not including canals & surface water transfers), lakes and groundwaters (numbers of water bodies).

	High	Good	Moderate	Poor	Bad
Rivers	0	285	374	55	3
Lakes	1	17	96	9	1
Groundwaters	NA	22	NA	16	NA

The most common failing elements are:

- in rivers - fish, phosphorus and metals
- in lakes - invertebrates and phosphorus
- in groundwaters - metals

As part of the implementation of WFD a programme of investigations has been targeted at water bodies failing their objectives, in order to identify the main pressures and develop solutions. This information is summarised in the updated River Basin Management Plans, and the number of water bodies impacted by the top five issues is shown in Figure 29.

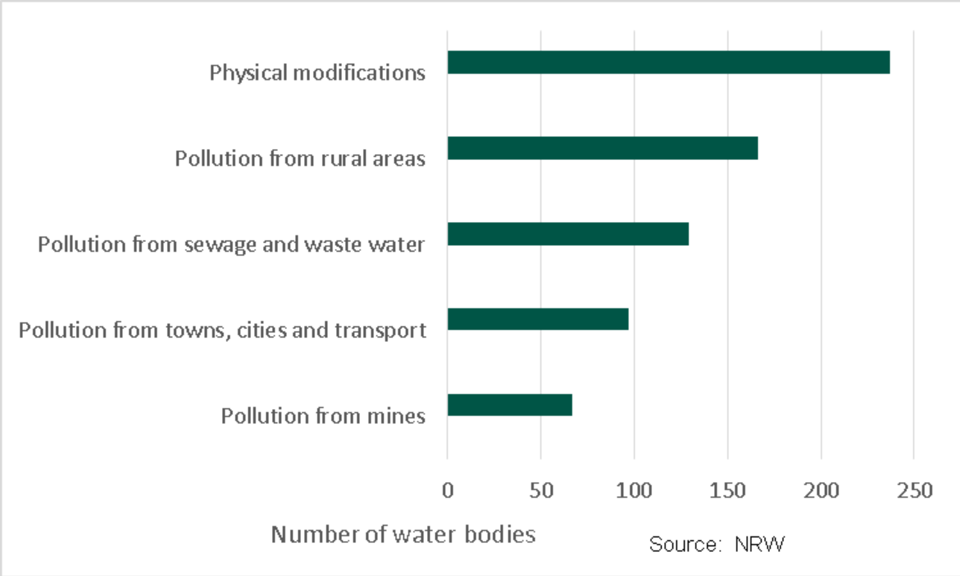

Figure 29 The five main reasons for not achieving good status in Wales. A water body can have more than one reason[285].

A majority of the lowland wetland features most closely associated with peat (namely topogenous fen and lowland raised bog) are unfavourable: insufficient grazing, diffuse water pollution and drainage issues are the main causal factors identified in NRW's actions database. The overall UK assessment of conservation status for all seven Habitats and Species Directive Annex I habitats associated with lowland wetlands in Wales was judged as bad, with modest declines in extent for all except calcareous fen.

Trends

Rivers

Prior to 2009 and the implementation of the new standards and methods for the WFD, rivers were classified according to the General Quality Assessment (GQA) for chemistry and biology.

The overall classifications for these are shown in Figure 30, Figure 31 and Figure 32. They show a general improvement in the achievement of the higher classes of quality over the period 1990 to 2010 when the assessment was last reported.

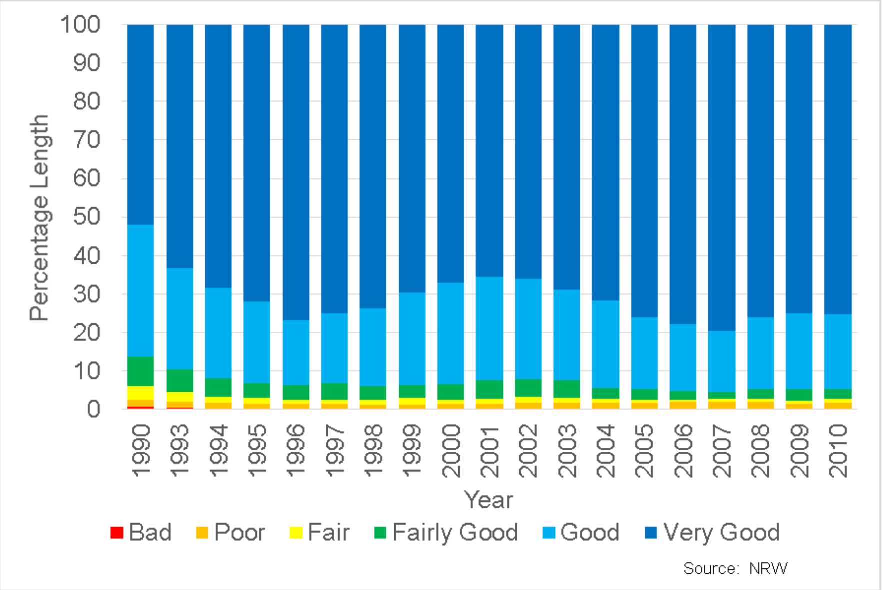

Figure 30 General Quality Assessment of river chemistry 1990 to 2010

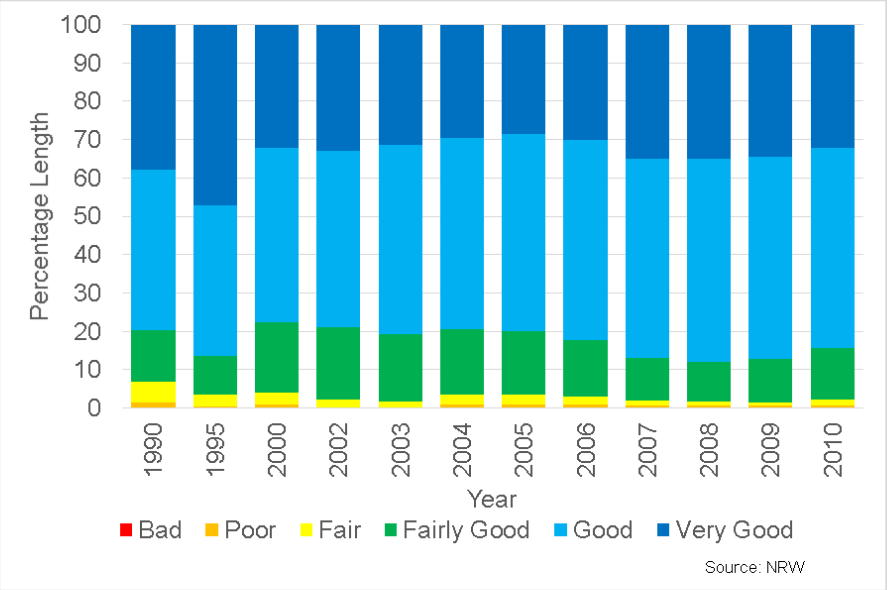

Figure 31 General Quality Assessment of river biology 1990 to 2010

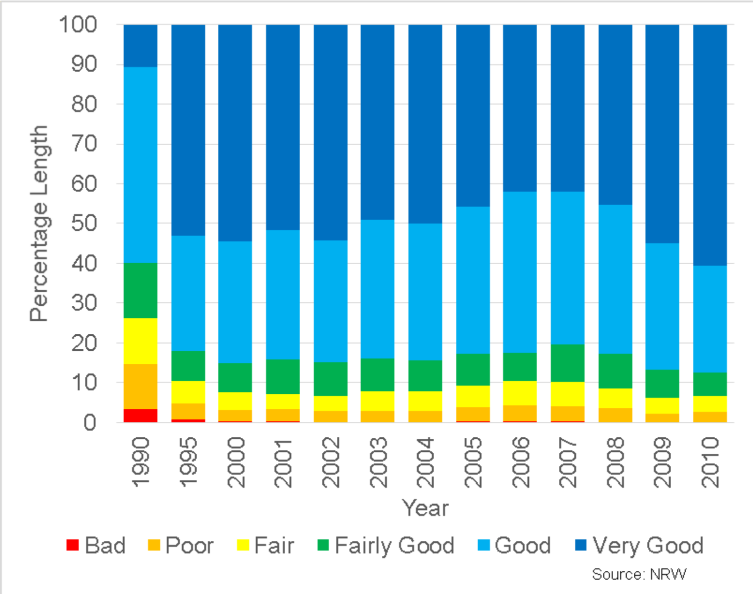

Figure 32 General Quality Assessment of phosphate in rivers 1990 to 2010

Streams (first or second Strahler Order flowing water bodies within 2.5 km of their source) and ponds (standing water bodies between $1m^2$ and 2 ha in area, that hold water for at least 4 months of the year) are not assessed under the WFD but are designated as priority habitats due to their importance for biodiversity, and they have high value to many people due to their local context. Analysis of long-term data has identified a general ongoing improvement in the quality of Welsh streams since 1990, based on an assessment of macroinvertebrate communities (NRW/GMEP 2016)[286]. Overall, nearly 80% of streams are in good or high condition, with approximately 6% deemed in poor or bad ecological condition (Figure 33 a). Of these streams, nearly 47% were pristine or predominantly unmodified by anthropogenic activity while approximately 34% showed significant or severe modifications (Figure 33 b). In contrast, only 16% of ponds sampled were judged to be in good ecological condition, with 34% in poor or very poor condition (Figure 33 c).

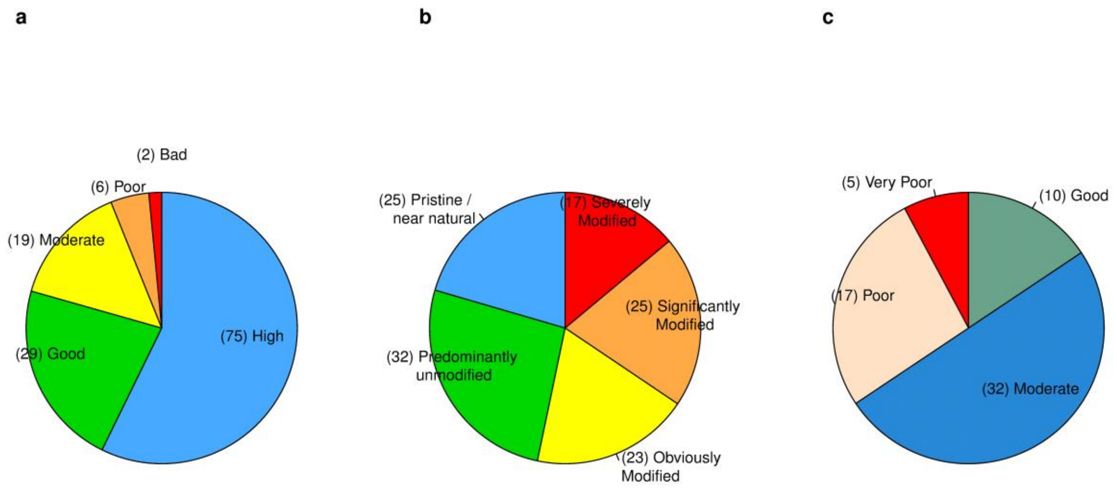

Figure 33 Ecological quality of freshwater priority habitats in GMEP survey years 1-3. Figures indicate a) stream ecological condition based on macroinvertebrate communities, b) stream habitat modification classes and c) pond ecological condition. N.B. the classification of stream and pond ecological condition have different classes and numbers of classes and are not comparable. Numbers indicate numbers of features assessed. Source: GMEP 2016[266]

Acidification

International action to reduce sulphur and nitrogen emissions since the 1980s has significantly reduced the source of acid deposition and the environment has shown a response. Long-term data on acidification from the Upland Waters Monitoring Network show that Welsh freshwaters in acid-sensitive areas are continuing to recover from acid rain damage.

CASE STUDY
Trends in acidification

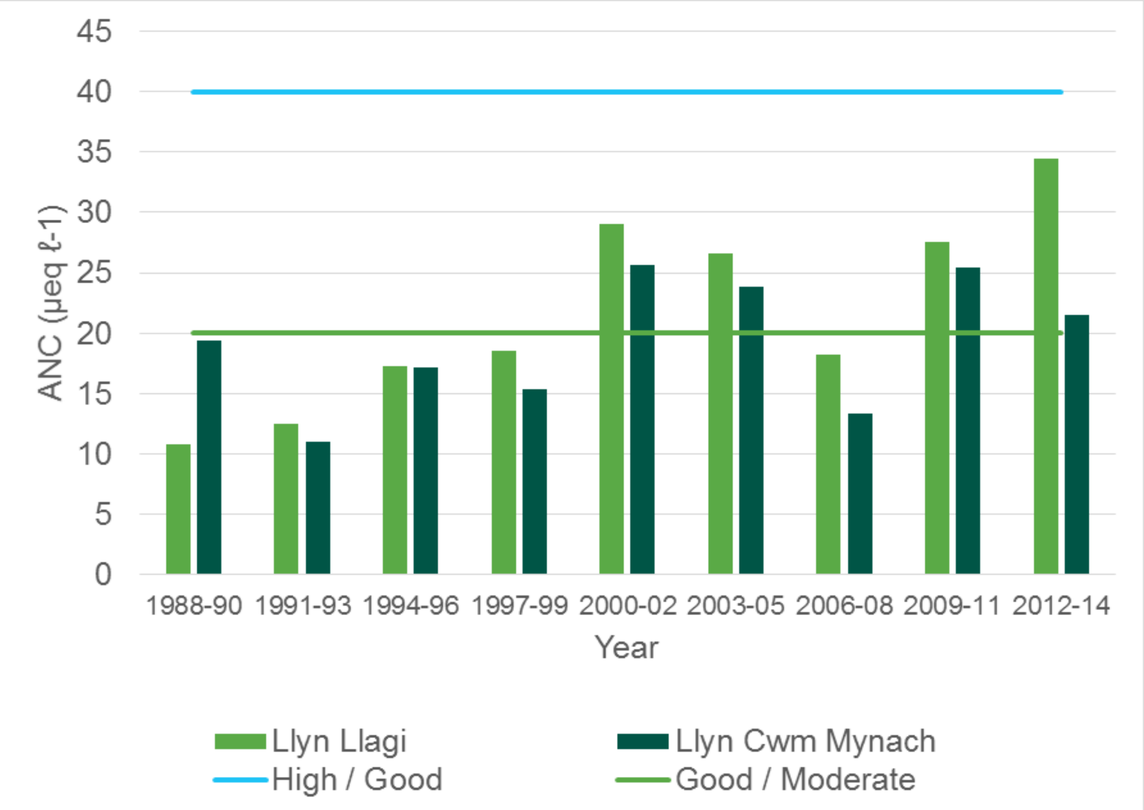

Figure 34 Acid Neutralising Capacity (ANC) status of the long-term Upland Waters Monitoring Network (UWMN) lake sites. The green line represents the Good / Moderate boundary and the blue line the High / Good boundary using current WFD standards[287].

Acid Neutralising Capacity (ANC) represents the ability of the water body to buffer against acid events and is considered a good measure of acidification. ANC has tripled in the un-forested catchment of Llyn Llagi since 1988 and the site has improved, going from moderate status to good status in terms of the WFD. The lake is likely to reach high status within the next 10-20 years based on current rates of improvement. Llyn Cwm Mynach, a forested catchment, has also improved although recovery has been slower. Other sites, both forested and un-forested, have shown improvements in acid status since 1991, with Afon Hafren and Afon Gwy going from poor to moderate status and, in the last 10 years, close to good status. There have also been significant increases in biodiversity in these systems for both invertebrates and diatoms[288]. However, fish populations have not yet shown a recovery, which suggests improvement is still needed.

Additional action, including following the forestry practice guide[289] for managing acidified catchments, aims to further improve the ecological quality of affected catchments by introducing forest management practices less likely to exacerbate acid deposition, and habitat improvements which increase ecological resilience.

Wetlands

Our lowland wetland resource reflects the long history of human land-use in Wales, with extensive habitat loss right up until the last decades of the 20th century. For example, the original extent of lowland raised bog in Wales may have been as much as 4,000 ha, more than twice the current resource[290], with loss resulting from drainage, peat cutting and agricultural reclamation. More recently, it is estimated that 72% of base-rich mire and 95% of bog and acidic fen were lost between 1920-22 and 1987-88 from the western part of the Llŷn Peninsula[291]. Habitat losses have lessened greatly since the turn of the 21st century, largely reflecting the success of agri-environment measures, the Environmental Impact Assessment regulations, SSSI designation and greater public awareness.

3.11. Urban Environments

The rural/urban definition used in this report is based on the methodology introduced in 2004 by the Welsh Government, The Countryside Agency, DEFRA, Office of the Deputy Prime Minister and the Office for National Statistics[292].

New legislation in Wales gives us the opportunity to develop inclusive and explicit policies for the urban environment, with the core objectives of environmental sustainability and improved health and well-being. This approach was recommended by The Royal Commission on Environmental Pollution in its 2007 Urban Environment paper[293].

Extent

Although Wales is a predominantly rural country (11.2% of the land area is classified as urban), 2.4 million people – 80% of its population – lives in towns and cities. Action to promote the wide-ranging contribution of ecosystem services and to mitigate the adverse impact of people on natural resources is therefore essential. Our towns and cities are where most people derive their direct benefits from natural resources (air, soundscapes, green infrastructure and wildlife) most of the time.

Green Infrastructure 'Green infrastructure' describes and includes all green and blue spaces in and around our towns and cities. The term allows us to refer to all of these spaces at once and consider their collective value. Component elements include parks, private gardens, agricultural fields, hedges, trees, woodland, green roofs, green walls, canals, rivers and ponds. The term covers all land containing these features, regardless of ownership, condition or size.

In 2013, urban tree canopy in Wales was 16.4% – mid range in world rankings, and covering 14,145 ha. High cover in the South Wales Valley towns contrasts with low levels of canopy in coastal communities[294]. Tree cover in deprived areas tends to be lower and relatively less rich in amenity trees.

In 2013, 22% of the urban environment was formal and informal open space[294]. 644,257 ha of potentially accessible urban green space has been mapped by NRW using its *Toolkit* methodology[295]. This figure is likely to be revised downwards as its actual accessibility is verified by site surveys.

In 2013, private gardens accounted for a sizeable 35% of all urban land. Characteristically the majority of gardens are found in low-density residential areas rather than in areas of deprivation[294].

The era of heavy industry and large scale extractive industry in Wales led to the creation of large areas of 'open mosaic habitats'[296] – now UK Priority habitats. As a unique category of urban open space these are a critically important resource for rare and threatened plants and animals which are becoming increasingly scarce in the wider countryside.

Many towns owe their location to the presence of water resources, to rivers in particular. A riparian network typically radiates throughout an urban area but urbanisation and industrialisation has often seen society turning its back on rivers, with sections of tributaries culverted. Although not necessarily widely distributed through towns, they are however important components of urban blue infrastructure, acting as attractive focal points for people and enhancing urban biodiversity. Whilst superficially natural in appearance, they have often been artificially created.

The very nature of the urban fabric has seen the construction of both linear and bodies of engineered and designed water. All offer qualities that natural water features offer but are quite site specific e.g. peri-urban reservoirs or civic centre fountains and cascades. Drainage channels and culverts form a ubiquitous network across towns, discharging surface run-off and 'grey' water.

There is a gradually increasing number of constructed wetlands, water features, and water-permeable surfaces (e.g. swales, infiltration basins etc.) which mimic natural drainage systems as a solution to flooding and pollution. Whilst mandated by the Flood and Water Management Act 2010, Sustainable Drainage (SuDS) techniques are not yet widespread, but have the potential to form a key component of urban green infrastructure.

Grey Infrastructure – the built environment & hard surfaces

It is important to recognise that the built form is the dominant feature of urban areas. Planners since the 19th century have recognised the importance of retaining and creating formal parks and establishing tree-lined avenues. Pressures of development have resulted in reduced areas of green infrastructure to the extent that many parts of Wales' towns, often the less-advantaged areas, are under-provided for in terms of accessible green space[297].

Roads, from neighbourhood cul-de-sacs, streets, and highways to major trunk routes, make up 16% of all towns[294]. Tree canopy cover only accounts for 9% of transport routes[294]. The Active Travel (Wales) Act 2013 legislates for the provision of routes designed for cycling and walking. 'Natural' components along transport corridors have traditionally been grass verges and limited tree-lined avenues in leafy suburbs, with more recent 'structure planting' alongside major new by-passes.

Above- and below-ground service runs are essential components of an effective functioning town. The extent of underground services and continuing pressures for additional trunking and cabling place a huge challenge on establishing new trees and maintaining existing ones. NRW's *Tree Cover in Wales' Towns and Cities*[294] study highlights an under-provision of trees in those densely populated Communities First cluster areas where the hard landscape and service constraints impose challenges to establishing trees successfully.

The very nature of the urban environment implies that significant areas are impervious, providing both environmental and costly challenges to removing surface run-off and pollution.

Buildings, roads and other artificial surfaces areas absorb heat better than vegetation and water, leading to urban areas becoming hotter than their rural surroundings and creating the Urban Heat Islands[298]effect. During heatwaves, night time temperatures in towns and cities remain high due to this effect, making it hard for people to recover from heat-stress suffered during the day, and deaths increase in vulnerable groups such as the sick and elderly[299]. Increasing the extent of water and vegetation in urban areas, and structuring them to give a more even distribution of green infrastructure can reduce the intensity of urban heat islands. A study in Manchester estimated that a 10% increase in vegetated surfaces could ensure the city suffered no more deadly 'hot nights' under the worst-case climate change scenario for 2080 than it currently suffers[300].

Condition

Green Infrastructure

Woodlands and Trees

Increasing tree loss in towns is due to: an ageing population of trees (leading to an increased number of trees that are dying and dangerous); disease; demands for new building development,; work to the utility infrastructure; a poor understanding of integrating new trees into the built environment (green infrastructure); and not putting into practice the 'right tree, right place' approach[301].

CASE STUDY **Coed Aber – Creating a tree-lined gateway to Aberystwyth**
During 2013-2015 partners Greener Aberystwyth Group, Ceredigion County Council and Natural Resources Wales seized the opportunity to transform this major approach road into town where two decades of mixed development had not included any associated green infrastructure. Welsh Government's Regeneration Area funding and Council match-funding enabled a £375,000 tree planting programme to be undertaken. The initial vision from the feasibility study culminated in a mile-long mix of 280 semi-mature specimen trees being planted. Species choice was based on 'right tree, right place', diversity and the need for future resilience, and balancing informal groupings with more formal avenue trees. With the huge pressures facing so many existing urban trees, Coed Aber demonstrates an excellent example of investing for the future to enhance Aberystwyth's image and economic prospects, as well as offering health and well-being benefits to inhabitants and visitors alike.

160 out of 220 towns (73%) showed an overall decline in canopy cover between 2000 and 2013, with 7,000 large amenity trees (those offering the greatest ecosystem services) lost between 2006 and 2013294 (Table 24). These figures need to be verified, but the loss is possibly due to increasing development pressure, loss of skilled staff and management resources, trees planted by the Victorians coming to the end of their lives, and low levels of replanting[294].

Table 24 Canopy cover & amenity tree loss 2006-2013: 'Top 10' urban areas

Canopy Cover Rank	Urban Area	County	2013 Canopy Cover	Urban Area - ha	Canopy Cover Loss ha	Tree Loss / Gain
1	Colwyn Bay	Conwy	17.9%	1,100	24.6	-750
2	Rhondda Fawr	Rhondda Cynon Taf	18.1%	1,538	23.6	-31,329
3	Flint	Flintshire	14.2%	394	10.1	-5,110
4	Caergwrie	Flintshire	29.7%	239	9.1	-1,496
5	Porthcawl	Bridgend	6.2%	541	8.5	-2,598
6	Port Talbot	Neath Port Talbot	8.2%	2,301	8.4	+9,895
7	Gresford	Wrexham	24.5%	192	6.6	-5,395
8	Monmouth	Monmouthshire	17.0%	379	6.1	+9,523
9	Ruthin	Denbighshire	11.7%	247	5.7	-4,304
10	Llangollen	Denbighshire	25.0%	152	5.3	-3,365

Key	0% - 5%	5.1% - 10%	10.1% -15%	15.1% - 20%	20.1% - 25%	> 25.1%

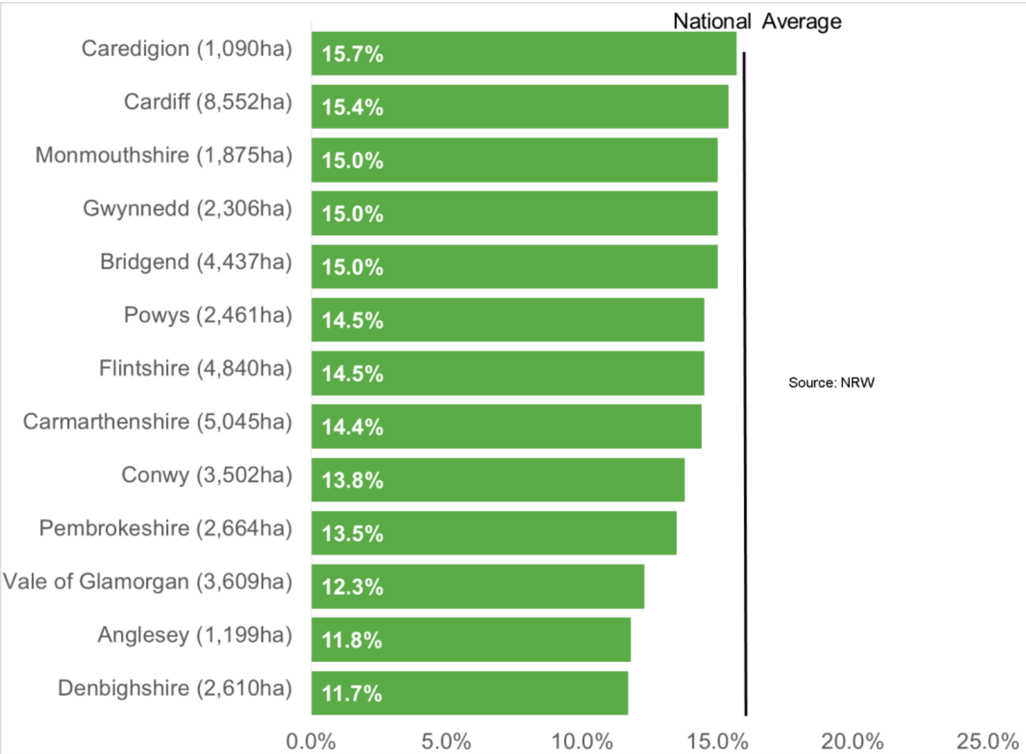

Figure 35 County Canopy Cover 2013 – below the 16.4% national average

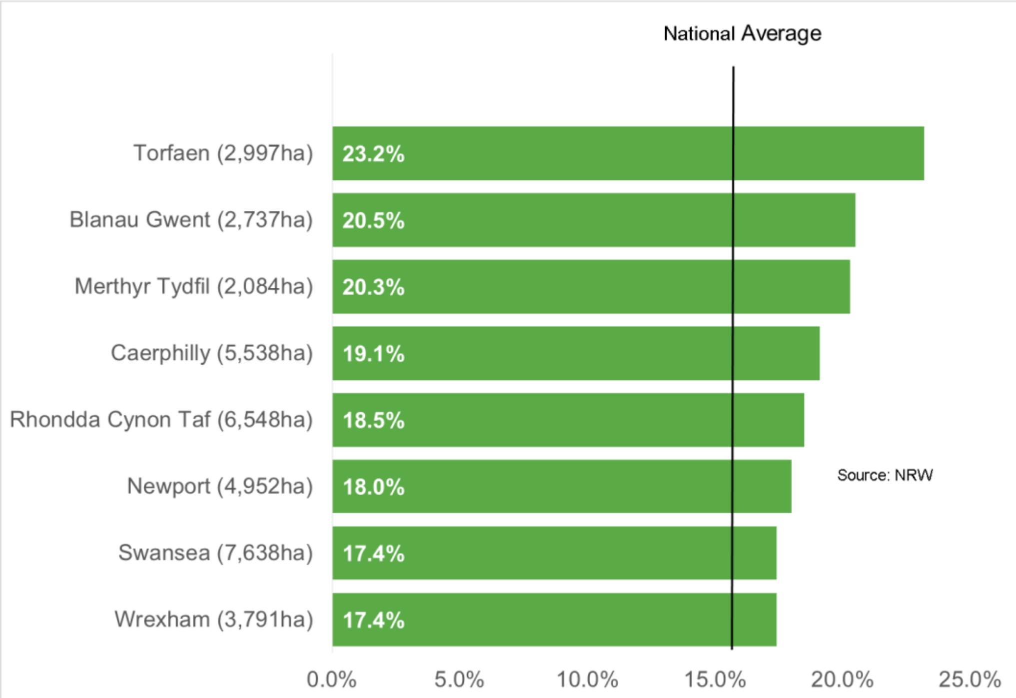

Figure 36 County Canopy Cover 2013 – above the 16.4% national average

Table 25 Canopy cover comparison: 'Top 10' and 'Bottom 10' Towns 2013

Rank	Town (Top 10)	Percentage Cover 2013	Towns (Bottom 10)	Percentage Cover 2013
1	Trimsaran	33.9%	Fochriw	2.8%
2	Treharris	30.2%	Tywyn	4.7%
3	Caergwrie	29.7%	Broughton	5.3%
4	Glanaman	28.9%	Bettws	5.4%
5	Aberbeeg / Llanhilleth	27.3%	Rhyl	5.5%
6	Abertillery	26.5%	Saltney	5.5%
7	Dolgellau	26.0%	Porthcawl	6.2%
8	Pontardawe (& Swansea Valley)	25.2%	Abertysswg	6.3%
9	Llangollen	25.0%	Town / Kinmel Bay	6.4%
10	Llay	25.0%	Rhoose	6.6%

Key: 0% - 5% | 5.1% - 10% | 10.1% -15% | 15.1% - 20% | 20.1% - 25% | > 25.1%

i-Tree Eco studies in Wrexham County Borough Council[302], the Tawe catchment[303] and Bridgend County Borough Council[304] show that the urban forest here:

- captures 6,409 tonnes of carbon from the atmosphere annually – worth £1.42 million
- stores 222,000 tonnes of carbon – worth £50 million.

CASE STUDY
Wrexham County Borough Council: Tree Strategy and i-Tree Eco Study

In 2013, Natural Resources Wales, Forest Research and Wrexham County Borough Council (CBC) piloted the first study in Wales to find the true value of urban trees[302]. The study found that Wrexham's trees save the local economy more than £1.2 million every year by:

- intercepting 27 million litres of rainfall before it enters the drainage system, equivalent of saving £460,000 in sewerage charges;
- absorbing 1,329 tonnes of carbon dioxide from the atmosphere;
- improving people's health by removing 60 tonnes of air pollution, saving health services £700,000.

Oak disease and ash die-back puts 11% of Wrexham's trees at risk. Just three species account for 42% of Wrexham's trees, and 10 species form 70% of the total population. Greater diversity of trees is needed to reduce the risk of pests and diseases. A wholesale loss of Wrexham's trees would cost around £900 million. Study results have been used in the new Wrexham CBC Tree & Woodland Strategy and woven into the updated Local Development Plan.

The studies also indicate that overall the urban forest age-class distribution is deficient in the larger-girthed trees that are the most beneficial to society, that species diversity could be improved upon, but that tree condition is good to excellent.

Natural greenspace, parks and playing fields

Well-managed, high quality parks and green spaces are critical elements of accessible natural green space because they are, by definition, managed for human enjoyment, and they have been proven to deliver multiple well-being benefits to people[305]. The Green Flag Award recognises and rewards the best parks and green spaces in the country as well as driving up quality and standards. A wide variety of green spaces are eligible to apply, from small urban parks to huge country parks, university campuses, housing estates and even cemeteries. There is also the Green Flag Community Award for community-managed spaces such as allotments, woodlands, local nature reserves and community gardens. 69 Local Authority managed and 41 community-managed public green spaces, in 19 local authority areas, won Green Flag Awards in 2015-16 (Figure 37).

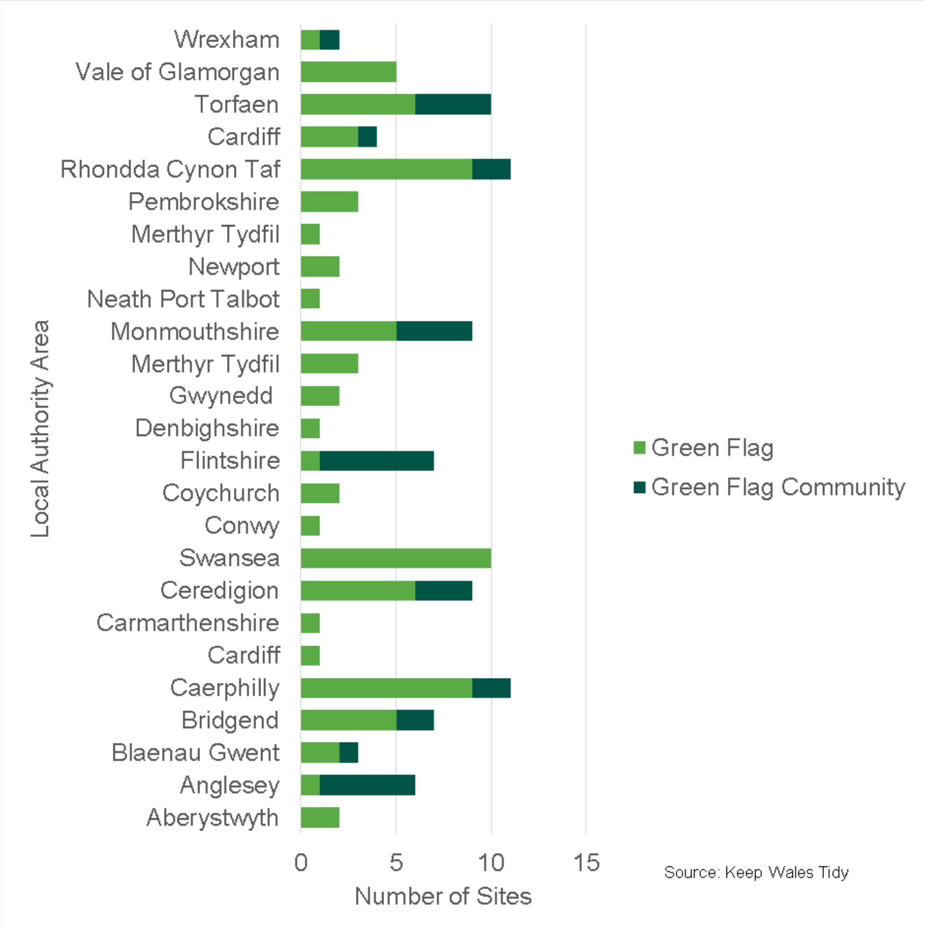

Figure 37 Green Flag Awards 2015-16

Residential gardens

Data in Cardiff show that 23% of the urban area is composed of gardens and that 25% of that is front gardens. If the trend to pave over front gardens for parking increased to 100% in Cardiff, it would result in a loss of permeable surfaces equivalent to 5% of the total area of the city[306]. Gardens provide a significant habitat for wildlife and they accommodate native species of plants and animals as well as introduced species[307]. Research has now shown the great benefit provided to native invertebrates in particular, by non-native plant species in domestic gardens[308].

Natural water courses and engineered water features

Water quality and freshwater habitats are addressed in section 3.10. The improvement in water quality since the 1970s has been a remarkable success story, from a virtually lifeless ecosystem to a healthy but gradual re-colonisation of aquatic flora and fauna into this urban resource.

Every 5% increase in tree cover reduces water run-off by 2%[309]. i-Tree Eco studies in Bridgend[303], the Tawe Catchment[304] and Wrexham[302] showed that urban woodlands and trees in those areas intercept 654 million litres of rainfall – saving £0.95 million each year in sewerage charges.

Grey Infrastructure – built environment & hard surfaces

Urban 'heat island'

Areas in Wales particularly at risk from the Urban Heat Island effect include Cardiff and Wrexham, and populations with restricted abilities to cope exist in Cardiff, Newport, Swansea and Rhondda Cynon Taf[310].

Pollution

Air quality

80% of Wales' population (predominantly in urban areas) is subjected to levels of atmospheric pollution as highlighted in Chapter 1. In the UK, two air pollutants (PM_{10s} and $PM_{2.5s}$ and nitrogen dioxide) contribute to the early deaths of 40,000-50,000 people[311]. Primary sources emanate from transport corridors and industry. Trees and vegetation, with the right species in the right location, can play an important role in removing airborne pollution[312]. i-Tree Eco studies in Bridgend[303], the Tawe Catchment[304] and Wrexham[302] showed that urban woodlands and trees in those areas remove 258 tonnes of pollution each year, saving the NHS £1.55 million (by reducing asthma and heart disease). Children living in areas with more street trees have a lower prevalence of asthma[313].

Trends

Green infrastructure

Woodlands and Trees

Significant canopy cover losses have been reported between 2009 and 2013 (Table 24). Setting canopy cover goals would move Wales' average towards the European 20-30% average.

i-Tree Eco studies in Bridgend[303], the Tawe Catchment[304] and Wrexham[302] showed that replacing these urban forests, if based on visual amenity calculations, is estimated to be £2.4 billion. A diversity of species throughout urban areas is critical in building resilience to climate change.

Trees are also under threat from:

- Chalara dieback of ash, which will probably affect over 10% of Bridgend County Borough's tree population;
- Phytophthera of alder, already present in South Wales, which could affect 15% of Tawe's trees;
- Asian longhorn beetle, which, if it arrives on these shores, would cause devastating tree loss of 40-65%.

Natural green space, parks and fields

The quality of parks and publicly accessible green space in urban areas saw a steep decline during the 20th century[314]. As a result of the work done by the Urban Green Spaces Task Force, a mini-renaissance in park management happened and park quality began to increase, as shown by the increase in the numbers of parks entered for and winning Green Flag Awards.

Residential gardens
Despite development pressure encroaching onto gardens, this asset will remain a major 'green' contributor to the urban scene. Trends in gardening and car parking demands are resulting in a more maintenance-free approach, with soil as a garden medium being replaced by hard core and paving. Evidence from London showed a 12% decline in the unsealed surface area of gardens between 1998 and 2008[315]. If this trend continues increased amounts of storm-water run-off from gardens can be expected, with an increased flood risk as a result. A detrimental effect on pollinators and other invertebrates can also be expected, as food resources for adult invertebrates are reduced.

Brownfield sites – Open Mosaic Habitats on Previously Developed Land
Many of these sites were created by the wide-scale closure of coal mines and the demolition of derelict metal works in the last decades of the 20th century. Redevelopment of this land, can cause the loss of unique habitats. A programme of re-profiling and stabilising coal tips has removed naturally developed vegetation and replaced it with trees and sown grass[316]. Some sites, such as Parc Slip, an opencast coal mine, have been acquired and restored for nature conservation management.

Natural water courses – rivers and streams
Since the late 1960s town planners and environment agencies have increasingly realised peoples' innate attraction to water and have been reversing the fortunes of rivers in terms of water quality, and restoring freshwater habitats by creating recreational corridors and placemaking for residential and business development.

Natural water bodies – lakes, ponds, and wetlands
The major trend envisaged will be the embedding of sustainable urban drainage (SuDS) practices across new development as per interim WG guidelines and pending legislation. Swales, ponds and wetlands will be an integral part of the SuDS approach, e.g. Dŵr Cymru / Welsh Water's (DC/WW) Llanelli Rainscape pilot.

Engineered water features – canals, reservoirs, fountains and drainage channels
Drainage solutions will again be aligned to the SuDS approach, to address excess surface water entering foul systems. NRW is currently in partnership with the City and County of Cardiff and DC/WW, implementing the Greener Grangetown pilot where interconnected rain gardens are at the forefront of the re-designed streetscape.

CASE STUDY
Greener Grangetown – sustainable urban drainage in action

The City of Cardiff Council and Dŵr Cymru/Welsh Water are investing in Greener Grangetown, an innovative scheme to better manage rainwater in the community. Using innovative techniques, and creating a number of community-focused green streets which feature 'pocket parks', this scheme will catch, clean and divert rainwater directly into the River Taff instead of pumping it over 6 miles through the Vale of Glamorgan to the sea. The work will help to make Grangetown a greener, cleaner place to live and will significantly reduce the surface water run-off from the area, and pumping and energy cost overheads.

Grey Infrastructure – built environment & hard surfaces

Buildings
Some of the most significant landscape changes recorded over the last 10 years have been the expansion of the built environment into the agricultural landscape, in particular residential and industrial expansion. Despite an apparently hostile growing environment, new-build and retro-fits are building in roof gardens and green walls as a means to ameliorate the urban environment and contribute to Sustainable Urban Drainage

Transport routes
Investment in modes of transport has traditionally been significant and it is essential that grey infrastructure taps into this resource in addressing key issues of pollution and creating safe and attractive travel routes, e.g. Greater Bristol's Bus Network, Swansea's Oystermouth Road 'boulevard' and Aberystwyth's Coed Aber. The emerging Cardiff City Region 'metro network' offers an exemplar opportunity.

Utilities
Dialogue is in progress across the engineering professions and the Tree and Design Action Group (TDAG) to offer best practice in sharing precious underground space, especially alongside streets and civic spaces, to accommodate both sustainable growing environments and combined service ducts.

Impermeable surfaces
SuDS guidance and pending legislation will help to bring about permeable paved solutions to allow surface water infiltration at source. If the Flood and Water Management Act 2010 is fully enacted and statutory standards for SuDS are enforced, then we can expect to see more SuDS in urban areas, with a consequent beneficial impact on biodiversity, a decrease in flooding, and even the potential for an increase in human mental well-being through increased contact with green spaces.

Urban 'heat island'
Increasing numbers of heatwaves are predicted as climate change continues and therefore an increasing number of dangerous 'hot nights' can be expected in the future. If vulnerable populations in Wales are not served by appropriately located and properly managed green infrastructure assets, then excess deaths can be expected in those populations during heat island events[310].

Pollution

Air quality – see Section 3.2

Noise
In 2012, Public Health Wales and local authorities in Wales reviewed complaints of annoyance arising from noise exposures from a variety of different sources, covering a 5-year period (2005-10). There were increases over the study period in four local authority areas. Strong associations were observed in analyses of noise-related complaint rates and deprivation status, where rates increased with rising levels of deprivation. The Welsh Government's Noise Action Plan for Wales 2013-18 includes environmental noise action plans required by the *Environmental Noise (Wales)*

Regulations 2006, together with information on Wales-wide policies relating to those forms of noise not covered by the Regulations, such as neighbourhood noise.

3.12. Coastal margins

Extent

The Welsh coastline extends over 2,740 km and the coastal margin habitats are primarily composed of sand dunes (8,101 ha), saltmarsh (7,345 ha) and sea cliffs (3,838 ha)[317]. Vegetated shingle (110 ha) and coastal lagoons (83 ha) comprise a far smaller proportion of coastal margin habitats[318] (see Chapter 3, section 3.12). Over 75% of the mapped sand dune and saltmarsh habitats are designated as SSSIs. In contrast, only 56% of sea cliffs and 50% of shingle are designated.

Coastal margins are naturally dynamic, experiencing erosion, accretion, longshore drift, storms, exposure to salt spray, and seasonal and tidal effects. Some coastal margin vegetation communities are ephemeral, such as shingle and strandline vegetation. The often extreme environments of the coast give rise to habitats characterised by specialist plant and animal species[319]. Saltmarshes are prevalent around the Welsh coastline[320] and are an important component of our natural coastal defences with up to 50% of wave energy attenuated in the first 10 to 20m of vegetated saltmarsh[317], and wave heights reduced by up to 20% through wave attenuation[321]. Coastal lagoons are expanses of shallow coastal water that are wholly or partially separated from the sea[319]. Though relatively uncommon in the UK and Europe, there are 13 coastal lagoons in Wales.

In general there has been a long-term (from 1900 depending on data source) decline in extent of coastal margin habitats in Wales, coupled with fragmentation as a result of a number of drivers including land claim for agriculture, forestry and development[317,322]. However, saltmarshes in Wales have increased in some estuaries such as the Dee, which means that net change in extent since 1945 is uncertain[322].

Condition

The Article 17 3rd round Wales reports[318] give the most up-to-date condition figures for coastal margin habitats (Chapter 3, section 3.12). These reports identify the factors affecting coastal margin habitats in Wales, which include both under- and overgrazing, agricultural intensification, airborne pollutants such as nitrogen deposition, invasive species, recreational activities, afforestation and coastal defences.

Assessments of the sand dune, coastal grassland and coastal heathland components of the sea cliff and shingle SSSIs found they were predominantly in unfavourable condition[323]. Saltmarsh was predominantly in favourable condition and the vertical sea cliffs were wholly in favourable condition[323]. Furthermore, with the exception of the vertical cliffs, all coastal margin habitat SSSI features were in decline[323].

The most frequently reported factor contributing to unfavourable condition for SSSI coastal margin habitats is undergrazing. Conversely, overgrazing is the most reported factor for saltmarsh[323].

Opportunities for the restoration of coastal margin habitats exist, such as sand dune rejuvenation (see case study), managed coastal realignment, and landscape-scale habitat management projects.

CASE STUDY
Sand dune rejuvenation conservation management

Figure 38 Sand dune rejuvenation work at Merthyr Mawr (South Wales)

Habitat stabilisation has reduced the intrinsic geomorphological interest of Welsh sand dunes and poses a threat to the nature conservation of the sites. Since the 1940s, habitat stabilisation has resulted in a large (>50%) reduction in bare and mobile sand[324],[325], which is critical to pioneer and early successional flora and fauna[326]. In 2012 sand dune rejuvenation work began at three sand dune sites (Newborough Warren, Kenfig and Merthyr Mawr) to address habitat stabilisation.

The topographical results of the rejuvenation work by 2015 are positive:

- Newborough: total area of new bare sand = 18.5 ha (total bare sand for the site = 58ha).
- Kenfig: total area of new bare sand = 10.20ha (total bare sand for the site = 14.2 ha).
- Merthyr Mawr: after 3 phases of dune rejuvenation, total area of new bare sand = 8.50 ha (total bare sand for the site = 28.5 ha) [327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340].

Further topographical monitoring is programmed for the three sites. Ecological monitoring covering the higher and lower plants and invertebrates is ongoing[341] and will continue into the future. Further large-scale sand dune restoration in Wales is currently being planned. These results demonstrate that rejuvenation work, coupled with ongoing grazing and scrub management, can have multiple benefits for these important pioneer habitats and the services they provide.

Sand dunes

Five Annex 1 habitats have been included in the assessment for sand dunes:

- Habitat 2110: Embryonic shifting dunes
- Habitat 2120: Shifting dunes along the shoreline
- Habitat 2130: Fixed dunes with herbaceous vegetation
- Habitat 2170: Dunes with *Salix repens*

- Habitat 2190: Humid dune slacks.

Three of the dune habitats (fixed dunes, humid dune slacks and dunes with *Salix repens*) were wholly in unfavourable condition. 45% of the area of embryonic shifting dunes and 68% of the area of shifting dunes along the shoreline were in favourable condition[318] (see Chapter 3, section 3.12).

Habitat change is one the major drivers of change on sand dunes, where human-induced change via afforestation and agriculture has altered sand dune extent and condition[322, 342], resulting in sand dune habitats becoming fossilised and stabilised. The extent of bare sand, pioneer and early successional habitat (important for invertebrates and pioneer plant species) has reduced dramatically. For example, at Newborough Warren mobile dunes (yellow dunes) have declined from 75% cover to 6% cover since the 1950s[343, 344, 345], and in Wales, the total area of bare sand now only accounts for approximately 135ha[344].

Saltmarsh

Three Annex I habitats are attributable to saltmarsh:

- Habitat 1330: Atlantic salt meadow
- Habitat 1310: *Salicornia* and other annuals colonising mud and sand
- Habitat 1420: Mediterranean thermo-Atlantic halophilous scrubs.

However, Mediterranean thermo-Atlantic halophilous scrubs is not a designated feature on any sites and is very small in extent, and it was therefore not assessed in the last round of Article 17 reporting. Of the two other main habitats, Article 17 data for Atlantic salt meadow in Wales show less than 40% as being in favourable condition, but for the pioneer community *Salicornia* and other annuals colonising mud the data show more than 80% in favourable condition[318] (See Chapter 3, section 3.12).

Overgrazing was identified as a negative pressure for the sites assessed as unfavourable for Atlantic salt meadow. Pollution is also a major pressure identified for saltmarsh habitats in general[318]. The spread of the invasive species *Spartina anglica* has impacted saltmarsh in Wales, primarily affecting the pioneer vegetation communities[318]. However, there has been die-back of this species at some sites in recent years[318]. Saltmarsh quality is a component of assessments carried out under the Water Framework Directive (WFD) which is covered in section 3.13 below.

Shingle

Two Annex 1 habitats have been included in the assessment for shingle:

- Habitat 1210: Annual vegetation of drift lines
- Habitat 1220: Perennial vegetation of stony banks.

The Article 17 data show that 100% of the area for Annual vegetation of drift lines has been reported as favourable, whilst 100% of the area of Perennial vegetation of stony banks has been reported as unfavourable[318] (see Chapter 3, section 3.12). The main pressures on both the habitats are anthropogenic trampling and the effect of shoreline structures which restrict sediment transfer. Without an influx of new sediment material, the shingle features are likely to decline[318].

Sea cliffs
Sea cliffs are represented by just one Annex I habitat type: Habitat 1230: Vegetated sea cliffs of the Atlantic and Baltic coasts.

This habitat includes the range of vegetation communities found on both hard and soft sea cliff, from exposed crevice communities of the vertical or near vertical cliff faces to the maritime grassland and heathland of the cliff tops.

Agricultural encroachment and intensification on the cliff tops is causing a decline in quality, sometimes reducing vegetation to narrow corridors along the cliff edge[317, 322]. In other areas abandonment of traditional grazing is allowing scrub encroachment, causing losses in both the extent and the quality of the cliff top habitats[317].

Some soft cliff sites are under particular pressure where sea defences along their bases causes stabilisation and a cessation of the natural coastal processes on these habitats. This is leading to a decline in the characteristic bare ground and open disturbed habitats[318]. These open habitats support rare invertebrates and provide the biodiversity interest for the soft cliff habitats[346.]

Coastal lagoons
Article 17 data show that 80% of the area of the Annex I habitat 1150: coastal lagoons is in favourable condition[318] (See Chapter 3, section 3.12). However, a number of pressures were identified as having an effect on coastal lagoon habitats. These included agricultural practices within lagoon catchments which affect the nutrient and silt loads deposited in the lagoons, human induced changes in hydrological condition, and recreational access[318].

Trends

Recent trends in the range and area covered by coastal margin habitats protected by the Habitats Directive in Wales are shown in Chapter 3, section 3.12.

Climate change is likely to have major impacts on the coastal margin habitats[322]. Coastal squeeze will occur where coastal habitats are constrained by steeply rising ground or coastal defences on the landward side, preventing natural landward rollback[317, 347, 348, 349, 350, 351]. Coastal squeeze may be mitigated by allowing coastal habitats to roll back inland. Managed realignment provides an opportunity for saltmarsh creation (and other habitats), allowing these habitats to move landward where previously constrained by coastal defences, keeping pace with sea level rise[352]. A programme of coastal realignment, the National Habitat Creation Programme, is currently being implemented by NRW.

Sand dunes
Habitats Directive Article 17 reporting assessments have shown that all the sand dune habitats (except for the dunes with *Salix repens* habitat), have declined in extent in recent years[318] (see Chapter 3, section 3.12). The mobility of sand dunes is important in maintaining biodiversity but as dunes are becoming increasingly stable[343, 344] this is reducing the range of species found in them[344]. The loss of mobile dunes and lack of creation of new dune slacks (the low-lying dips in sand dunes) as a

result of this stabilisation is now considered to be a trend that has affected all dune systems in Wales[344].

Saltmarsh

Section 42 and Habitats Directive Article 17 reporting in 2007[353] and 2013[318] respectively[354] have shown that saltmarsh has declined in recent years. Coastal squeeze is the primary pressure in Wales[355]. Losses of saltmarsh through coastal squeeze are predicted with sea level rise. Shoreline Management plans covering Wales set out predictions for loss of saltmarsh and intertidal habitats by 2105[356, 348, 349, 357].

Shingle

The long-term trend for shingle extent is predicted to be decreasing[318]. Warmer temperatures as a result of climate change will favour invasive species, especially garden escapees, affecting native shingle species[317, 358].

Sea Cliffs

The short-term trend for vegetated sea cliffs was reported as declining in the 3rd round of Article 17 reporting[318] (see Chapter 3, section 3.12). Lack of survey data has made it difficult to detect long-term trends in sea cliff habitats[317, 318]. NRW are currently conducting a programme of baseline habitat surveys for the sea cliffs.

Coastal lagoons

The latest habitat status reports (Section 42 reporting[354] and Article 17 reporting in 2007[353] and 2013[318]) found coastal lagoons were stable. Recent assessments of some lagoons show unexpected community changes. Due to their rare and isolated nature, and without appropriate management of activities, the changes could result in local extinctions of important species[359]. Furthermore, hard flood defences and the effects of climate change may hinder the development and evolution of coastal lagoons[322].

3.13. Marine

Coastal and marine waters

Extent

The Welsh marine area extends to 12 nm, covering just under 15,000 km^2 or 41% of the territory of Wales[360]. Thirty-five per cent of water inside the 12 nm is designated as Natura 2000 sites. The Water Framework Directive covers the entire Welsh coastline out to 1 nm, with 32 estuarine and 23 coastal water bodies.

Condition

Classification for ecological and chemical status in estuarine and coastal water bodies includes a number of different elements (Table 26). In 2015, 38% of estuarine and coastal water bodies achieved good or better ecological status[361]. For those that did not achieve their objectives, the most prevalent causes of the failures were physical modifications, and inputs of nutrients and chemicals from point and diffuse sources.

Table 26 Water Framework Directive status for intertidal and subtidal elements[361]

Element	Habitat(s)	Water bodies assessed	High (pass)	Good (pass)	Moderate (fail)	Poor (fail)
Seagrass	Intertidal	7	4	3	-	-
Saltmarsh	Intertidal	14	3	7	4	-
Opportunistic macroalgae	Intertidal	40	28	10	2	-
Benthic macroinvertebrates	Intertidal & Subtidal	23	2	14	7	-
Estuarine fish	Subtidal	7	-	7	-	-
Phytoplankton	Subtidal	20	10	5	3	2
Chemical Status	Estuarine & coastal	55		39	16	
Dissolved inorganic nitrogen	Estuarine & coastal	32	9	3	20	

The pressures on estuarine and coastal waters are most commonly derived from riverine inputs and direct discharges to the marine environment which have been described in section 3.10, and only those specific to the marine environment are discussed here. The most common failures for chemicals in the estuarine and coastal environment are for mercury and Brominated Flame Retardants[361]. These and other chemicals, such as polychlorinated biphenyls (PCBs), can impact on marine mammals, but concentrations of many of these substances have declined since the 1990s due to bans or significant restrictions on use[362]. Impacts on marine mammals range from disruption to their endocrine systems, increased susceptibility to disease, increased parasitic burden, reduced fertility, and poor body condition[363]. Analysis of stranded marine mammals in Wales contributed to a pan-European study that found

PCB levels in the blubber of some species remain above known toxicity thresholds[364].

Despite the number of water bodies that do not achieve good status for dissolved inorganic nitrogen, only a small number of water bodies experience negative ecological impacts as a result.

Algal toxins associated with paralytic shellfish poisoning (PSP) and lipophilic toxins (LTs), including diarrhetic shellfish poisoning (DSP) and amnesic shellfish poisoning (ASP), can accumulate in shellfish which can subsequently pose a risk to human health. Outbreaks of toxic phytoplankton blooms cannot be predicted and cannot be directly linked to anthropogenic inputs. PSP toxins were detected in the Milford Haven shellfish production area in 2001, 2010 and 2011, but levels remained within safe limits in 2001 and 2011, only prompting temporary closure of the fishery in 2010. LT levels above the statutory limit were detected in Swansea Bay in 2011, prompting closure of the shellfish beds there[360]. ASP levels above the regulatory limit have not been detected in Welsh waters[360].

Marine macro-pollution (e.g. plastic bags, lost and discarded fishing gear and other anthropogenically-derived debris) is often found entangled in reef structures, within bays and beaches, and in the nests of seabirds[365]. An OSPAR report[366] on marine litter in the north-east Atlantic indicated that, on average, 2,655 items were collected per km of beach during a survey of 38 beaches in Wales, although this accumulation is influenced by currents and prevailing winds[367]. Microplastics are an emerging issue in the marine environment, where they can enter directly via sewage systems or arise from the fragmentation of larger items[368]. They can be ingested by marine species and release chemical contaminants, impairing the survival of species and accumulating through the food chain[369, 370]. However, not enough is known about their levels in Welsh waters to comment on state or current trends.

22 Shellfish Water Protected Areas (SWPAs) are subject to a wide range of measures to endeavour to achieve the microbial guideline of less than 300 *E. coli* per 100 ml shellfish flesh and intervalvular fluid. Three of 22 SWPAs achieved the guideline in 2014[371]. However, almost all shellfish beds meet the hygiene classification of Class B, allowing shellfish to be placed on the market following depuration. Rainfall levels, diffuse agricultural contributions and discharges from combined sewer overflows are important external factors in compliance.

The revised Bathing Water Directive sets standards for the management and surveillance of bathing water sites and for compliance against microbiological standards. It required assessments of bathing waters against much stricter criteria in 2015. All 102 sites met the required standards, with 80% of Welsh bathing waters achieving the highest European classification of excellent, a further 16% met good status, and the remaining 4% achieved sufficient status[372]. In 2014 all 102 bathing waters were sampled during the bathing season and 100% passed the mandatory European standard, while 88% passed the tougher European guideline standard[373]. This is compared with 99% achieving mandatory compliance and 89% achieving guideline standards in 2013[374]. Good quality bathing waters are very important for coastal communities, visitors and the economy in Wales.

Trends

The improvement in bathing water quality is a significant achievement. Actions taken by Natural Resources Wales and our predecessor bodies, together with Dŵr Cymru, Local Authorities, farming organisations and landowners to improve water quality over the last 20 years have significantly contributed to this achievement. Improvements have been made locally, such as sewerage and outfall improvements, and more broadly, such as reducing diffuse water pollution from farmland in the wider countryside. The improvement is also reflected in the public perception, as a survey of visitors to Wales in 2013 showed that on a scale of 10, the satisfaction with the sea water quality was 8.6, which had improved from 7.9 in 2011[375].

The improvements to sewerage and outfalls since the 1990s have also resulted in significant improvements in the microbial quality of shellfish flesh in the Dee, Menai Strait East and Burry Inlet North, which amount to approximately 90% of the value of the shellfish industry in Wales.

Monitoring undertaken as part of the OSPAR Riverine Inputs and Direct Discharges programme, and the now discontinued Harmonised Monitoring Scheme, provides an examination of trends in nutrients from river catchments to the sea. In Welsh waters, concentrations of phosphorous in half of the rivers monitored have decreased; ammoniacal nitrogen has also reduced in some rivers. Dissolved inorganic nitrogen does not show a consistent trend[376, 377]. Some chemicals derived from industrial sources have declined since the 1990s due to bans or significant restrictions on use[362], while the state, impact and trends of others are yet to be established.

Climate change impacts on intertidal and subtidal habitats

Loss of priority marine species and habitats due to changing marine environment

Climate change impacts on marine ecosystems are less well understood than for terrestrial counterparts. However, a number of key studies highlight distribution changes and potential risks to marine habitats and species as a result of climate change. MarClim (Marine Biodiversity and Climate Change) have shown that distribution of intertidal species is changing across Wales and the UK[378, 379], with the topshell *Gibbula umbilicalis* having extended its range northwards in Wales in the last decade. Modelling suggests that horse mussel *Modiolus modiolus* reefs may disappear from Welsh waters as a result of climate warming[380]. The Marine Climate Change Impacts Partnership have also published a number of reports that highlight current and likely future changes to marine ecosystems as a result of climate change. Sea-level rise and increased storm frequency are likely to have a significant impact on some intertidal and shallow subtidal habitats (mostly intertidal sand, mud and saltmarsh habitats) via coastal squeeze and erosion. These impacts are likely to be most notable in and around estuaries and along sections of defended coast[381] (see also Section 3.3– Hydrological Processes).

Loss of calcifying marine species as a result of ocean acidification

Chapter 3 of the UK CCRA2[382] summarises likely impacts of ocean acidification on the marine environment. Impacts on Welsh marine habitats and species in the

Climate change impacts on intertidal and subtidal habitats
short term are uncertain, though studies suggest longer term impacts on marine (particularly calcifying) species are likely by the end of the century under current emission scenarios[383]. **Changes in yield of marine fisheries/aquaculture** Climate change impacts, notably changes in sea temperature and chemistry, are having an impact on spawning, migration and the range and distribution of marine fisheries, with cold water species such as cod moving deeper and northwards towards the arctic and southern water species such as anchovy and boarfish increasing their range northwards in to UK and Irish waters[384, 385, 386]. Productivity in the Irish Sea may be impacted by the shift in range distribution of commercial species; opportunities may exist for increasing aquaculture production in Wales[386, 382].

Intertidal

Extent

The Welsh coastline is made up of a wide variety of intertidal habitat types, from sheltered to exposed rocky shores, muddy and sandy estuaries, and a range of soft sediment shores including species-rich, fully marine muddy gravel shores and open coast low diversity sandy beaches. The coastline is approximately 2,740 km in length[387] and covers around 56,856 hectares of intertidal habitat[388]. Sand and rock make up equal proportions of the length of the coast, but the area of sediment shores is significantly greater (42,554 ha) than the area of rocky shore (8,059 ha)[388]. 75% of the intertidal of Wales is designated as a Site of Special Scientific Interest (SSSI).

Intertidal rocky habitats are widespread throughout most of Wales. Areas dominated by biogenic reefs, where the habitat is built by animals such as the honeycomb worm *Sabellaria alveolata* or the blue mussel *Mytilus edulis*, are relatively common. Honeycomb worm reefs have recently re-established on the north Wales coast after a long absence[389, 390]. Biogenic reefs are important for stabilising the shore and providing habitat for other organisms[391].

A number of wholly or partially intertidal habitats are protected by the Habitats Directive and the most recent assessment found that the extent of intertidal mudflats and sandflats and estuaries was declining in Wales[392]. Recent trends in the range and area covered by these habitats in Wales are shown in Table 26. The extent of estuaries were found to be stable over the short term, but there has been a significant loss of estuary habitat over the longer term[392]. However, intertidal seagrass beds (*Zostera noltii*) were found to have increased on the whole since the previous reporting period[393, 394, 395].

Intertidal habitats are at risk from coastal squeeze impacts, partly due to climate change effects such as sea level rise. There have also been some small ongoing losses of intertidal reef extent due to developments like marinas[392].

Condition

Condition assessments for Welsh habitats of principal importance, last undertaken in 2008, found that honeycomb worm reefs were stable, while mudflats, seagrass beds and sheltered muddy gravels were considered to be declining[396]. However, more recent assessments have found that all seven coastal water bodies with seagrass beds were in high or good status for the seagrass element[361], as shown in Table 26.

The most recent assessment of marine habitats protected under the Habitats Directive found that the extent of intertidal mudflats and sandflats and estuaries was declining in Wales[392]. Findings include evidence of some unfavourable infaunal community changes and an increase in observations of invasive non-native species (INNS)[392]. The marine environment is at risk from INNS due to the difficulty in identifying and eradicating the species, and coastal margins are most at risk because of links to the main pathways of introduction and spread such as shipping, aquaculture, recreational boating and coastal development[397]. There are currently considered to be 16 species of non-native marine plants and 32 species of non-native animals recorded on Welsh coasts[398].

Many of the habitats described here are subject to protection under the EU Habitats Directive or have been identified as habitats of principal importance under interim Section 7 list , but assessing them is difficult due to the resources required to effectively monitor their condition over a suitable timescale.

Trends

Recent trends in the range and area covered by intertidal habitats in Wales are shown in

Table 27. Estuaries were found to be stable in the short term (2001-2012) and declining in the longer term (1989-2012). Mudflats and sandflats were found to be declining in both the short and the longer term[392]. Assessment of intertidal elements of the predominantly subtidal ‘Large shallow inlets and bays’ feature found stable populations of the nationally scarce intertidal amphipod *Pectenogammarus planicrurus*. There are intertidal examples of ‘Submerged or partially submerged sea caves’, and although some minor losses in recent years have been reported, these have not detracted significantly from the overall extent of the resource. Recent trends in predominantly subtidal habitats are shown in Table 28 Short and long-term trends in range and extent of Annex I predominantly subtidal habitats in Wales. All information from 2013 Habitats Directive Article 17 reporting.

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Table 27 Short- and long-term trends in range and extent of Annex I predominantly intertidal habitats in Wales. All information from 2013 Article 17 Habitats Directive reporting.

Habitats Directive Annex I habitat	Range of habitat in Wales			Area of habitat in Wales		
	Surface area of range (km²) *	Short-term trend (2001 – 2012)	Long-term trend (1989 – 2012)	Surface area of habitat (km²) †	Short-term trend (2001 – 2012)	Long-term trend (1989 – 2012)
Estuaries	591.91	→	↓	591.91	→	↓
Mudflats and sandflats not covered by seawater at low tide	416.66	↓ 1% or less/year	↓ 1% or less/year	416.66	↓ 1% or less/year	↓ 1% or less/year

* Range - defined as 'the outer limits of the overall area in which a habitat type or species is found at present. It can be considered as an envelope within which areas actually occupied occur.
† Area - actual area covered by the habitat type within the range in the biogeographical or marine region concerned.

Key: → = stable; ↓ = decreasing; ↑ = increasing; - = no information.

Subtidal

Extent

The seas around Wales are relatively shallow, only exceeding 100 m in a small area of the Welsh inshore area to the west of Pembrokeshire and in the deep trenches to the west of Anglesey[360]. The subtidal habitats are influenced by a variety of physical processes such as tidal flow, wave action, water clarity and geological processes. Sands, gravels and mixed sediments are most common, but muds do accumulate locally. Large expanses of subtidal rock are relatively uncommon in Welsh waters due to the widespread deposition of subtidal sediments, but are commonly found in the intertidal area[360].

Although habitat maps are very variable in their confidence, with some areas not surveyed and based on interpolated and modelled data, current estimates are that 75% of the Welsh seabed to 12 nm comprises sands and gravels, 5% is mixed sediments, 2% mud and 10% rock.

The main areas of subtidal reefs are around and to the north of Anglesey, around the Llŷn Peninsula, and off the Pembrokeshire Coast. There are also highly productive kelp forests (brown algae) along most of the Welsh coastline[399]; subtidal biogenic horse mussel and Ross worm *Sabellaria spinulosa* reefs; and seagrass meadows known to be important for juvenile fish[400,401].

Condition

In the most recent assessments of habitats of principal importance in Wales[396], maerl, horse mussel beds, tidal rapids and sublittoral sands and gravels were all reported as declining. Mud habitats in deep water were reported as fluctuating, but probably stable. A number of wholly or partially subtidal habitats are protected by the Habitats Directive and their status is summarised in Table 28.

The results shown in Table 26 show that the majority of water bodies achieve high or good status for subtidal elements (although note that this only covers waters within 1 nm of the shore). However, 30% of water bodies assessed for the benthic invertebrates element failed, and 25% of water bodies assessed for the phytoplankton element failed. Inshore subtidal areas are important nursery and spawning grounds for a range of fish species, and all seven waterbodies assessed for fish communities achieved ‘good’ status[361].

The marine environment remains highly diverse and there have been improvements in water quality in recent years. Although our evidence suggests marine habitats are in variable condition, they are able to support healthy populations of many species of seabirds and marine mammals. The first reporting cycle for the Marine Strategy Framework Directive is commencing in 2017 and this will provide valuable insight into the environmental status of the marine environment as a whole in Wales and the UK. In addition, the Welsh National Marine Plan and effective management of the network of Marine Protected Areas will also contribute to the sustainable management of natural resources in the marine environment.

Trends

Recent trends in the range and area covered by protected marine habitats in Wales are shown in Table 28. The extent of sandbanks and reefs was found to be declining over the short and long term in Wales. Large shallow inlets and bays were stable, with no significant habitat losses in extent over the short term (2001-2012)[392].

Historically, extensive beds of native oyster *Ostrea edulis* were present across Welsh seas but these have largely been lost, with the exception of small areas in Milford Haven and isolated locations across the South Wales coast[402]. Efforts to regenerate the existing population in Swansea Bay are in place[403], highlighting a potential opportunity in terms of ecosystem services.

The *Zostera marina* seagrass bed within the Skomer Marine Conservation Zone appears to have increased in extent between 1997 and 2014[404].

Table 28 Short and long-term trends in range and extent of Annex I predominantly subtidal habitats in Wales. All information from 2013 Habitats Directive Article 17 reporting.

Habitats Directive Annex I habitat	Range of habitat in Wales			Area of habitat in Wales		
	Surface area of range (km^2) *	Short-term trend (2001 – 2012)	Long-term trend (1989 – 2012)	Surface area of habitat (km^2) †	Short-term trend (2001 – 2012)	Long-term trend (1989 – 2012)
Sandbanks slightly covered by sea water all the time	6,224.87	→	→	564.23	↓	↓
Large shallow inlets and bays	1,514.51	→	→	1,514.51	→	→
Reefs	3,035.65	↓ 1% or less/year	↓	3,035.65	↓ 1% or less/year	↓
Submarine structures made by leaking gases	-	-	-	-	-	-
Submerged or partially submerged sea caves	-	→	→	-	→	↓

* Range - defined as 'the outer limits of the overall area in which a habitat type or species is found at present.' It can be considered as an envelope within which areas actually occupied occur.
† Area - actual area covered by the habitat type within the range in the biogeographical or marine region concerned.

Key: → = stable; ↓ = decreasing; ↑ = increasing; - = no information.

The most detailed landscape baseline in Wales and a key source for SoNaRR reporting on landscape state, condition and trend is LANDMAP[405]. LANDMAP explains the physical, geological, ecological, visual, historic and cultural landscape: the summary descriptions, evaluations and management recommendations aid our understanding of landscape and identify important landscape qualities and characteristics. By capturing multi-dimensional landscape information it ensures that all aspects of the landscape can be taken into account. It is the focus for landscape monitoring in Wales, enabling the tracking of change and identifying key factors determining landscape change, condition and resilience.

Landscape Character Areas (LCAs) are identified at both a local planning authority level and at a national level, with 48 National Landscape Character Areas (NLCA) identifying regional landscapes. They offer overall landscape summaries linked to the 5 LANDMAP layers, key characteristics, and forces for change, and may be linked to design or sensitivity studies. Special Landscape Areas that identify areas of high landscape importance, often linked to LCAs, are identified by some authorities.

Seascape information complements terrestrial landscape information. The 29 national Marine Character Areas (MCAs), the 50 Regional Seascapes and the local Seascape Character Assessments (SCA) provide seascape information that includes character areas and profiles of characteristics, qualities, and forces for change.

The Register of Landscapes of Historic Interest in Wales identifies 58 historic landscapes of national significance. Historic Landscape Characterisation (HLC) of each registered landscape provides more detailed information at a local level.

The Tranquil Areas Map of Wales identifies zones of tranquillity from built-up to undisturbed areas with dark night skies, and reports on the direction of change between 1997-2009, including the key factors contributing to a loss of tranquillity.

National Park and Areas of Outstanding Natural Beauty (AONB) management plans identify special qualities that are to be protected and enhanced as well as objectives and actions that include landscape. To inform the review of management plans, every 5 years the Designated Landscapes (DLs) collect evidence and data regarding state and trends of the special qualities and produce their State of the AONB/ National Park reports. The State of DL reports are vital for reviewing management options and policy approaches.

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("Accessed" refers to the date the link was last accessed)

Part A – Natural Resources

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Part B: Ecosystem Evidence

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