Office for National Statistics

Statistical bulletin

UK natural capital: mountains, moorland and heath accounts

Ecosystem accounts for the mountains, moorlands and heath (MMH) environment in the UK. This is the first iteration of the MMH ecosystem account.

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1 . Main points

- In 2017, electricity generation in the UK from onshore windfarms in mountains, moorlands and heath was over 24 times larger than in 2003.
- The removal of carbon dioxide equivalent by mountains, moorlands and heath during 2017 was estimated to be valued at £130 million.
- In 2017, the removal of pollutants from the atmosphere (particularly fine particulate matter (PM2.5)) by mountains, moorlands and heath led to an overall saving of £10.9 million in associated health costs.
- Mountains, moorlands and heath in the UK provided a cultural service of £199.3 million in 2017.
- The present value of the cost of maintaining and restoring UK mountains, moorlands and heath is estimated at approximately £6.8 billion.
- The overall asset valuation of mountains, moorlands and heath was estimated at £20,141 million in 2017.

2 . Collaboration and acknowledgements

This publication is produced in partnership with the Department for Environment, Food and Rural Affairs (Defra).

Department for Environment Food & Rural Affairs

The recently published 25 Year Environment Plan restated the government's commitment to working with the Office for National Statistics (ONS) to develop a full set of natural capital accounts for the UK. Such accounts will help support the monitoring of progress under the plan as well as providing evidence and statistics to inform better decision-making as envisaged in the plan.

We would also like to thank colleagues at the Centre for Ecology and Hydrology (CEH), Natural England (NE), Joint Nature Conservation Committee (JNCC), Scottish Natural Heritage (SNH) and Natural Resource Wales (NRW) for their valuable comments and review of this work.

3 . Things you need to know about this release

This bulletin contains ecosystem accounts for the mountains, moorlands and heath (MMH) environment in the United Kingdom. This forms part of the UK natural capital accounts being developed by the Department for Environment, Food and Rural Affairs (Defra) and the Office for National Statistics (ONS). This is the first iteration of the MMH ecosystem account and builds on the article UK natural capital: developing UK mountains, moorland and heathland ecosystem accounts, incorporating data and analysis.

All methods are continually improved upon as the natural capital accounts are developed, so remain in experimental status. Revisions to estimates in future releases are highly likely. The monetary accounts should be interpreted as a partial or minimum value of the services provided by the natural environment, as a number of ecosystem services, such as flood risk mitigation from natural resources, are not currently measured, and conservative assumptions are typically adopted where there is uncertainty.

4 . What are ecosystem accounts?

Each habitat can be thought of as an asset supplying a number of services that the economy and society benefit from. For example, food, water or clean air. The ecosystem accounts monitor the size and condition of these assets and also the quantity and value of the services supplied.

In this bulletin, the mountains, moorlands and heath ecosystem accounts are presented in four sections:

- the size of the area covered by each habitat (extent account)
- indicators of the quality of the ecosystem and ability to continue supplying services (condition account)
- quantity and value of services supplied by the ecosystem to society
- the costs of maintaining and restoring the habitat (restoration account)

5 . Extent of mountains, moorlands and heath in the UK

The extent of an ecosystem habitat or environmental asset simply measures the area of land it covers. The extent estimates provide both a primary indicator of the overall state of those habitats as well as the first step towards assessing the health and management of those habitats.

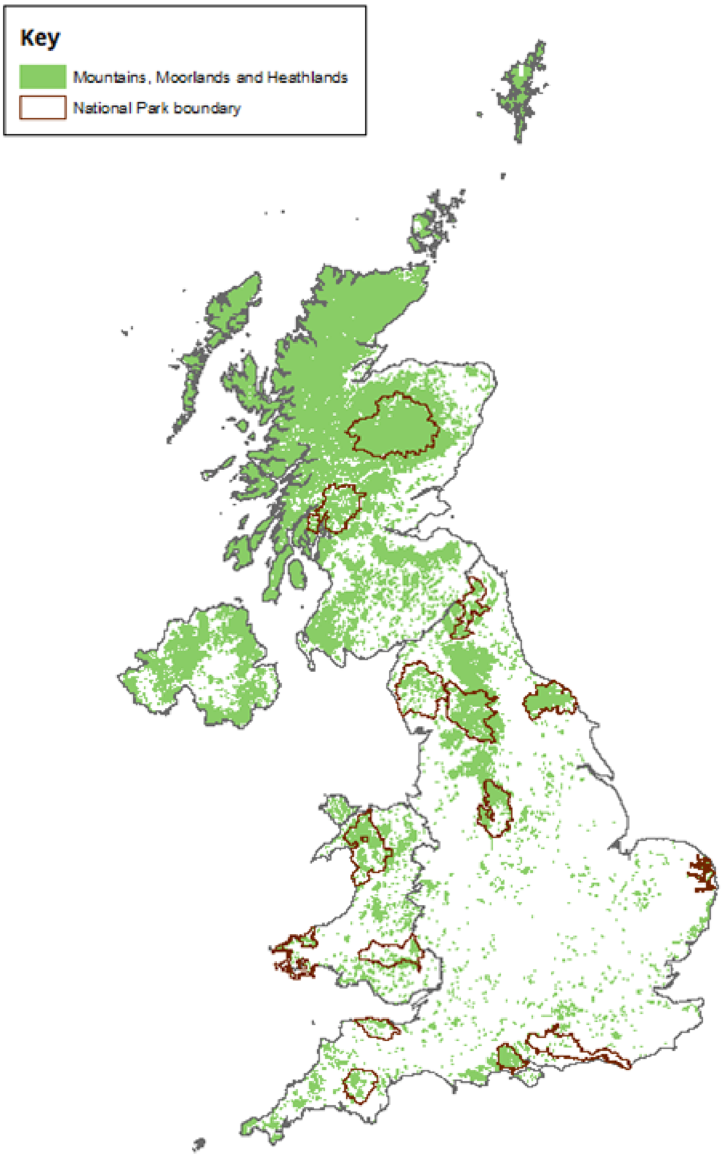
The UK National Ecosystem Assessment (UK NEA) classifies mountains, moorlands and heath (MMH) into six sub-habitats:

- bracken
- dwarf shrub heath
- inland rock
- montane
- upland bog
- upland fen, marsh and swamp

This section will approach each of these sub-habitats in turn, before coming to an aggregate estimate for the extent of MMH in the UK.

The data used to estimate MMH extent are the Land Cover Map 2015 (LCM2015), which uses satellite imagery and digital cartography to provide land cover information for the UK. However, differences between the aggregation of habitats in LCM2015 as compared with UK NEA mean that not all sub-habitats can be identified.

Figure 1: Map of mountains, moorlands and heath (MMH) extent, using Land Cover Map 2015



Bracken

Bracken (Pteridium) is a genus of large course ferns, with the most common being Pteridium aquilinium. According to UK NEA (2011) this sub-habitat must have a continuous canopy cover (95%) of bracken at the height of growing season.

Bracken in the LCM2015 (which is one of the MMH UK NEA sub-habitats) is included within acid grassland. As bracken is a sub-habitat that is very specifically defined, the land cover year-on-year may be variable, therefore it is not possible to apportion out the LCM2015 acid grassland to obtain the extent of bracken.

Dwarf shrub heath

In line with the UK NEA (2011) definition, dwarf shrub heath comprises areas with greater than 25% cover of plant species from the heath family or dwarf gorse.

The heather grassland and heather classifications from LCM2015 are to be taken together to form dwarf shrub heath, as classified by the UK NEA habitat classes. According to the LCM2015, dwarf shrub heath covers 2,502,800 hectares of land in the UK, or 10.2% of UK land cover. Compared with broadly equivalent estimates from 2007, this constitutes a 18.5% increase in the intervening period.

Upland fen, marsh and swamp

This sub-habitat comprises multiple components. Fens are peatlands that receive water and nutrients from groundwater and surface runoff, as well as from rainfall; flushes are associated with lateral water movement, and springs with localised upwelling of water; and swamps are characterised by tall emergent vegetation (UK NEA, 2011).

In the LCM2015 fen, marsh and swamp is not distinguished between that in upland and that in lowland, as such the entire sub-habitat will reside in MMH. There will be some overlap with the currently published freshwater accounts, that also include fen, marsh and swamp. It is estimated that 18,500 hectares of UK land cover are classified as fen, marsh and swamp, around 0.08% of total land cover.

Upland fen generally occurs in small patches of less than 0.5 hectares. The resolution of national remote sensing data is too coarse to map smaller areas. Remote sensing methods used in LCM2015 therefore underestimate the extent of fen, marsh and swamp.

Upland bog

Bog comprises wetland vegetation that is usually peat-forming and has a peat depth bigger than 0.5 metres. The LCM2015 aggregates upland and lowland bog into a single categorisation, similarly to fen, marsh and swamp, therefore the entire sub-habitat will reside in MMH.

Separating out upland bog from lowland bog is complex, as it cannot be done on purely an altitudinal basis, because blanket bog in Scotland goes down to sea level. As a result, it has not been possible to separate out upland bog from lowland bog for this report. Again, there will be some overlap with the currently published freshwater accounts, that also include bog.

Bog constitutes 960,200 hectares of UK land cover, or 3.92%, making it a large component of MMH. Compared with broadly equivalent estimates from 2007, this is a 12% decrease of UK land cover of bog, in the intervening period.

Inland rock

This broad habitat includes areas such as inland cliffs, caves, screes and limestone pavements, as well as various forms of excavations and waste tips such as quarries and quarry waste. Inland rock occurs throughout the uplands, and is particularly characteristic of high altitudes, but is also found at low altitudes (UK NEA, 2011).

It is estimated that 182,700 hectares of UK land cover are classified as inland rock, around 0.75% of total land cover. Like the other MMH land cover classes, the majority of inland rock (82%) exists in Scotland, with a much smaller proportion in England (13%) and Wales (4%).

Montane

In the UK, the montane habitat is sometimes defined as any areas over 600 metres above sea level, that is, on a purely topographical basis (UK NEA, 2011). In LCM2015, montane is no longer classified. The judgement of the Centre for Ecology and Hydrology (CEH) is that the LCM should track habitat change over time and as such an altitude-only habitat is not appropriate for inclusion.

Areas previously classified as montane are now spread across the remaining habitats, in whichever habitat it happens to sit. While much of this area is likely to remain in MMH, moving to upland bog, inland rock and heather, some may be placed outside this broad habitat. Therefore, it is not possible to calculate the extent of montane habitat within the UK.

Table 1 reports the total area of the MMH habitat, as defined within this study, based on land cover information. The MMH environment accounted for 3,664,200 hectares, in 2015, of the 24.5 million hectares in the UK. The MMH area therefore covers approximately 15% of land in the UK. As previously mentioned, some of the MMH habitat, as defined in this report, that would be in the UK NEA freshwater definition is included here – notably lowland fens and lowland bog.

Table 1: Extent of mountains, moorlands and heath area and broad habitats contained within it, UK, 2015

LCC	Land cover class	UK km²	UK hectares
8	Fen	185	18,500
9	Heather	9,697	969,700
10	Heather grassland	15,331	1,533,100
11	Bog	9,602	960,200
12	Inland rock	1,827	182,700
Total area		36,642	3,664,200

Source: Land Cover Map 2015, Centre for Ecology and Hydrology

6 . What is the condition of mountains, moorlands and heath in the UK?

The condition of an ecosystem asset, in terms of its characteristics, reflects its overall quality (United Nations System of Environmental-Economic Accounting (UN SEEA), 2014) and assists in determining the quantity and quality of services the asset provides.

This section will review the indicators of condition across the mountains, moorlands and heath (MMH) habitat, covering the condition status of sites of special scientific interest (SSSI) in each of the six sub-habitats pertinent to MMH defined in Section 5:

- biodiversity
- soil quality
- water quality
- the volume of sheep grazing
- accessibility

For this iteration of the report it was not possible to include burning on the MMH habitat and some biodiversity indicators. However, this is aimed to be included in future releases of this report.

Management practices

A SSSI is designated for nature conservation purposes and is a form of protected area in Great Britain. These areas are of particular interest due to either their biological (flora or fauna, or both) or geological conservation values.

SSSIs are currently designated by an official devolved national authority. These authorities are Natural England (NE), Scottish Natural Heritage (SNH), Natural Resources Wales (NRW) and the Northern Ireland Environment Agency (NIEA) – in Northern Ireland “SSSIs” are referred to as areas of special scientific interest (ASSIs) (Cottam, 2019).

Special areas of conservation (SACs) are another conservation designation of strictly protected sites under the European Commission Habitats Directive. These sites are part of a network of important high-quality conservation sites that will make a substantial contribution to the conservation of the 189 habitat types and 788 species identified under Annexes I and II of the Directive (JNCC).

The fact that an area is designated as a SSSI or SAC provides some condition information since we know that when it was designated it was considered of high natural value. In addition, there are requirements to monitor the condition of these sites, which can provide quantitative data on the status of the habitats represented.

The conservation status of natural habitats is considered “favourable” when the area covered within the range is stable or increasing and the species structure and functions, which are necessary for its long-term maintenance, exist and are likely to continue to exist for the foreseeable future (Joint Nature Conservation Committee (JNCC), 2002). The intention is that Favourable Conservation Status reflects the “long-term maintenance” and “foreseeable future” criteria incorporated in Articles 1e and 1i of the Habitats Directive. For a feature to be assessed as being in favourable condition, the ecological circumstances need to be such that there is a reasonable expectation that the feature will be maintained in that condition (that is, not deteriorate) in the long-term (JNCC, 2019).

Table 2 shows the condition of SSSI and ASSI sites and SAC sites across the UK for various MMH habitats. Notably, this table is missing both bracken and inland rock; however, while this isn’t comprehensive, it remains informative about the broad condition of MMH across the UK.

For some habitats, the percentage of SACs and the percentage of SSSI and ASSIs in favourable condition is similar. However, montane grasslands and heaths and blanket bogs show substantial differences, presumably driven by differences in monitoring and differences between the sample of sites under each conservation classification.

Designated SSSIs or ASSIs with interest features, such as habitat types, species, Earth science features, habitat mosaics and species assemblages must have their condition assessed at least once within a six-year period under UK legislation (JNCC, 2019). Each feature must be identified, monitored, assessed and reported on separately (JNCC, 2019).

Data in Table 2 are based on data for the period April 1998 to March 2005. The data were provided by the country agencies to JNCC in July and August 2005. There were no SSSI data for Wales in any of the reporting categories and the return percentage was unknown (JNCC, 2006).

Of the habitats in Table 2, blanket bogs have the greatest percentage of SSSI and ASSI sites in favourable condition and the lowest percentage in unfavourable condition, at 58% and 27% respectively. On the other end of the spectrum, both lowland and upland heath have a relatively low percentage of SSSI and ASSI sites in favourable condition and a relatively high percentage in unfavourable condition – though, lowland heath does have a substantial percentage of recovering habitat.

Table 2: Sites and areas of special scientific interest (SSSIs) and special areas of conservation (SACs) condition status across the UK, by mountains, moorlands and heath sub-habitat

		Favourable	**Unfavourable - recovering**	**Unfavourable**	**Destroyed (whole or part)**
Montane grasslands and heaths	SAC	27%	12%	61%	0%
	SSSI/ASSI	45%	10%	45%	0%
Upland Heath	SAC	19%	21%	57%	3%
	SSSI/ASSI	21%	28%	48%	3%
Lowland Heath	SAC	21%	43%	33%	3%
	SSSI/ASSI	17%	47%	33%	3%
Blanket bogs	SAC	45%	14%	39%	2%
	SSSI/ASSI	58%	15%	27%	0%
Upland fens and marshes	SAC	45%	19%	36%	0%
	SSSI/ASSI	46%	18%	34%	2%

Source: Joint Nature Conservation Committee (JNCC)

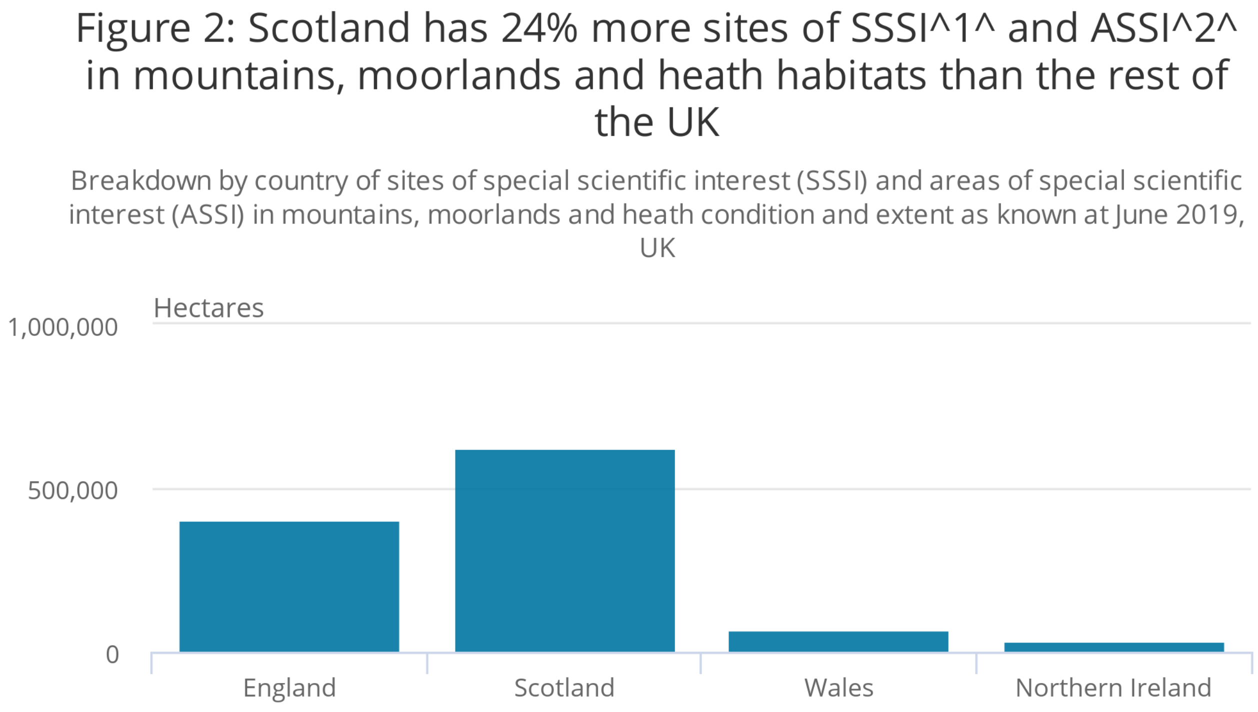
Figure 2 shows that Scotland has 626,710 hectares of SSSIs within MMH habitats, this means that 21.8% of Scottish MMH habitats are classified as SSSIs. Scotland has 24.0% more SSSIs extent in MMH habitats than the rest of the UK combined.

England has 407,267 hectares of SSSIs within MMH habitats, which makes up 81.3% of English MMH habitats. Similarly, Wales has 65,554 hectares of SSSIs within MMH habitats, making 63.3% of Welsh MMH. Only 18.0% of MMH in Northern Ireland is classified as ASSI.

In total, it is estimated that over 1.1 million hectares of SSSI and ASSI in the UK are MMH habitats. Due to Scotland having the most MMH extent, Scotland accounts for over half of the total SSSIs and ASSIs in the UK, at 55.3%. England had the second-highest proportion of MMH SSSIs and ASSIs (36%), then Wales (5.8%) and Northern Ireland (2.9%).

Figure 2: Scotland has 24% more sites of SSSI[1] and ASSI[2] in mountains, moorlands and heath habitats than the rest of the UK

Breakdown by country of sites of special scientific interest (SSSI) and areas of special scientific interest (ASSI) in mountains, moorlands and heath condition and extent as known at June 2019, UK



Source: Natural Resources Wales, Natural Scottish Heritage, Open data Northern Ireland, Land Cover Map 2015 (LCM2015)

Notes:

1. SSSI is special scientific interest.

2. ASSI is areas of special scientific interest.

Table 3 shows the condition of English SSSIs across each of the habitats discussed in the extent account (except for bracken, which is not defined in these data). Apart from mountain heath and willow scrub sub-habitat, each sub-habitat has seen an increase in the unfavourable condition of their SSSIs, between 2012 and 2018. Lowland heathland is the only sub-habitat with more SSSIs in a favourable condition in 2018 than in 2012.

Table 3: Sites of special scientific interest (SSSIs), in hectares, condition status for England, by mountains, moorlands and heath sub-habitat, 2012, 2014, 2016 and 2018

		2012		2014		2016		2018	
Blanket bog	SSSI Favourable	24,421	13%	24,995	13%	24,061	13%	25,325	13%
	SSSI Recovering	159,807	85%	158,622	85%	156,407	84%	155,814	82%
	SSSI Unfavourable	3,011	2%	3,622	2%	6,771	4%	9,774	5%
Lowland heathland	SSSI Favourable	15,756	34%	18,094	39%	18,987	41%	21,105	46%
	SSSI Recovering	27,973	61%	25,535	56%	24,719	54%	21,823	48%
	SSSI Unfavourable	2,112	5%	2,215	5%	2,301	5%	2,862	6%
Mountain heath and willow scrub	SSSI Favourable	1	0%	1	0%	56	1%	2	0%
	SSSI Recovering	5,033	98%	5,033	98%	4,977	97%	5,121	99%
	SSSI Unfavourable	117	2%	117	2%	117	2%	28	1%
Upland flushes fens and swamp	SSSI Favourable	2,125	33%	1,997	31%	2,015	31%	1,986	31%
	SSSI Recovering	4,199	64%	4,239	65%	4,180	64%	4,044	63%
	SSSI Unfavourable	187	3%	274	4%	317	5%	390	6%
Upland heathland	SSSI Favourable	20,593	13%	19,816	12%	20,837	13%	21,434	13%
	SSSI Recovering	137,785	86%	136,709	85%	135,181	85%	132,893	84%
	SSSI Unfavourable	1,578	1%	3,432	2%	3,948	2%	4,666	3%

Source: Natural England

Table 4 shows the condition of Scottish SSSIs across each of the habitats discussed in the extent account (except for bracken, which is not defined in these data). Every sub-habitat has observed an increase in the number of SSSI report features classified as favourable condition and a decrease in those classified as unfavourable, between 2010 and 2018. However, substantial differences exist between the percentage of report features in favourable condition across habitats, with 85% for inland rock as compared with dwarf shrub heath at 50%.

Table 4: Sites of special scientific interest (SSSIs) condition status for Scotland, by mountains, moorlands and heath sub-habitat, snapshots taken in 2007, 2010, 2015 and 2018

		2007	**2010**	**2015**	**2018**
Upland bog	Favourable	67%	61%	63%	67%
	Unfavourable	33%	29%	25%	18%
	Unfavourable recovering due to management	-	9%	12%	15%
	Not assessed	-	1%	1%	0%
Dwarf shrub heath	Favourable	34%	40%	44%	50%
	Unfavourable	64%	41%	32%	27%
	Unfavourable recovering due to management	-	3%	24%	23%
	Not assessed	-	2%	0%	0%
Upland fen marsh and swamp	Favourable	53%	58%	69%	77%
	Unfavourable	47%	24%	14%	13%
	Unfavourable recovering due to management	-	13%	17%	10%
	Not assessed	-	0%	0%	0%
Inland rock	Favourable	82%	75%	80%	85%
	Unfavourable	18%	17%	12%	8%
	Unfavourable recovering due to management	-	3%	7%	5%
	Not assessed	-	4%	1%	1%
Montane	Favourable	35%	38%	44%	62%
	Unfavourable	65%	51%	36%	27%
	Unfavourable recovering due to management	-	8%	18%	11%
	Not assessed	-	3%	1%	0%

Source: Scottish Natural Heritage

Notes

1. 2007 is inconsistent with the rest of the dates. Back to table

It was not possible to obtain data on SSSIs and ASSIs condition for Wales and Northern Ireland, but in future iterations of the report this will hopefully be included.

Soil indicators

Soils shape and feed the ecological systems and habitats they sit within. Soils are varied and a sign of good quality for one soil type can equally be a signal of damage in another place. The rich, near static and deep dark soils of peatlands contrast starkly with the nutrient poor and ephemeral substrate of sand dunes. Trends over time within specific soil categories provides a robust approach to tracking change in soil condition, for example, a loss of soil organic matter or acidification of a soil whatever its initial starting point is nearly always a sign of degradation.

The Environment Agency suggest specific key indicators to use when observing soil quality (Environment Agency, 2006). These include:

- pH level
- vegetation composition
- organic matter content
- bulk density

Table 5 displays three of these four indicators and looks at the broad habitats assessed by the Countryside Survey (CS), that make up a part of MMH.

Acidity

The soil within the MMH habitat has always been naturally acidic, however, for much of the last century soil was unnaturally acidified as a result of sulphur deposition, unnaturally decreasing the soil pH.

Table 5 shows an increase in the pH level of soil across all MMH broad habitats from 1978 to 2007 reflecting the recovery from this acidification in response to the reductions in sulphur emissions from the 1980s onwards (Review of Transboundary Air Pollution (RoTAP), 2012). This indicates an improved condition for MMH soils and a success of the emission reduction policies put in place by government.

Vegetation composition

Changes in vegetation composition indicate shifts in nutrient availability. Some plant species are adapted to surviving with low levels of nutrients and these species are often outcompeted by faster-growing species that can exploit nutrient rich soils.

Eutrophication is when there is an excessive richness of nutrients, which causes a dense growth of plant life. Eutrophication was found to have impacted British MMH vegetation between 1978 and the last CS in 2007, however, changes differed in magnitude and direction over time depending on the kind of vegetation examined.

Heath and bog together saw a reduced eutrophication signal between 1990 and 2007 while acid grassland showed signs of increasing eutrophication across the 29-year period. All three habitat types ended up more eutrophic, in terms of their indicative plant species composition, in 2007 than in 1978 (Smart and others, 2003; Smart and others, 2012; Carey and others, 2008). These results indicate a negative change in the condition indicator for the MMH habitat, which usually has a low soil fertility.

Organic matter content

Organic matter content is made up of plant and animal residues in different stages of composition (Grubinger, no date) and is another good indicator of the condition of soil.

Ideally, soils should be slowly increasing their levels of organic matter content over time as they have been doing since the last glaciation 11,000 years ago. However, as the climate changes, or grazing pressure, or burning or cutting intensity increases, there can be a loss of organic matter content due to increased decomposition rates of soil organic matter and/or increased erosion of the organic-rich top layer of soil.

The CS uses loss on ignition (LOI) data to measure the loss of soil organic matter. Loss on ignition is a test in which the soil is dried, weighed and then ignited for a set period. After this period, the percentage of the dry weight lost on ignition can be calculated.

From 1978 to 2007, the percentage of LOI fluctuated across the MMH broad habitats. The percentage of LOI in the bracken and bog habitats increased by 7.4% and 3.8%, respectively, over the aforementioned period, a positive condition indicator for MMH. However, the percentage of LOI in the dwarf shrub heath and fen, marsh and swamp habitats decreased by 3.7% and 0.5%, respectively, a negative condition indicator for MMH. However, these changes were not statistically significant and so should be treated as potential trends to check in the future as the next cycle of samples are analysed.

Bulk density

The final indicator of soil condition is bulk density, which is related to the amount of land use. If there are too many animals, too much traffic or plants aren't growing well in an area it will lead to compaction of soil, which can be measured as bulk density.

Compacted soil prevents plant growth and increases the risk of erosion (Sustainable Agriculture and Soil Conservation (SoCo), 2009) making it a negative condition indicator. The CS only reports bulk density for 2007 and so the change in condition of soil overtime cannot be deduced from this.

Table 5: pH, loss of ignition (LOI) and bulk density in mountains, moorlands and heath habitats for the years 1978, 1998 and 2007, UK

	pH			**Loss on ignition**			**Bulk density**
	1978	**1998**	**2007**	**1978**	**1998**	**2007**	**2007**
Bracken	4.1	4.5	4.6	28.2%	28.2%	35.6%	0.4
Dwarf shrub heath	4.2	4.5	4.6	55.5%	54.4%	51.8%	0.4
Bog	4.3	4.5	4.5	74.9%	81.8%	78.7%	0.2
Fen, Marsh and Swamp	4.6	5.4	5.5	42.1%	46.0%	41.6%	0.5

Source: Countryside Survey and Centre for Ecology and Hydrology

Ecological condition indicators

Water quality

Upland lakes are defined as those situated beyond the limit of enclosed agricultural land and occupying predominantly MMH landscapes. The Upland Water Monitoring Network (UWMN) collects data on acidity, acid neutralising capacity (ANC), dissolved organic carbon (DOC), nitrate and non-marine sulphate. Year-on-year changes in these values provide a trend that can give an indication of water quality.

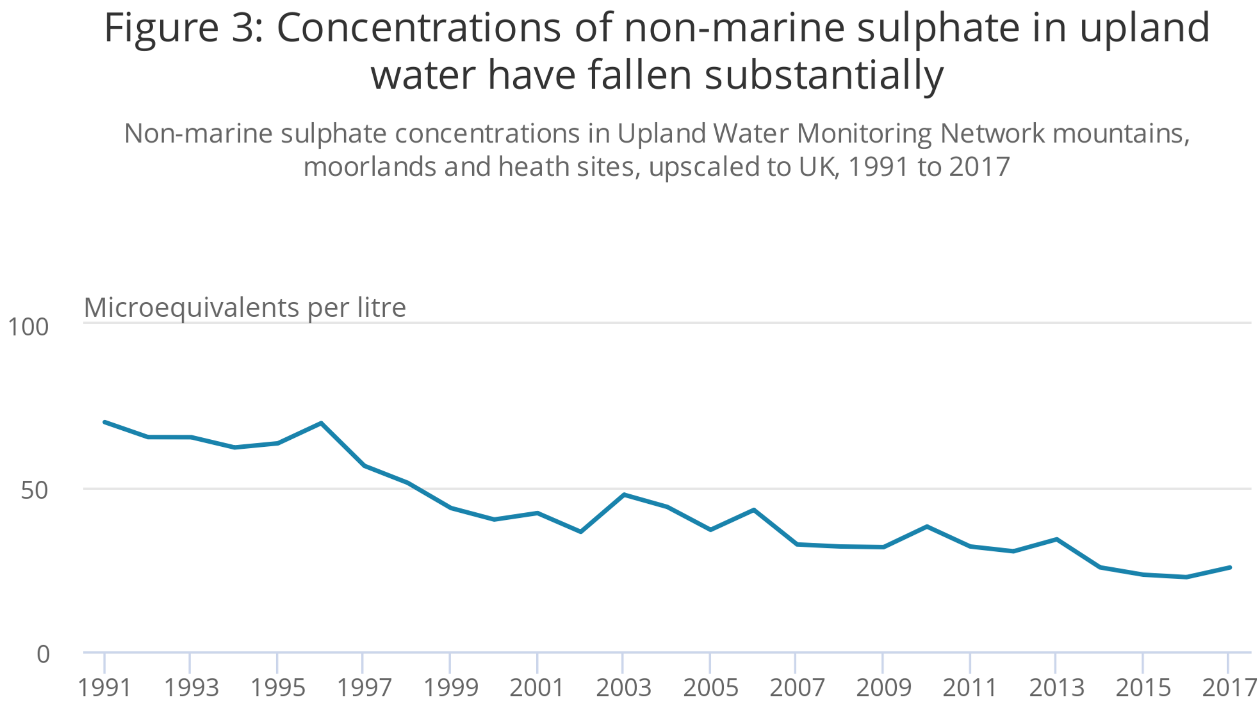
The Uplands Waters Monitoring Network (UWMN) have a sample of 26 sites around the UK monitoring water quality. Sites that were in MMH areas were extracted and data were upscaled to a UK level for the purpose of this report. The number of sites is limited but they show highly coherent behaviour.

Non-marine sulphate

Non-marine sulphate represents the chief acidifying anion (a negatively charged ion) in most sensitive UK freshwaters (Kernan and others, 2010). The concentration of non-marine sulphate in upland waters has fallen substantially between 1991 and 2017 (Figure 3). However, concentrations of non-marine sulphate were constant until a significant decline began after 1995. Decreasing non-marine sulphate is favourable for water quality because ongoing research suggests it has a significant role in the recovery of acidified water.

Figure 3: Concentrations of non-marine sulphate in upland water have fallen substantially

Non-marine sulphate concentrations in Upland Water Monitoring Network mountains, moorlands and heath sites, upscaled to UK, 1991 to 2017



Source: Upland Water Monitoring Network, Centre for Ecology and Hydrology and Office for National Statistics

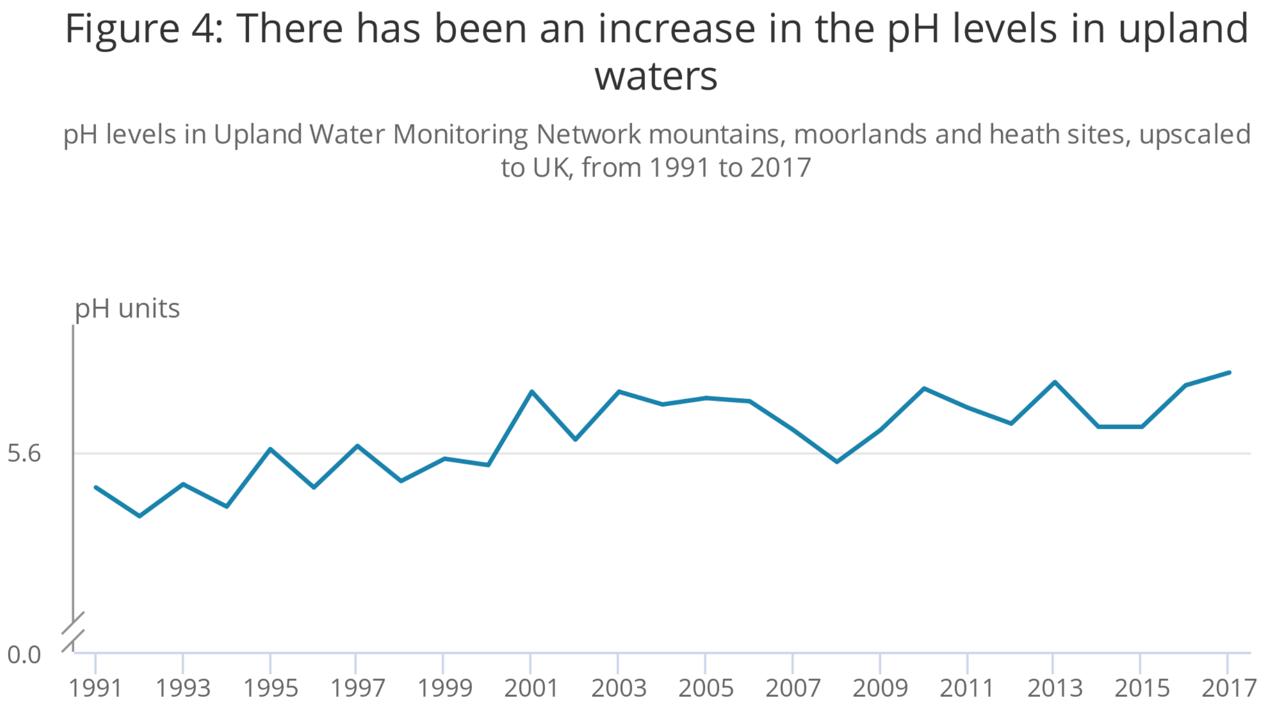
pH

pH is a measure of the acidity or alkalinity of water. It is measured on a scale of pH units between 0 and 14, with low numbers being acidic, 7 being neutral and higher values being classed as alkaline.

Extreme values of pH can cause problems for aquatic fauna. For example, fish may develop skin irritations or impaired gill functioning (McCaffrey, no date). Between 1991 and 2017, despite a relatively monotonic improvement, there has been an increase in the pH levels of upland waters (Figure 4). This is considered biologically favourable for water quality as it will result in a decline in the acidity of water. The progressive rise in pH was mostly driven by a decrease in non-marine sulphate.

Figure 4: There has been an increase in the pH levels in upland waters

pH levels in Upland Water Monitoring Network mountains, moorlands and heath sites, upscaled to UK, from 1991 to 2017



Source: Upland Water Monitoring Network, Centre for Ecology and Hydrology and Office for National Statistics

Notes:

1. 2007 is inconsistent with the rest of the dates.

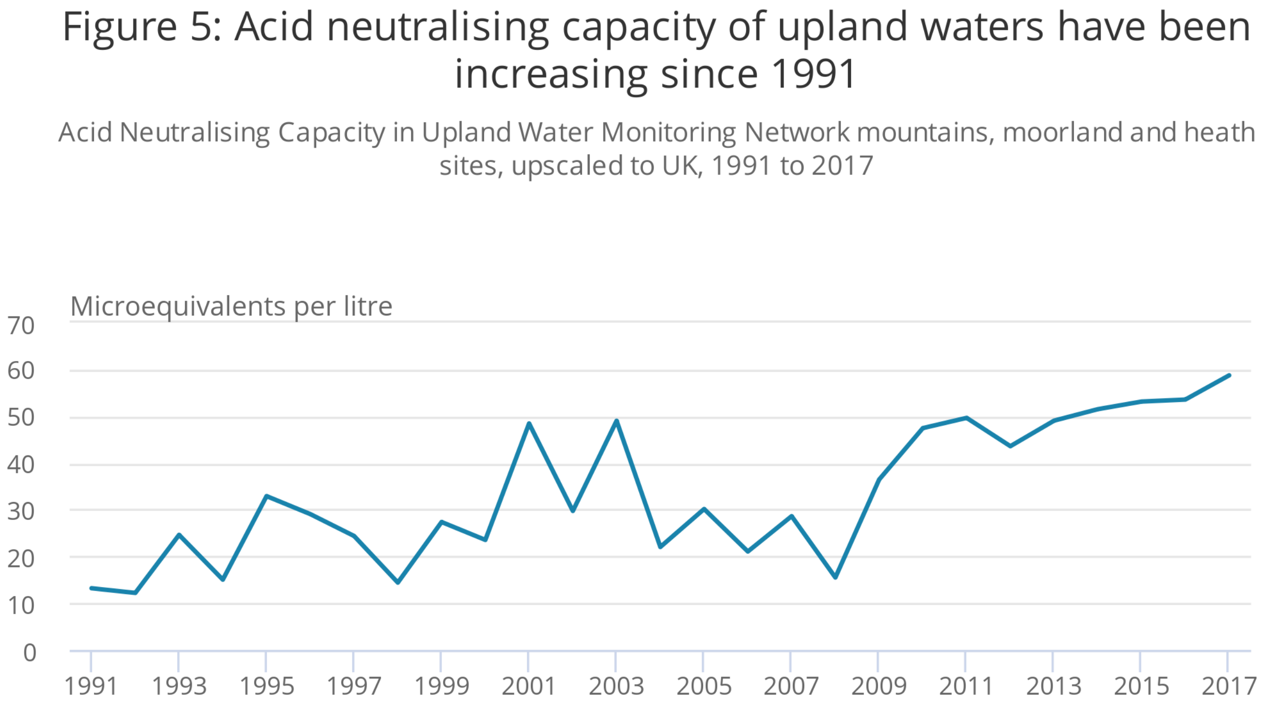
Acid neutralising capacity

Acid neutralising capacity (ANC) is a measure of the capacity of water to resist changes in pH levels. Research has shown that lakes with calcium levels greater than calcium 100 microequivalents per litre have adequate capacity to neutralise acid deposition (Aquatic Restoration Partnership, 2019). Increase in ANC is favourable for water quality because it increases the ability of the system to neutralise acid input.

The acid neutralising capacity of upland waters between 1991 and 2017 has been increasing (Figure 5), this is favourable for water quality as the water has more capacity to resist changes in pH levels and thus less sensitive to acidification.

Figure 5: Acid neutralising capacity of upland waters have been increasing since 1991

Acid Neutralising Capacity in Upland Water Monitoring Network mountains, moorland and heath sites, upscaled to UK, 1991 to 2017



Source: Upland Water Monitoring Network, Centre for Ecology and Hydrology and Office for National Statistics

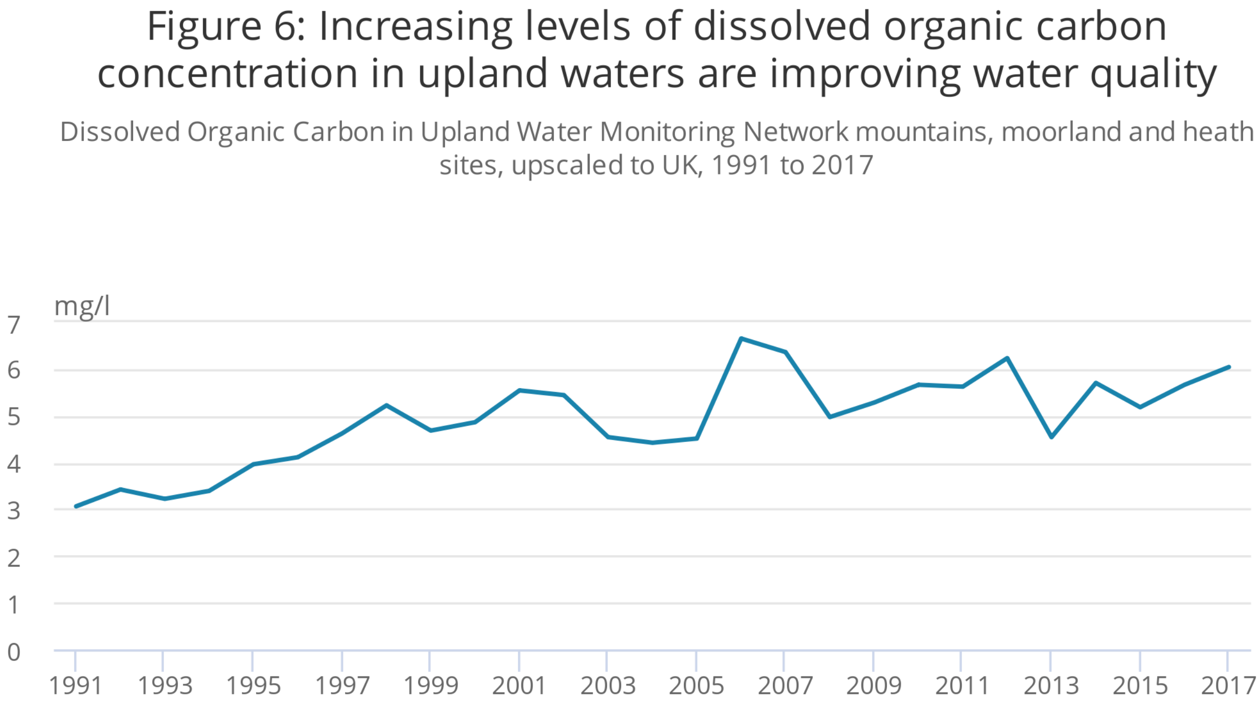
Dissolved organic carbon

Dissolved organic carbon (DOC) is derived largely from the degradation of plant and soil organic material and is dominated by high molecular weight humic matter in the form of humic fulvic acids. These compounds are efficient at absorbing light and exert a control on water transparency (Kernan and others, 2010). DOC in finished water can lead to aesthetic problems and increase the potential for bacterial regrowth in the distribution system (Real Tech Water, no date).

Throughout the time series, on average there has been an increasing upward trend in levels of dissolved organic carbon concentration in upland waters (Figure 6), this is an indication of recovery from acidification and thus favourable for water quality.

Figure 6: Increasing levels of dissolved organic carbon concentration in upland waters are improving water quality

Dissolved Organic Carbon in Upland Water Monitoring Network mountains, moorland and heath sites, upscaled to UK, 1991 to 2017



Source: Upland Water Monitoring Network, Centre for Ecology and Hydrology and Office for National Statistics

Nitrate

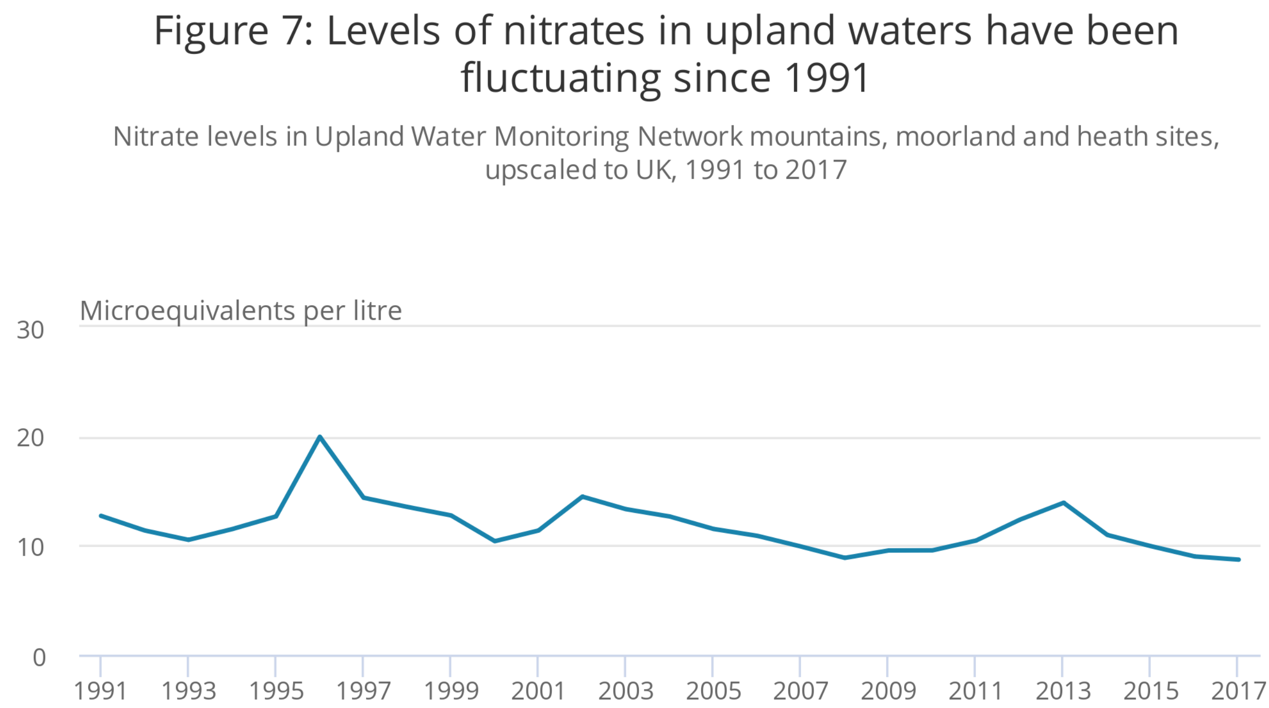
Between 1991 and 2017, the level of nitrates in upland waters has been fluctuating (Figure 7).

There are health and environmental reasons for concern about the level of nitrates in water. Under the Drinking Water Directives of 1980 and 1998, drinking water is required to have a nitrate concentration of less than 50 milligramme per litre (House of Commons, 2008).

Nitrogen is an essential nutrient in aquatic ecosystems but when nutrient availability increases, eutrophication can result. The main concerns about eutrophication are limitations on the water use and increased costs of treatment but health risks can also be associated with algal blooms (Wilson, 1999).

Figure 7: Levels of nitrates in upland waters have been fluctuating since 1991

Nitrate levels in Upland Water Monitoring Network mountains, moorland and heath sites, upscaled to UK, 1991 to 2017



Source: Upland Water Monitoring Network, Centre for Ecology and Hydrology and Office for National Statistics

Biodiversity indicators

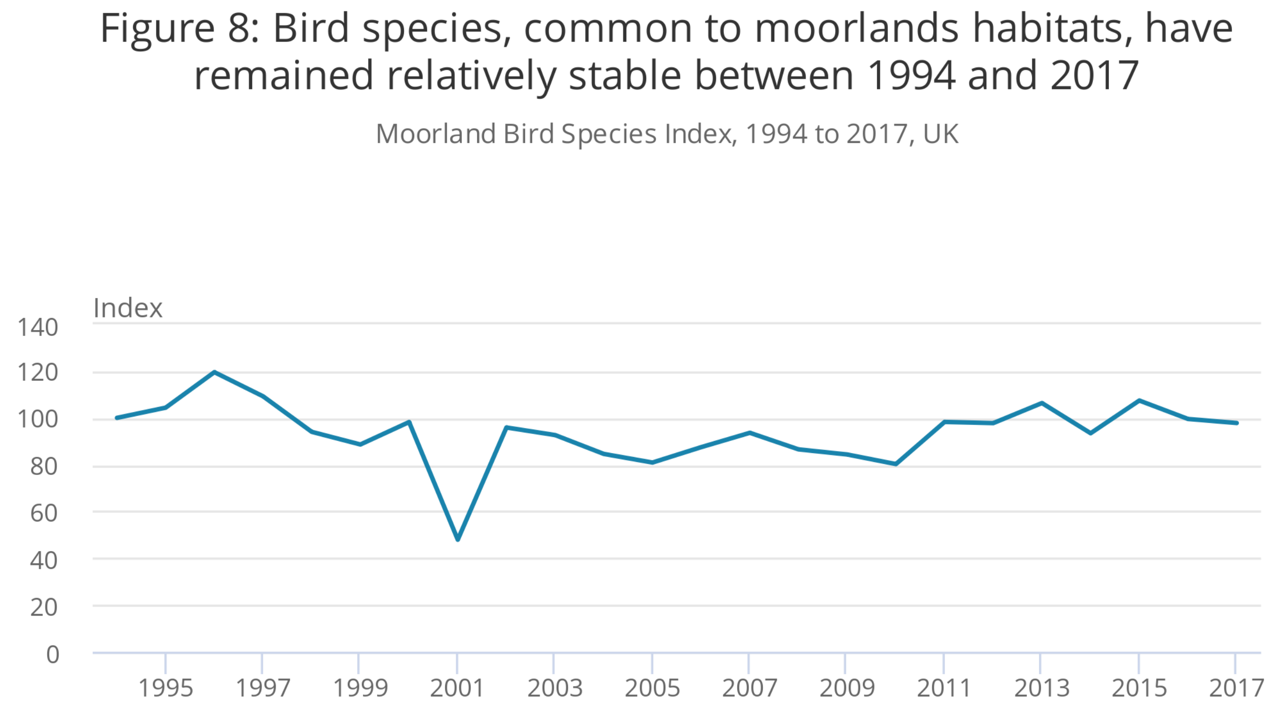
Specialist bird populations

The Moorland Bird Index, shown in Figure 8, is an unsmoothed index calculated by the Office for National Statistics (ONS). It displays the fluctuation in bird species, common to moorlands, over time and suggests that the ability of the moorland habitats to maintain biodiversity has remained relatively stable over time, although there is some fluctuation through the period. Noticeably, the 50% sharp drop in 2001 is an anomaly in the trend that can be attributed to foot and mouth disease. This caused decreased sightings for moorland bird species, due to footpath closures in this year (Donaldson and others, 2006), biasing the trend.

2002 sees a recovery in the index, returning to approximately the same level as it was prior to the foot and mouth outbreak, in 2000. To find out more about how bird populations are counted please visit the [Breeding Bird Survey, British Trust for Ornithology (BTO) website](#).

Figure 8: Bird species, common to moorlands habitats, have remained relatively stable between 1994 and 2017

Moorland Bird Species Index, 1994 to 2017, UK



Source: Breeding Birds Survey and Office for National Statistics

Whilst the overall index appears stable the disaggregated data is more turbulent. The index is calculated and presented as one in which the bird species are of equal weights but there are some species that have a considerably lower population such as Merlin, Hen Harrier and Black Grouse, who together make up on average 0.3% of the total population for moorland birds. The most commonly seen moorland birds are Meadow Pipit, Common Gull and Curlew, who together account for 79% of the total population for moorland birds.

Although the overall trend shows the population of moorland birds to be relatively stable there are certain species that have over doubled in population, from 1994 to 2017, such as the Raven and Black Grouse. Similarly, certain species have approximately halved in population numbers, from 1994 to 2017, such as the Whinchat, Golden Eagle and Merlin.

Relevant volume estimates

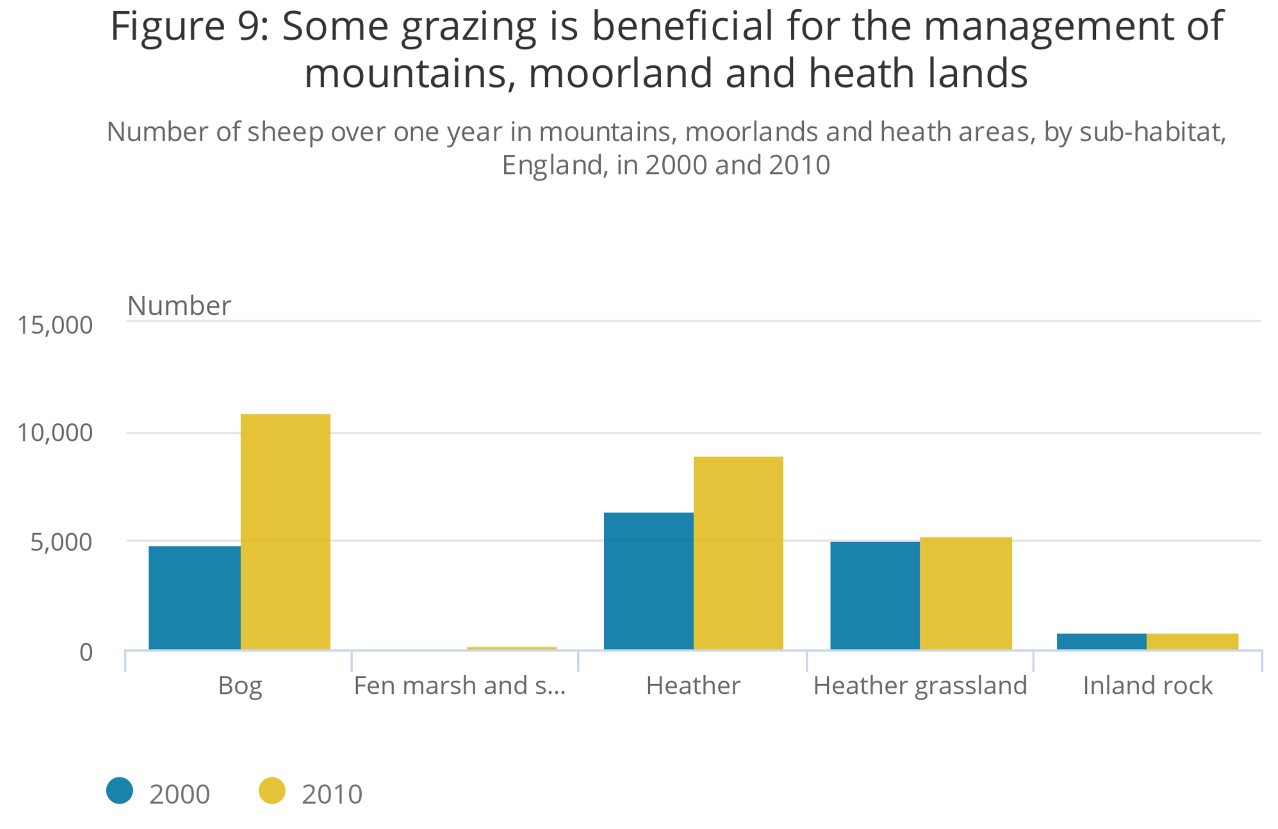
Volume of sheep grazing

Grazing, by sheep, on MMH lands gives an indication to the amount of agriculture being carried out, in this habitat. Some grazing is beneficial for the management of MMH lands, however, too much can be damaging to the condition of the habitat (English Nature, 2004).

Female and male sheep figures are taken from the Department for Environment, Food and Rural Affairs (Defra)'s maps of livestock populations and overlaid with an MMH map to extract an estimate of the amount of grazing within the MMH habitat. Data are obtained for census years 2000 and 2010, where there was a 70% response rate from all farms in England. The 30% gap was estimated based on actual responses (Defra, no date).

Figure 9: Some grazing is beneficial for the management of mountains, moorland and heath lands

Number of sheep over one year in mountains, moorlands and heath areas, by sub-habitat, England, in 2000 and 2010



Source: Department for Environment, Food and Rural Affairs, Centre for Ecology and Hydrology and Office for National Statistics

Figure 9 shows that from 2000 to 2010, the number of sheep over one year in all sub-habitats of MMH has increased. Overall, the total amount of sheep, in the MMH habitat has significantly increased, and has more than doubled over the decade, from 17,094 sheep to 26,104 sheep. The presence of sheep in 2000 can predominantly be found in heather areas, accounting for 37% of sheep grazing in MMH.

However, in 2010, sheep were predominantly found in bog areas, with 41.8% of sheep grazing in MMH. Heather grassland accounted for 29% of sheep grazing in 2000, compared with 20% in 2010. The remainder of sheep grazing, found in the fen, marsh and swamp, and inland rock sub-habitats accounted for a negligible 5.3% in 2000 and 3.7% in 2010.

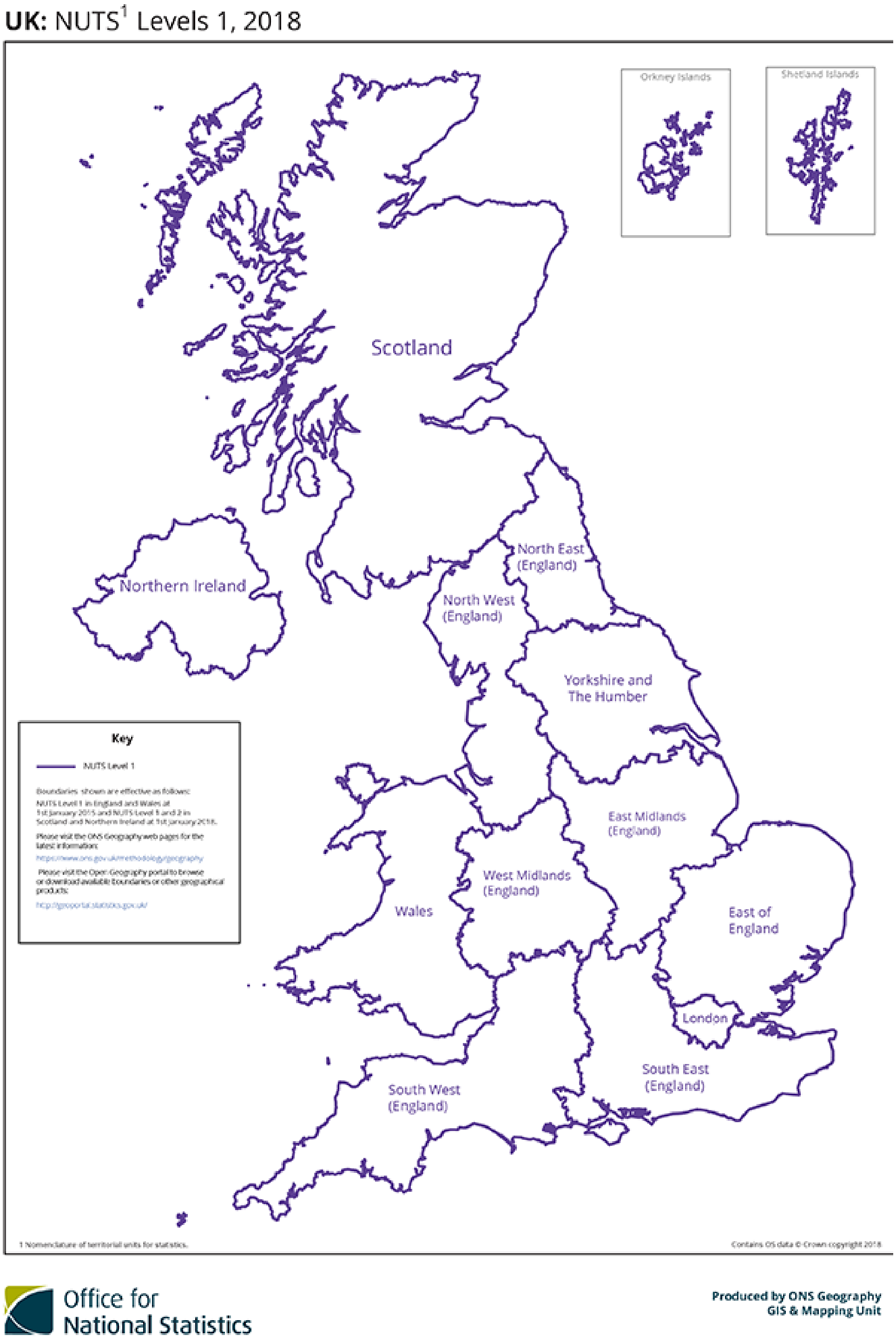
An increase in livestock numbers demonstrates an increase in agriculture on MMH lands. This can lead to a loss of heather moor, therefore higher volumes of sheep within MMH could portray a worsening condition of the habitat (Alonso, Hartley and Thurlow, 2001).

Access

One of the primary pressures on the MMH habitat is the proximity of human habitation to it. Too much access to the habitat, by humans, disturbs wildlife and habitat fragmentation increases the vulnerability of populations of rare species (UK National Ecosystem Assessment (UK NEA), 2011). Conversely, recreation is a significant ecosystem service in the UK (please see UK natural capital: Ecosystem service accounts, 1997 to 2015 for more information) and increased accessibility of outdoor spaces functionally increases the supply of this service.

To determine levels of accessibility in MMH areas a variety of data sources, including Open Street Map (OSM), national public transport access nodes (NaPTAN) and Addressbase, were used. It is important to note that as a result of using open data, the path lengths may not accurately represent the National Park path lengths, as some paths captured may be privately owned and not public paths. The data presented in Table 6 are broken down by Nomenclature of Territorial Units for Statistics (NUTS) regions, as displayed in Figure 10.

Figure 10: Map of NUTS regions, UK



Source: NUTS Level 1, January 2018, generalised clipped boundaries in the UK and Office for National Statistics

Table 6: Number of Addressbase residential properties and public transport links within mountains, moorlands and heath

NUTS118NM	Addressbase	Train Stops	Bus Stops	Path length (m)	Road length (m)	MMH area (KM2)	Total area (KM2)
North East (England)	989	0	43	935,126.2	260,973.6	1,110.9	8,592.4
North West (England)	1,339	1	51	1,076,792.6	261,461.3	995.2	14,164.1
Yorkshire and The Humber	1,389	0	194	2,752,847.9	626,077.8	1,745.9	15,409.1
East Midlands (England)	1,694	0	38	491,996.0	121,419.6	240.6	15,643.3
West Midlands (England)	872	0	19	282,090.4	108,742.9	84.7	13,003.7
East of England	1,879	0	12	412,997.7	74,100.5	109.8	19,135.6
London	124	0	6	50,441.5	15,700.9	3.6	1,573.5
South East (England)	3,464	0	107	1,519,809.1	331,560.2	253.8	19,088.8
South West (England)	5,002	1	121	1,318,332.2	527,736.0	472.9	23,851.4
Wales	4,104	2	121	1,124,107.2	527,956.4	1,030.4	20,782.1
Scotland	6,183	5	817	11,174,444.8	4,577,736.6	28,914.2	78,803.2
Northern Ireland	NA	NA	NA	NA	NA	NA	NA

Source: Open Street Map, National Public Transport Access Nodes and Addressbase

The most accessible part of MMH is perceived to be in Scotland, where approximately 80% of MMH in Great Britain is found, as seen in Table 6, with 817 bus stops, five train stops and 6,183 residential properties within the MMH area.

Yorkshire and The Humber has approximately 5% of MMH within it, which is, after Scotland, where most of MMH is found. The region has 194 bus stops, but no train stops and only 1,389 residential properties, compared with Wales, where approximately 3% of all MMH in UK is found, that has 121 bus stops, two train stops and 4,104 residential properties within the MMH area.

However, looking at the public transport links in comparison with the extent of the area, Scotland only has one bus stop per 13,677 metres of path, compared with London that has on average one bus stop per 8,407 metres of path and one bus stop for every 0.6 square kilometres of MMH, despite having the lowest number of bus stops in MMH (six bus stops). This is the lowest across all the NUTS regions and means that on average those visiting MMH in London would have to travel less to find a bus stop. Unlike other regions, Scotland has five train stops in MMH areas.

Table 7: Number of Addressbase residential properties and public transport links within one kilometre of mountains, moorlands and heath

NUTS118NM	Addressbase	Train Stops	Bus Stops	Train 1KM Path	Bus 1KM Path	Path length (m)	Path length (m) /number of bus 1KM in MMH	Path length (m) /number of train 1KM in MMH
North East (England)	218,143	13	4,213	8	2,042	935,126.2	222	71,932.8
North West (England)	369,724	50	6,157	24	2,952	1,076,792.6	174.9	21,535.9
Yorkshire and The Humber	335,073	31	7,306	23	5,079	2,752,847.9	376.8	88,801.5
East Midlands (England)	253,533	21	4,687	16	3,273	491,996.0	105	23,428.4
West Midlands (England)	192,471	12	2,869	7	1,525	282,090.4	98.3	23,507.5
East of England	334,793	51	4,657	35	2,831	412,997.7	88.7	8,098.0
London	282,870	38	3,214	31	2,263	50,441.5	15.7	1,327.4
South East (England)	621,686	89	9,255	56	5,887	1,519,809.1	164.2	17,076.5
South West (England)	559,489	42	10,068	22	5,911	1,318,332.2	130.9	31,388.9
Wales	485,733	91	9,892	48	4,046	1,124,107.2	113.6	12,352.8
Scotland	454,599	111	12,599	66	6,219	11,174,444.8	886.9	100,670.7
Northern Ireland	NA	NA	NA	NA	NA	NA	NA	NA

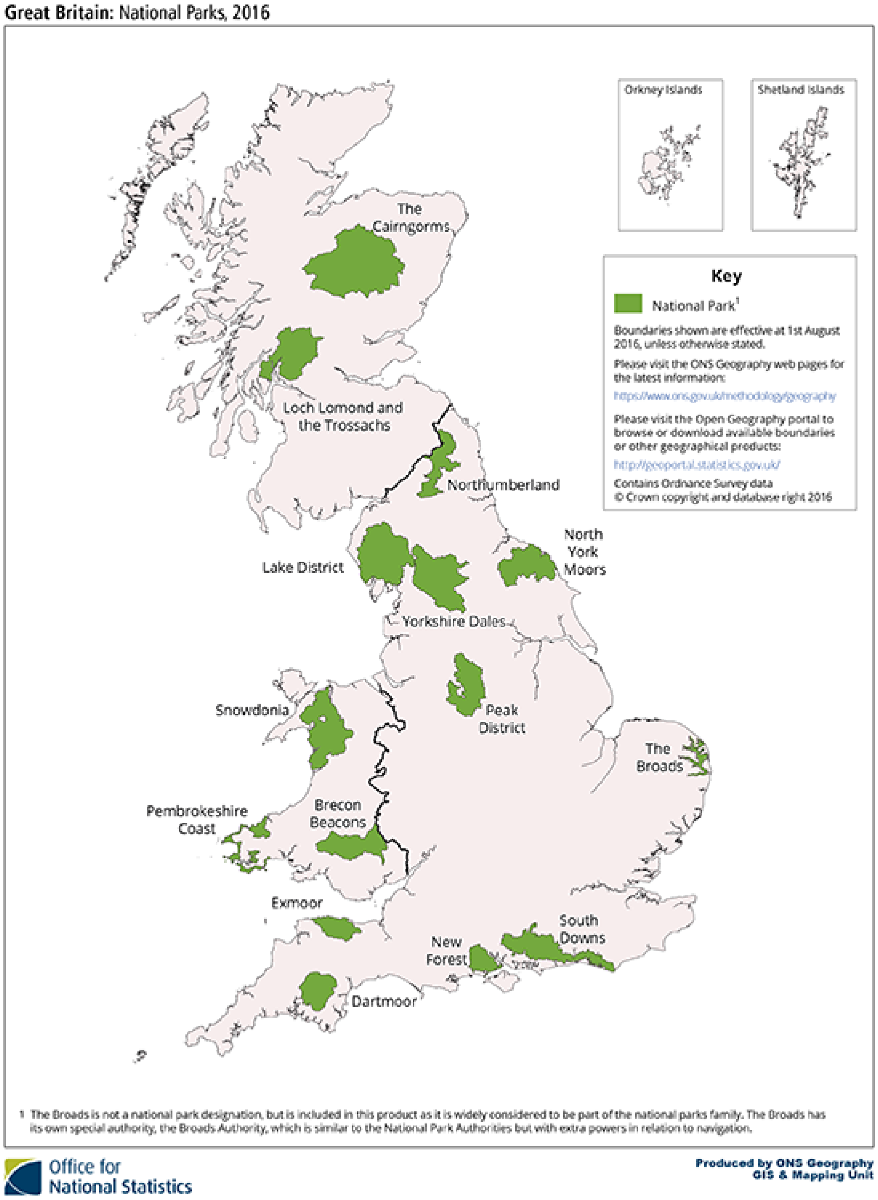
Source: Open Street Map, National Public Transport Access Nodes and Addressbase

Table 7 shows that MMH destinations in Scotland have the most public transport links. However, when taking into account the extent of the MMH area, again London has the most bus and train stops, with a nearby (within one kilometre) bus stop for every 16 metres of MMH paths and a nearby train stop for every 1,327 metres.

Path length per bus stop indicates the distance visitors would need to travel along paths to find a bus stop. The shorter the length the more accessible the site is considered. Although it seems that people living in the West Midlands (England) will find it more difficult to access MMH areas by public transport, having the fewest links despite having more MMH than London, the West Midlands has on average a bus stop for every 98.3 metres nearby a MMH path and on average a train stop for every 23,428.4 metres nearby a MMH path.

However, people living in the South East (England) will find it easier to walk to MMH areas as there are 621,686 residential properties within one kilometre of the MMH area. People living in the West Midlands (England) will find it more difficult to access MMH areas by walking, having the fewest residential properties within one kilometre of MMH areas.

Figure 11: Map of UK National Parks, 2016



Source: National Parks UK

The UK has 15 National Parks, as displayed in Figure 11. ArcGIS was also used to determine accessibility to areas of MMH within UK National Parks, using OSM, NaPTAN and AddressBase.

Table 8: Number of Addressbase properties and public transport links within mountains, moorlands and heath national parks

National Parks	Addressbase	Train stops	Bus stops	Path length (m)	Path length (m) /number of bus stops in MMH	MMH area KM2	MMH area KM2 /number of bus stops in MMH
South Downs	6	0	4	35,507.3	8,876.8	6.8	1.7
Pembrokeshire Coast	19	0	0	40,193.0	0.0	21.0	0.0
The Broads Authority	307	0	4	113,568.4	28,392.1	34.5	8.6
Exmoor	2	0	6	116,212.8	19,368.8	34.1	5.7
Brecon Beacons	40	0	2	128,860.4	64,430.2	95.4	47.7
Northumberland	4	0	0	139,683.8	0.0	154.8	0.0
Dartmoor	6	0	7	141,346.1	20,192.3	116.9	16.7
The Loch Lomond and the Trossachs	57	0	2	167,371.0	83,685.5	284.9	142.4
Lake District	7	0	1	243,335.3	243,335.3	127.7	127.7
Snowdonia	94	0	7	257,943.5	36,849.1	271.0	38.7
Peak District	88	0	26	601,546.0	23,136.4	367.2	14.1
Yorkshire Dales	117	0	7	774,881.9	110,697.4	626.1	89.4
North York Moors	47	0	24	823,929.5	34,330.4	480.0	20.0
New Forest	122	0	47	915,927.5	19,487.8	146.6	3.1
The Cairngorms	58	0	13	1,799,327.6	138,409.8	3,136.3	241.3

Source: Open Street Map, National Public Transport Access Nodes and Addressbase

The National Park with the most public transport links is the New Forest, where only approximately 2.5% of MMH in National Parks is found (Table 8) with 47 bus stops and 122 residential properties. Meanwhile, The Cairngorms National Park (where approximately 53.1% of MMH in National Parks is found) only has 13 bus stops and 58 residential properties within the National Park.

Despite the South Downs National Park having the smallest amount of MMH extent compared with all Great Britain National Parks (approximately 0.11%) it has more bus stops than the Lake District, Northumberland, Brecon Beacons and Loch Lomond and the Trossachs. The South Downs National Park has a bus stop for every 163.6 metres of path in MMH, meaning it is the most accessible by bus.

Interestingly, even though the Cairngorms National Park has the highest number of bus stops, it also has the largest extent of MMH, and so visitors would need to travel, on average, 7,197 metres on paths to find a bus stop, suggesting that this National Park is the least accessible.

Furthermore, the South Downs National Park has six residential properties within the park, which is higher than Exmoor and Northumberland have. In terms of residential properties, most people live within The Broads Authority National Park and the least within Exmoor National Park.

Table 9: Number of Addressbase residential properties and public transport links within one kilometre of mountains, moorlands and heath national parks

National Parks	Addressbase	Train Stops	Bus Stops	Train 1KM Path	Bus 1KM Path	Path length (m)	Path length (m) /number of bus stops in MMH	Path length (m) /number of bus stops within 1KM path
South Downs	7,615	-	217		135	35,507.3	163.63	263.0
Pembrokeshire Coast	5,258	1	103		46	40,193.0	390.22	873.8
The Broads Authority	2,817	3	48	3	40	113,568.4	2366.01	2,839.2
Exmoor	1,671	-	58		40	116,212.8	2003.67	2,905.3
Brecon Beacons	2,731	-	82		43	128,860.4	1571.47	2,996.8
Northumberland	458	-	57		12	139,683.8	2450.59	11,640.3
Dartmoor	5,107	-	152		106	141,346.1	929.91	1,333.5
The Loch Lomond and the Trossachs	4,800	4	177	2	94	167,371.0	945.6	1,780.5
Lake District	3,926	-	166		96	243,335.3	1465.88	2,534.7
Snowdonia	6,480	8	354	4	194	257,943.5	728.65	1,329.6
Peak District	8,130	3	383	2	296	601,546.0	1570.62	2,032.3
Yorkshire Dales	6,426	5	205	3	126	774,881.9	3779.91	6,149.9
North York Moors	4,980	6	160	6	138	823,929.5	5149.56	5,970.5
New Forest	14,066	4	512	4	403	915,927.5	1788.92	2,272.8
The Cairngorms	8,086	6	250	4	152	1,799,327.6	7197.31	11,837.7

Source: Open Street Map, National Public Transport Access Nodes and Addressbase

Table 9 shows that, again, the New Forest has the most public transport links. Meanwhile, Northumberland and Exmoor National Parks have the least links, with 57 and 58 bus stops, respectively, and no train stops for neither, nearby the National Parks. Both also have 12 and 40 bus stops, respectively and no train stops nearby a MMH National Park path.

However, again the South Downs National Park has a bus stop for every 263 metres nearby MMH paths, meaning it is the most accessible by bus. Similarly, The Cairngorms is the least accessible, with a bus stop for only every 11,838 metres nearby a MMH path.

People living in the New Forest will also find it easier to walk to MMH National Park areas as there are 14,066 residential properties nearby the MMH National Park area. People living in Northumberland will also find it more difficult to access MMH National Park areas by walking, having the least residential properties, 458, nearby MMH areas, despite having approximately 2.6% of MMH in National Parks. This is more than the South Downs where approximately 0.11% of MMH in National Parks is found.

As a time series for this data could not be obtained it is not possible to say whether accessibility of MMH has been increasing or decreasing over time and therefore whether this is a positive or negative condition indicator of the habitat. For future iterations of the report it will be possible to build up a time series and to determine whether path and road length within MMH areas have been increasing, having a negative effect on the habitat.

7 . What ecosystem services do mountains, moorlands and heath provide?

Mountains, moorlands and heath (MMH) areas provide many services to the economy and society. This section builds on the main findings from the Scoping Study and aims to assess the contribution of these services, by capturing the flow of services in monetary and non-monetary units.

The ecosystem services accounts presented are partial as it was not possible to estimate monetary and non-monetary units for all of the services that MMH provide and there are some services provided that are not captured in the accounts. The ecosystem services are split into provisioning, regulating and cultural services. Table 10 presents the services captured in this release.

Table 10: Environmental services included in this publication

	Included	**Not included**
Provisioning	Wind power	Reared animals and their outputs
Products such as food, water and fuel		Wild animals
		Freshwater
		Peat extraction
		Biomass-based energy resources
Regulating	Carbon sequestration	Flood risk mitigation
Benefits such as water purification, climate regulation, noise and air pollution reduction and flood hazard reduction	Air pollution removal by vegetation	
	Waste detoxification	
Cultural	Recreation	Science and education
Non-material benefits, for example recreational enjoyment and aesthetic experience	Field game sports	Spiritual, symbolic and other interactions

Source: Office for National Statistics

This release presents initial and highly experimental estimates.

Provisioning services

The food production, drinking water and peat extraction provisioning services have not been included in this release to avoid double-counting, as they are accounted for under the farmland and freshwater ecosystem accounts.

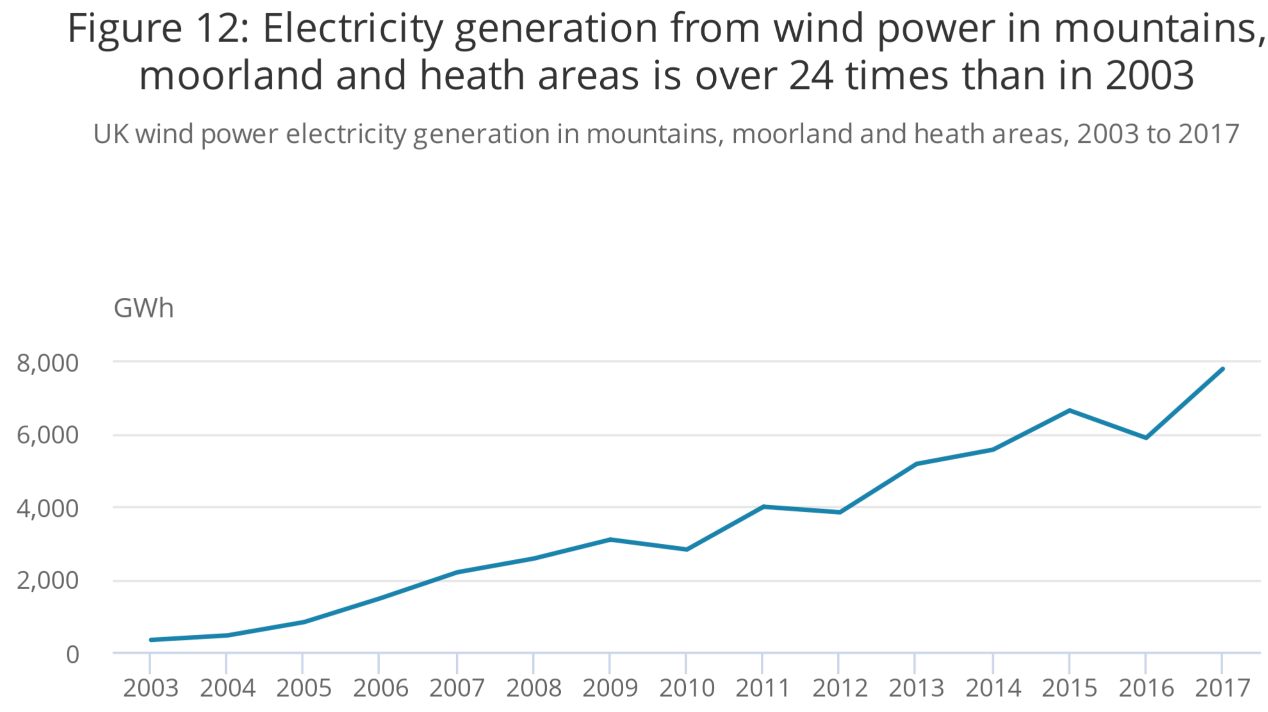
Wind power provision

Overall estimated electricity generation from wind power in MMH areas has increased significantly since 2003. Policies such as the EU Renewable Energy Directive and Renewable Obligation (RO) target have helped contribute towards the increase, and by 2017 electricity generation in MMH areas was approximately 7,800 gigawatt hours, over 24 times larger than in 2003.

Most years have seen increases except 2010, 2012 and 2016, as shown in Figure 12. The decrease in 2016 is attributed to a decline in wind generation, of 10.2%, due to a 10.9% reduction in average wind speeds. The wind generation load factor, a measure of generation efficiency being the utilisation of total generation capacity, decreased from 29.3% to 23.6% between 2015 and 2016, also reflecting this.

Figure 12: Electricity generation from wind power in mountains, moorland and heath areas is over 24 times than in 2003

UK wind power electricity generation in mountains, moorland and heath areas, 2003 to 2017



Source: Department for Business, Energy and Industrial Strategy and Office for National Statistics

The Office for National Statistics (ONS) Natural Capital Team is currently altering the methods we use to calculate the annual and asset values for renewable energy provision. It has not been possible to update these in time for this report and so the decision was made not to use the old method for this report. However, it is planned to be included in future iterations of MMH accounts.

Regulating services

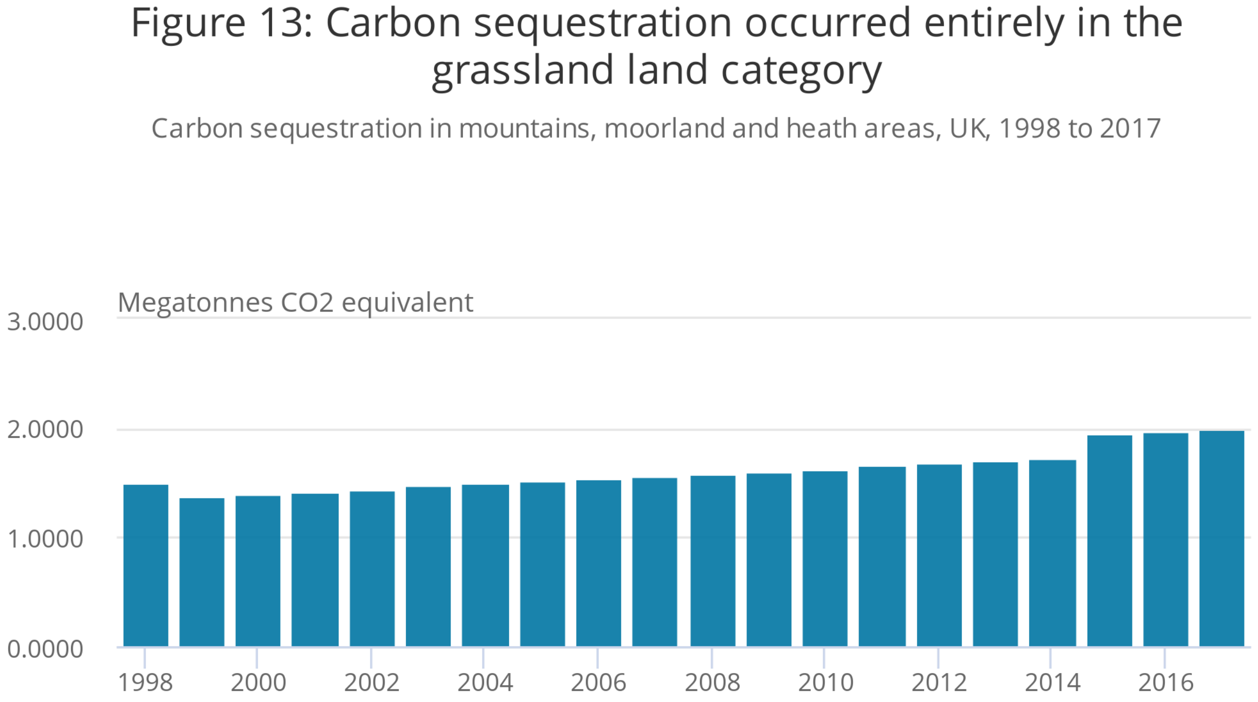
Carbon sequestration

Overall estimated carbon sequestration in MMH in the UK increased by 33.2% from 1.49 million tonnes of carbon dioxide equivalent (MtCO2e) in 1998 to 1.99 MtCO2e in 2017, as shown in Figure 13. Over the period 1998 to 2017, estimated carbon sequestration decreased to a low of 1.38 MtCO2e, in 1999, and increased to a high of 1.99 MtCO2e, in 2017.

Upland woodlands are reported on in the woodland accounts and not included here. Within MMH habitats, carbon sequestration between the years 1998 to 2017 occurred entirely in the grassland land use change category, with the wetlands land use change category emitting more carbon than it sequesters. It is important to note that upland forests are not included within this report and neither are wetlands, as wetlands provides a disservice and the purpose of this report is to capture the benefits.

Figure 13: Carbon sequestration occurred entirely in the grassland land category

Carbon sequestration in mountains, moorland and heath areas, UK, 1998 to 2017



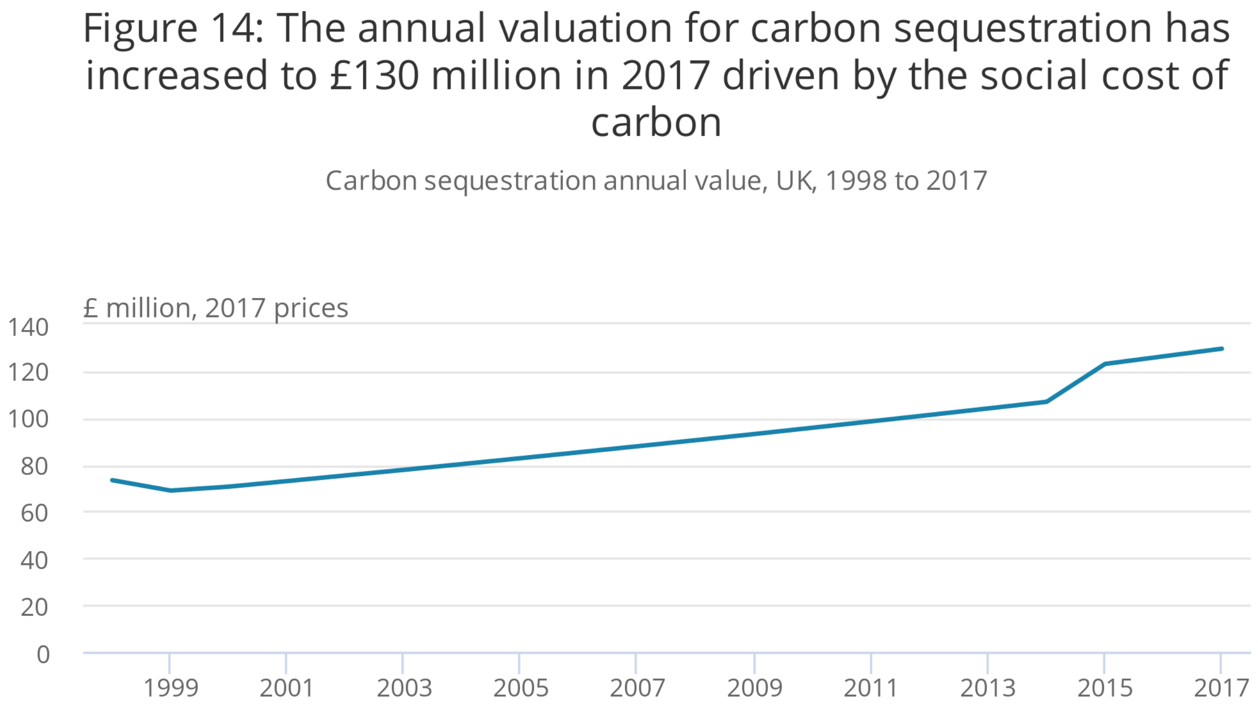
Source: Office for National Statistics and National Atmospheric Emissions Inventory (NAEI)

Projected annual carbon sequestration estimates, up to 2050, show a continued increase in overall carbon sequestration, at an average rate of around 1.2% annually, to 4.6 MtCO2e in 2050. The increase in carbon sequestration over this time period is entirely attributed to the grassland land use change category.

Estimated annual valuations of the regulating service carbon sequestration provided, show a positive trend, with the overall value increasing from £73 million to £130 million between 1998 and 2017, as shown in Figure 14. This trend has been driven by a steady increase in the social cost of carbon (1.5% annual growth over this period), which is estimated to keep increasing until around 2080. Carbon sequestration’s estimated annual valuation is projected to be £479 million in 2050, for MMH.

Figure 14: The annual valuation for carbon sequestration has increased to £130 million in 2017 driven by the social cost of carbon

Carbon sequestration annual value, UK, 1998 to 2017



Source: Office for National Statistics, National Atmospheric Emissions Inventory (NAEI) and the Department for Business, Energy and Industrial Strategy (BEIS)

The asset valuation of the carbon sequestration regulating service, utilising future annual valuation projections, increased between 1998 and 2017 from £7 billion to £11 billion.

It is also important to note that whilst peatlands', that are found in MMH areas, carbon sequestration is reasonably low per year, peat stores millions of tonnes of carbon for a very long period when in good condition. Therefore, although grassland will outcompete peat on the carbon sequestration measure, peat in good condition is more effective at storing carbon. You can find out more about carbon sequestration and carbon storage of peatlands in the report Ecosystem accounts for peatlands.

Air pollution removal

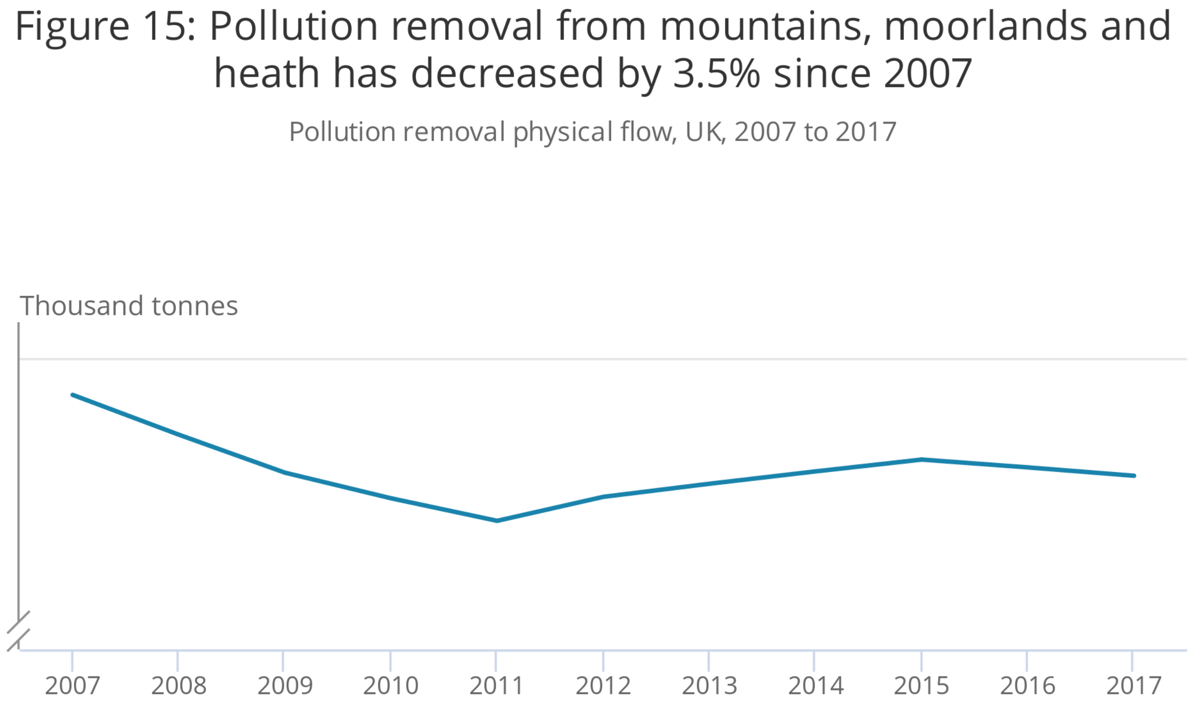
Air pollutant removal has been modelled for 2007, 2011, 2015 and 2030. Between these years a linear interpolation has been used and adjusted for real pollution levels as an estimation of pollution removal (please see Methodology section for more information).

The pollutants included in this analysis are PM2.5, PM10, nitrogen dioxide (NO2), ground-level ozone (O3), ammonia (NH3) and sulphur dioxide (SO2).

Physically, the amount of pollution MMH have removed from 2007 to 2017 fluctuated, but has decreased overall by 3.5%, from 126,000 tonnes to 122,000 tonnes, as seen in Figure 15. Beyond 2017, pollution removal by MMH areas is projected to continue to decrease to 119,000 tonnes in 2030; as a result of less pollution being emitted into the atmosphere to be removed.

Figure 15: Pollution removal from mountains, moorlands and heath has decreased by 3.5% since 2007

Pollution removal physical flow, UK, 2007 to 2017



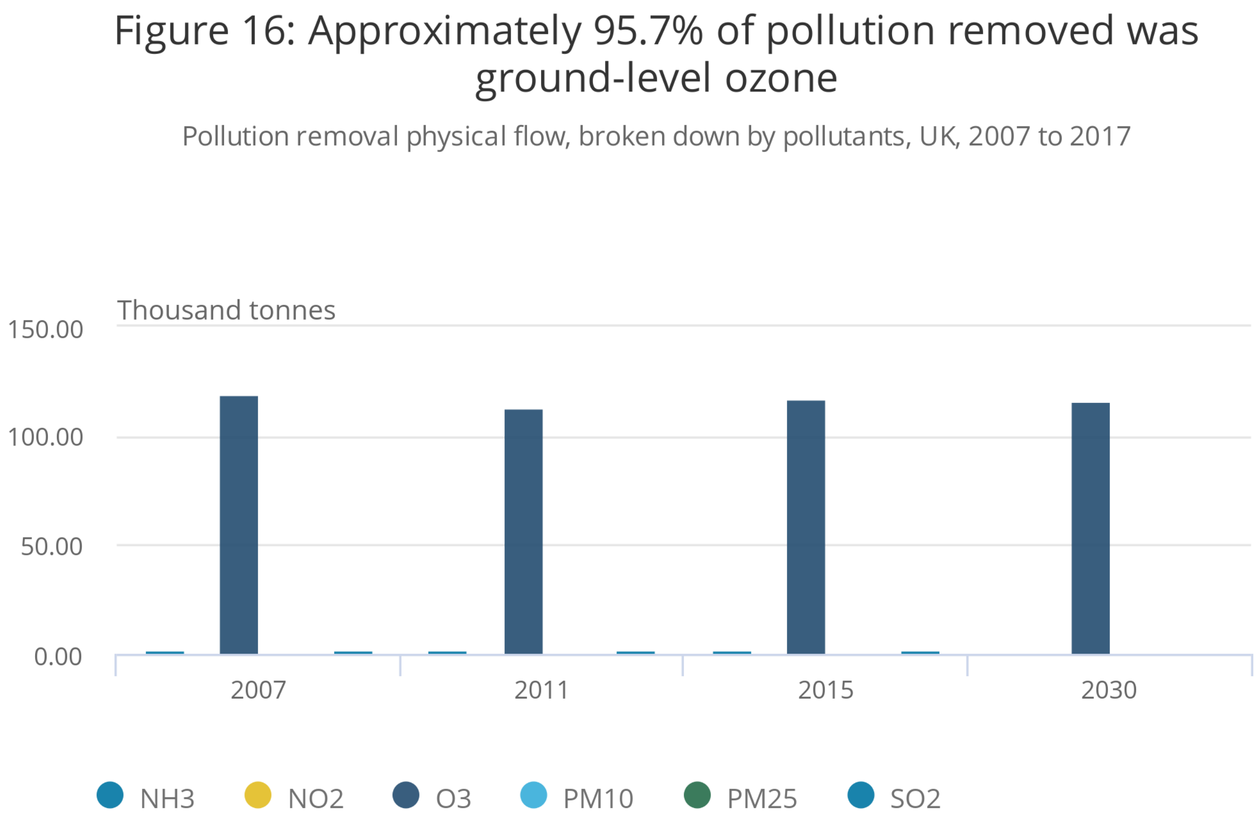
Source: Office for National Statistics and the Centre for Ecology and Hydrology

PM2.5 (fine particulate matter with a diameter of less than 2.5 micrometres, or 3% of the diameter of a human hair) is a component of PM10. Ground-level ozone represents approximately 95.7% of pollution removal from 2007 to 2017, as seen in Figure 16, and is estimated to continue to do so. Note that you can deselect Ozone from Figure 16 to make the other air pollutant data more readable. However, the most harmful pollutant is PM2.5, which can bypass the nose and throat to penetrate deep into the lungs, leading to potentially serious health effects and healthcare costs.

PM2.5 represents approximately 0.5% of the mass of pollutants removed from 2007 to 2017, the lowest proportion of all pollution removal included in this analysis.

Figure 16: Approximately 95.7% of pollution removed was ground-level ozone

Pollution removal physical flow, broken down by pollutants, UK, 2007 to 2017

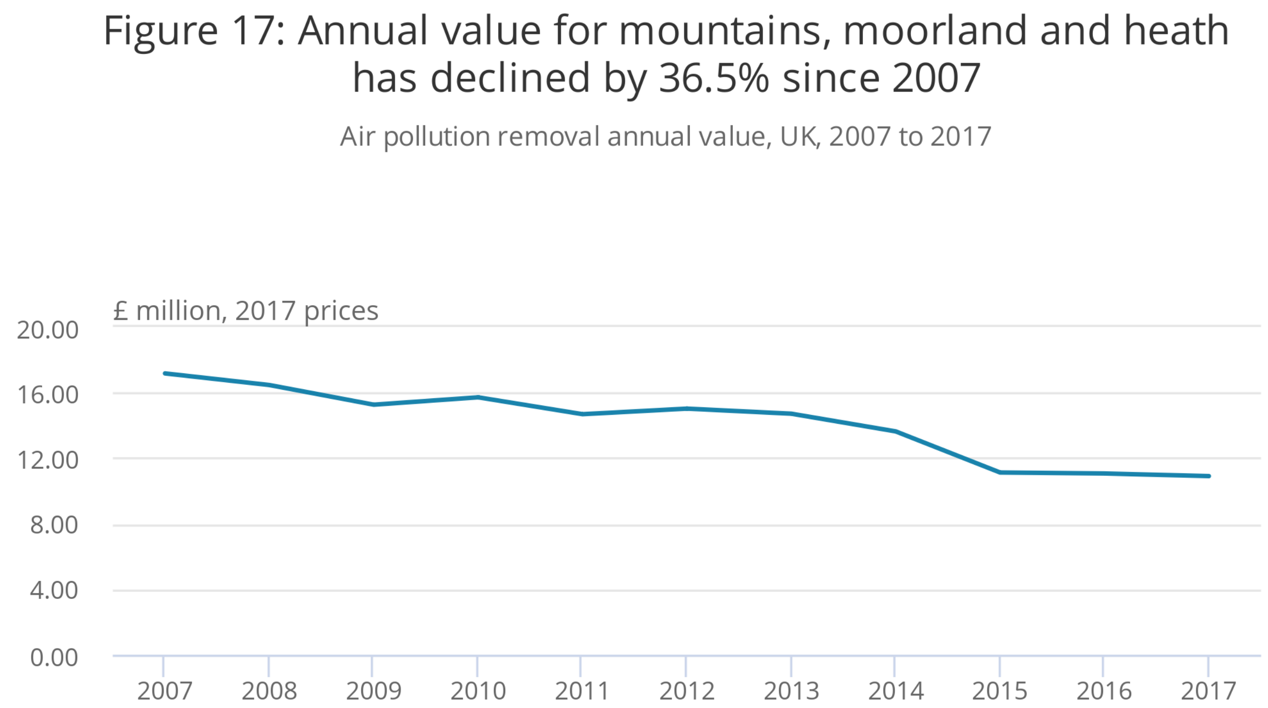


Source: Centre for Ecology and Hydrology and Office for National Statistics

The pollution removal regulating service is valued through avoided health cost modelling, detailed in Section 11 of this report. Pollution removal annual valuation for MMH declined by 36.5% from £17.2 million in 2007 to £10.9 million in 2017, as seen in Figure 17. The declining trend, as aforementioned, is due largely to less pollution being emitted into the atmosphere. The asset valuation of the pollution regulating service for MMH increased by 0.5% between 2007 and 2011, from £389.3 million to £391.3 million.

Figure 17: Annual value for mountains, moorland and heath has declined by 36.5% since 2007

Air pollution removal annual value, UK, 2007 to 2017



Source: Centre for Ecology and Hydrology and Office for National Statistics

Waste detoxification

Plant-soil systems of MMH habitats intercept and retain various atmospheric pollutants, including anthropogenic sulphur, nitrogen and heavy metals that would otherwise contaminate drainage waters. MMH soils also buffer the effects of acid deposition on upland stream and lake ecosystems.

The UK National Ecosystem Assessment (UK NEA) states “water quality is more strongly linked to ecosystem processes in the uplands than in the lowlands”. Water quality is regulated by MMH as less polluted run-off from uplands dilute polluted freshwater in the lowlands. However, the UK NEA does remark on the sensitivity of MMH habitats to anthropogenic pollution, which can reduce the ability of the habitat to regulate downstream water quality (ONS, 2017). This impacts the value of water for uses such as drinking water quality, agricultural uses and recreation uses.

The ability of an ecosystem to reduce waste concentrations depends on both the properties of the waste and the properties of the ecosystem (Ahmed and Osibanjo, 2019). Freshwater systems can dilute, store and detoxify waste products and pollutants, however, there are threshold levels and some systems may accumulate substances to toxic levels (UK NEA, 2011).

Growing evidence suggests that the reduction in acid deposition has caused an increase in naturally occurring organic acids in the form of dissolved organic carbon (DOC), concentrations of which are the result of the incomplete decomposition of organic matter (Evans, Monteith and Cooper, 2005). Since 1991, there has been an increase in the concentration of DOC in upland waters. It is possible, therefore, that DOC concentrations may be returning to preindustrial, hence prewater treatment levels, which in turn could have ecological benefits for upland waters.

The potential for the MMH habitat to detoxify water would impact the treatment costs for the drinking water supply.

Cultural services

This section presents the cultural service of nature providing recreational opportunities. Other cultural services are also provided by natural capital, such as aesthetic appreciation and heritage value. These additional cultural service accounts are not yet developed, and further work is needed to clarify where non-recreational cultural services are truly additional to what is accounted for under recreational services.

The estimates of recreation are scaled from the Monitor of Engagement with the Natural Environment Survey (MENE) to represent the UK population. Current estimates do not include Scotland, Wales or Northern Ireland surveys. However, we will seek to fully incorporate additional surveys, such as Scottish Recreation Survey (ScRS) and Welsh Outdoor Recreation Survey (WORS), in future estimations of outdoor recreation.

It is worth noting that the MENE Survey used focuses on short day-trips from home and misses out potentially large amounts of spending on outdoor activity from domestic tourism, which future reports will include.

Recreation

In 2017, almost 37 million visits and over 46 million hours were spent in the MMH habitat in the UK. The MENE survey used for the UK national natural capital accounts is an England-based survey, which we extrapolate to the UK population – therefore likely leading to some biases. Recreation in MMH was valued at £199.3 million in 2017 (see Table 11).

Since 2009, time spent has decreased by 61.7%, from 121.5 million hours in 2009 to 46.5 million hours in 2017. This was caused primarily by a decline in the number of visits by 17.2% over this time period.

Table 11: Number of visits to mountains, moorlands and heath hours spent and expenditure according to Monitor of Engagement with the Natural Environment Survey (millions), UK, 2009 to 2017

	2009	2010	2011	2012	2013	2014	2015	2016	2017
Visits (million)	44.5	38.2	62.8	50.9	70.6	43.7	64.7	63.3	36.9
Time spent at habitat (hours)	121.5	98.8	108.1	125.3	171.4	56.9	104.9	165.2	46.5
Expenditure (£ million)	264.8	252.5	199.2	203.6	349.9	112.2	111.7	276.3	199.3

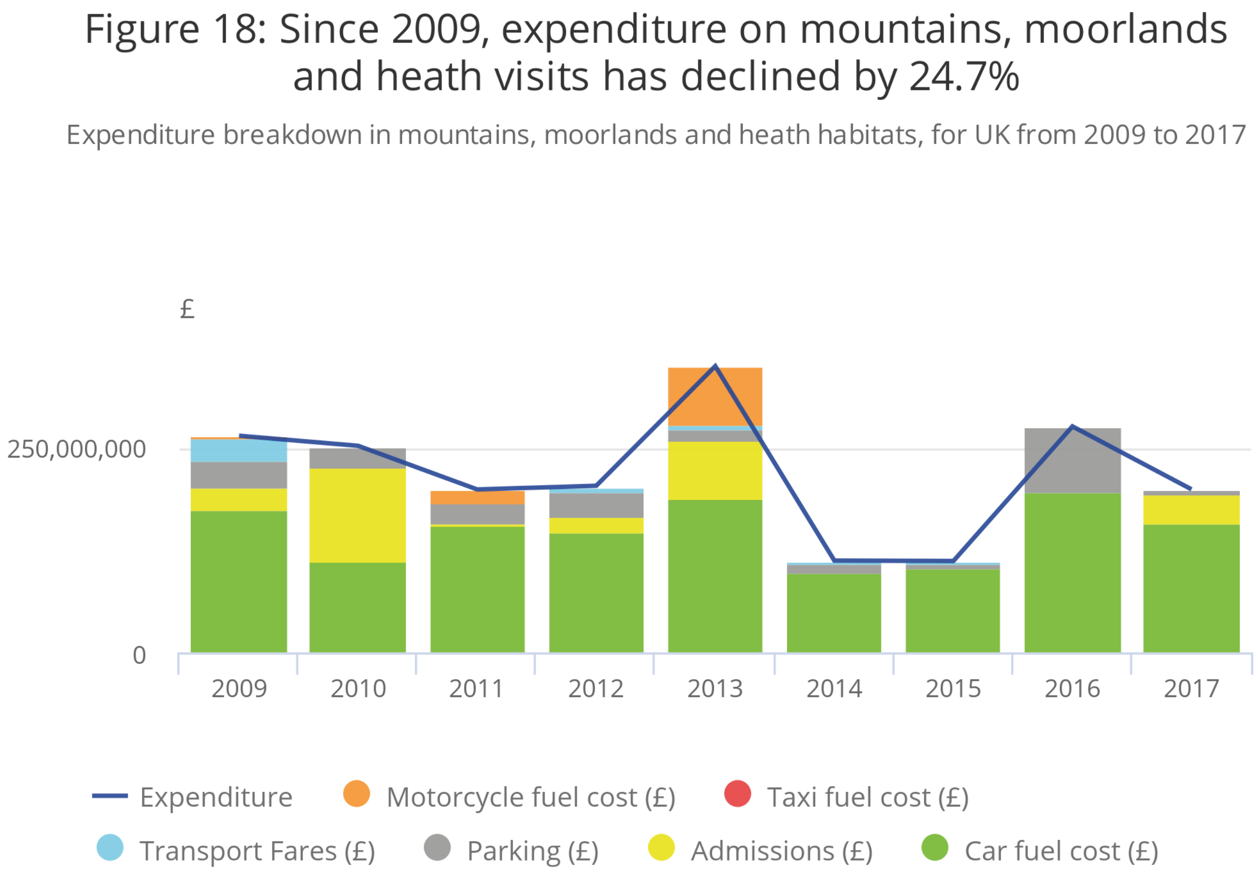
Source: Monitoring of Engagement with the Natural Environment survey and Office for National Statistics

Given that MMH only makes up 15.0% of the UK, it is not surprising that the total time spent and number of visits at MMH habitats in the UK was the lowest of all habitats across the whole time series. Although, when people visited MMH they spent the longest time. Apart from 2017, on average, time spent on each MMH visit was higher than the UK average across all habitats.

The UK adult population spent 2.1 hours on MMH visits, 67.6% higher than the UK average (1.2 hours). Despite this, on average time spent per visit at MMH habitats has declined by 53.8% in this period; from 2.7 hours in 2009, to 1.3 hours in 2017.

Figure 18: Since 2009, expenditure on mountains, moorlands and heath visits has declined by 24.7%

Expenditure breakdown in mountains, moorlands and heath habitats, for UK from 2009 to 2017



Source: Monitoring of Engagement with the Natural Environment Survey and Office for National Statistics

Between 2009 and 2017, spending on outdoor recreation at MMH habitats decreased by 24.7%, from £264.8 million in 2009 to £199.3 million in 2017. This was driven mainly by a decline of 9.5% in spending on car running costs, which accounted for the highest proportion of spending (71.8%). In this period, expenditure per visit at MMH habitats also decreased. The UK adult population were spending on average £0.54 less on each MMH visit.

However, it is important to note that the majority of MMH, approximately 80%, is in Scotland. Therefore, these estimates presented in this section are likely to have underestimated the visits, time spent and expenditure in MMH areas in the UK, as England data are used to upscale to a UK level meaning the data presented are not accurately reflective of the UK as a whole. The Natural Capital Team are currently working on improving recreation estimate methods.

Field sports: game

Recreational hunting has been defined as the pleasant occupation of pursuing wild animals and engaging in the chase, to distinguish it from managed culling, “pest” control or hunting for a staple food (Hall, no date).

Game shooting is a recreational activity, some of which takes place in MMH estates. It is estimated that there are 343,983 hectares of land in England and Wales (British Association for Shooting and Conservation (BASC), no date) and 1 million hectares of land in Scotland (Scottish Land and Estates, 2013) used for grouse shooting.

In total, for all game shooting, there are an estimated 1,700,000 (Public and Corporate Economic Consultants (PACEC), 2014) shooting days provided throughout the UK. Much of the shooting takes place in England, with an estimated 550,000 participants annually, 91.6% of total participants (PACEC, 2014).

Commonly shot animals in MMH areas include red grouse and red deer. For this analysis, only red grouse and red deer are considered as they are the most commonly shot wild animals, as opposed to pheasants, that are commonly shot, but are reared to supplement stocks for shooting (Game Farmers Association (GFA), no date). Other species that could be considered include mountain hare in Scotland, black grouse, however, the numbers are very low, and rabbits, but they are subject to ad-hoc hunting activities and so are difficult to estimate.

Of wild game species, the British Trust for Ornithology (Robinson, 2005) estimate that there are 230,000 breeding pairs of red grouse in the UK.

UK breeding is defined as the number of pairs breeding annually. The Deer Initiative (no date) estimate that there are approximately 2 million deer in the UK, of which around 350,000 (Parliamentary Office of Science and Technology, 2009) are red deer. However, deer are known as being very difficult to quantify due to their mysterious and free-roaming nature (Smart, Ward and White, 2004).

From the PACEC report (2014) we know that an estimated 400,000 red grouse were shot in 2004 to 2005 and an estimated 700,000 red grouse were shot in 2012 to 2013, a 75% increase in red grouse hunting, over eight years. However, this could be due to the cyclical nature of red grouse populations, as well as more intensive management of the habitat and predators (Martínez-Padilla and others, 2014). There were also an estimated 74,000 red deer being stalked in 2012 to 2013.

It is estimated that the total spend by shooting sports participants is £2,500 million. However, it is not clear how much of this can be attributed to solely red grouse and red deer.

Of the overall shot animals, an average of 62% are eaten on site or taken away by shooting participants, 35% are used as food elsewhere and 3% are damaged and discarded as being unfit for human consumption (PACEC, 2014).

In 2017, Mintel UK Retail valued sales of unprocessed game meat at £120 million (Mintel, 2018) and annual venison sales were estimated at £2 million (SPICe, 2013). However, these totals cannot be attributed to red grouse and red deer that are shot in MMH areas.

At present, it has not been possible to obtain a time series of:

- population numbers for red grouse and red deer
- annual figures of red grouse and red deer being shot
- the expenditure on the shooting of both red grouse and red deer
- or the cost of red grouse meat and venison

It is also difficult to tell which aspect of game shooting is hunting for recreation and which aspect is hunting for provision. Therefore, for this iteration of the report, ecosystem services for game shooting in MMH have not been calculated.

8 . Restoration

Restoration is the process of actively managing the recovery of an ecosystem service that has been degraded, damaged or destroyed as a means of sustaining ecosystem resilience and conserving biodiversity (Martin, 2017). Restoration costs are those costs required to return the ecosystem asset to its condition (or, its capacity) at some earlier time; this concept differs from maintenance costs, which are those required to return the ecosystem to its condition at the start of the accounting period.

Whilst the ecosystem services aim to capture the benefits that the habitat provides, the restoration section aims to capture the costs incurred in restoring and maintaining the habitat. The extent, condition and ecosystem services aid in highlighting areas in which degradation is occurring and where restoration would be most beneficial.

The following section highlights the estimated maintenance and restoration costs needed for mountains, moorlands and heath (MMH), in order to restore natural capital and support a sustainable farming sector. The data presented on maintenance and restoration are taken from Assessing the costs of Environmental Land Management in the UK (Rayment, 2017).

The estimated costs are based on the following assumptions:

- the level of ambition applied in estimating land management needs, which is largely modelled on existing targets.
- cost estimates are based on current or recent agri-environment payment rates and historic unit costs
- proportion of priority habitats maintained annually is 100%
- proportion of priority habitats requiring restoration takes place over 10 years

These costs are not designed to estimate the total budget needed for future farming policies across the UK as they specifically focus on land management interventions and do not include supporting investments, for example, advice, monitoring and evaluation or wider funding associated with agricultural or rural development. The expenditure required to both restore natural capital and support the sustainable farming sector will be more than what the tool has produced.

There are important differences between the way in which the extent of the MMH habitat is calculated within the Rayment (2017) model, presented in this section, and the rest of the report. Throughout this report the Land Cover Map 2015 (LCM2015) is used to calculate the extent of MMH, whereas the Rayment (2017) model uses: England: Department for Environment, Food and Rural Affairs (Defra) (2016) England Biodiversity Strategy Indicators; Northern Ireland: Unpublished Department of Agriculture, Environment and Rural Affairs (DAERA) data – Status and Trends of Priority Habitats in 2010; Scotland – UK Biodiversity Action Plan (BAP) targets 2006 and Wales: Natural Resources Wales (2016) The State of Natural Resources Report (SoNaRR). Table 12 shows the extent of the MMH habitats, using different data sources.

Table 12: Extent of mountains, moorlands and heath by different sources, UK

	Rayment extent	LCM2015 extent
Fen, Marsh and Swamp	139,941	18,500
Bog	2,278,478	960,200
Heath, Heather, Scrub	1,050,388	2,502,800
Inland Rock	3,702	182,700
TOTAL	3,472,509	3,664,200

Source: Rayment 2017 and Land Cover Map 2015 Centre for Ecology and Hydrology

The difference in estimated extent is due largely to the Centre for Ecology and Hydrology (CEH) placing deteriorated bog amongst other sub-habitat classifications, whereas within the Rayment (2017) model, deteriorated bog is included under bog with the intention for it to be restored.

Cost estimates, based on current cost rates, are presented in the following tables.

The following figures, in Table 13, represent estimated annual costs by Rayment (2017), over a 10-year period. The estimated cost of maintenance and restoration for the MMH habitat is £291 million annually.

Broken down into sub-habitats, Table 13 shows that bog requires the costliest maintenance and restoration, at £189 million per year, whilst montane requires the least maintenance and restoration, at £0.3 million per year. The majority of the costs relates to maintenance (72%) of the MMH habitat.

Table 13: Estimated annual costs (thousands) of maintenance and restoration, over a 10-year period, broken down by sub-habitat, UK

HAB1	Maintain	Restore	Total
Dwarf Shrub Heath	£75,622.8	£6,783.3	£82,406.1
Fen, Marsh Swamp	£16,636.9	£2,724.4	£19,361.3
Bog	£117,271.5	£72,016.1	£189,287.6
Montane	£314.7	£0.0	£314.7
Inland Rock	£498.3	£0.0	£498.3
TOTAL	£210,344.2	£81,523.8	£291,868.0

Source: Rayment 2017

Table 14 shows the costs, over a 10-year period, broken down by country. Scotland requires the most costly maintenance and restoration, at 63.2% of total UK costs, whilst Wales requires the least, at 7.73%.

Table 14: Estimated annual costs (thousands) of maintenance and restoration, over a 10-year period, broken down by country, UK

	Maintain	Restore	Total
England	£49,409.87	£4,973.92	£54,383.80
Northern Ireland	£17,003.60	£13,456.09	£30,459.69
Scotland	£125,583.59	£58,886.71	£184,470.30
Wales	£18,347.16	£4,207.08	£22,554.24
UK	£210,344.23	£81,523.80	£291,868.03

Source: Rayment 2017

The Office for National Statistics (ONS) has estimated the present value of maintenance and restoration, over 100 years. The total value of maintenance and restoration of the MMH priority habitat is estimated at £6.98 billion.

Broken down into sub-habitats, Table 15 shows that, as aforementioned, the largest costs relate to bog, at £4.12 billion (59%), whilst the lowest costs relate to montane, at £9.3 million (0.13%).

Table 15: Estimated present value (thousands) of maintenance and restoration, over 100 years, broken down by sub-habitat, UK

HAB1	Maintain	Restore	Total
Dwarf Shrub Heath	£2,258,349.90	£58,388.89	£2,316,738.79
Fen, Marsh Swamp	£496,833.69	£23,450.73	£520,284.42
Bog	£3,502,121.72	£619,891.73	£4,122,013.45
Montane	£9,399.17	£0.00	£9,399.17
Inland Rock	£14,881.57	£0.00	£14,881.57
TOTAL	£6,281,586.05	£701,731.34	£6,983,317.39

Source: Rayment 2017 and Office for National Statistics

Table 16 shows the present value, over 100 years, broken down by country. The maintenance and restoration in Scotland is valued the highest, at 60.96% of overall costs, whilst Welsh costs are valued the lowest, at 8.36%.

Table 16: Estimated present value (thousands) of maintenance and restoration, over 100 years, broken down by country, UK

	Maintain	Restore	Total
England	£1,475,545.02	£42,813.98	£1,518,359.00
Northern Ireland	£507,784.77	£115,825.82	£623,610.59
Scotland	£3,750,348.44	£506,878.31	£4,257,226.76
Wales	£547,907.81	£36,213.23	£584,121.04
UK	£6,281,586.05	£701,731.34	£6,983,317.39

Source: Rayment 2017 and Office for National Statistics

9 . What is the asset value of mountains, moorlands and heath?

The asset account includes projections of the ecosystem services. They are estimated by capitalising the annual flow of services from the natural resource that are expected to take place over a projected period. This period is known as the asset life.

The environmental services included in the asset account are produced from renewable resources whose stock is not exhausted over time, for example, vegetation in the mountains, moorlands and heath (MMH) area removing pollutants, so the asset life is set at 100 years.

The value of the asset is obtained by estimating the net present value (NPV) of the asset. The annual value of all ecosystem services, in this publication, are projected for the life of the asset and discounted. For more information on monetary flow and asset accounts, please refer to the Principles of natural capital accounting publication.

The figures presented in this section are a partial benefit valuation of the ecosystem services that MMH provides, as only carbon sequestration, air pollution removal and recreation services are included.

Table 17 presents the asset value per ecosystem service for the years 2014 and 2017. The overall natural capital asset value in MMH in the UK was estimated at £20,052 million in 2014, with carbon sequestration accounting for approximately half of this. The asset prices calculated for recreation are based on England Monitor of Engagement with the Natural Environment Survey (MENE) data being upscaled to obtain UK estimates.

From 2014 to 2017, the overall asset value was estimated to increase by 0.44%, to £20,141 million. In this year carbon sequestration accounted for over half of this, at 52.5%.

The Natural Capital Team is currently working on improving the methods used to calculate UK estimates and so some figures may be subject to change for future iterations of the MMH accounts.

Table 17: UK mountains, moorlands and heath asset values (£ millions) by service, 2014 and 2017

Service	**2014**	**2017**
Carbon sequestration	9,898	10,576
Air pollution removal	385	391
Recreation	9,769	9,174
Total	20,052	20,141

Source: Office for National Statistics

The services presented in this section display a £20 billion annual benefit in 2017, with the value set to increase year-on-year. The estimated annual costs of maintenance and restoration for MMH, as discussed in Section 8, is £0.3 billion, over a 10-year period.

The value that the MMH habitat provides is approximately 67 times larger than the costs of maintaining and restoring MMH. However, the estimated value of the benefits from the ecosystem services are only a partial benefit valuation, whilst the Rayment (2017) model presents a thorough costing. The value that ecosystem services in MMH provide is likely to be much larger, if all ecosystem services were captured, and so the two are currently difficult to compare.

Further, it was not possible to conduct a detailed cost-benefit analysis as it is not fully understood how improved condition of the habitat will affect the value of the services it provides.

10 . Next steps

Future development of the extent account would aim to split out upland and lowland bog and upland and lowland fen, marsh and swamp. Future technologies may also enable us to accurately calculate the extent of bracken.

The mountains, moorlands and heath (MMH) scoping study set out a number of condition indicators to include in the accounts, some of which could not be included. For future iterations of this report additional indicators such as biodiversity and burning on the MMH habitat will aim to be included. Additionally, a time series of all condition indicators need to be included in order to identify changes to the condition of natural capital assets over time.

The ecosystem service accounts are partial. Further development is needed to calculate monetary stocks for renewable energies, and monetary and non-monetary stocks for services such as game shooting and waste detoxification.

11 . Methodology

Specialist bird populations

To calculate the index the species data of total individuals counted in the UK are taken and divided by the total number of squares surveyed, to calculate a mean count per square. 1994 was then used as a base year and a geometric mean index was calculated for the following species: Red Grouse, Golden Plover, Curlew, Common Gull, Meadow Pipit, Whinchat, Wheatear, Raven, Black Grouse, Hen Harrier, Golden Eagle and Merlin, to obtain an overall moorland species year-on-year index.

Carbon sequestration

Estimates relate to the removal of carbon gas from the atmosphere by UK terrestrial ecosystems. The approach used combines data on the physical changes in subdivisions of the land use, land-use change, and forestry (LULUCF) sector (published in the Greenhouse gas inventory and LULUCF emission projections), with information on the central non-traded price of carbon.

The LULUCF sector breakdown identifies carbon sequestration activities in the following subcategories:

- forest land remaining forest land
- land converted to forest land
- cropland remaining cropland
- land converted to cropland
- grassland remaining grassland
- land converted to grassland
- wetlands remaining wetlands
- land converted to wetlands
- settlements remaining settlements
- land converted to settlements
- harvested wood products remaining harvested wood products
- land converted to harvested wood products

To apportion these values to calculate estimates of carbon sequestration within mountains, moorlands and heath (MMH), LULUCF categories were mapped to the Land Cover Map 2007 and 2015 class categories. From the mapping exercise it was concluded that, under the LULUCF categories, MMH corresponded to grassland and wetlands. The extent of the Land Cover class categories, that corresponded to MMH and LULUCF classes grassland and wetlands, was taken and used to apportion the LULUCF estimates for grassland and wetlands. This then enabled us to calculate an estimated physical flow, annual value and asset value for carbon sequestration in MMH.

For the years 2010 to 2016, actual physical estimates of carbon sequestration by land use class are sourced from the greenhouse gas inventory. In the asset valuation, projections of carbon sequestration rates are provided for the years 2017 to 2050 by the National Atmospheric Emission Inventory (NAEI) in the LULUCF emission projections. Central projections are used. For years used in the projections beyond 2050, the carbon sequestration rate is assumed to be constant as at 2050 levels.

The carbon price used in calculations is based on the projected non-traded price of carbon schedule. This is contained within the data table 3 of the Green Book supplementary guidance. Carbon prices are available from 2010 to 2100. Prices prior to 2010 are backdated in line with recent trends. Prices beyond 2100 are assumed to be constant at 2100 levels.

The non-traded carbon prices are used in appraising policies influencing emissions in sectors not covered by the EU emissions trading system (ETS) (the non-traded sector). This is based on estimates of the marginal abatement cost (MAC) required to meet a specific emission reduction target. Beyond 2030, with the development of a more comprehensive global carbon market, the traded and non-traded prices of carbon converge into a single traded price of carbon.

Air pollution

Air quality regulation estimates have been supplied in consultation with the Centre for Ecology and Hydrology (CEH). This section entails a brief description of the methodology. For a more detailed explanation please see the full methodology report published in July 2017.

Calculation of the physical flow account uses the European Monitoring and Evaluation Program Unified Model for the UK (EMEP4UK) atmospheric chemistry and transport model, which generates pollutant concentrations directly from emissions and dynamically calculates pollutant transport and deposition, considering meteorology and pollutant interactions.

As CEH only estimated pollution capture for years 2007, 2011, 2015 and 2030, a linear adjustment index was calculated to obtain a full time series, from 2007 onwards. The linear adjustment index was determined by taking actual air pollution data and calculating the percentage of pollution capture, for the aforementioned years, as a proportion of actual air pollution levels. A trend of the percentage of pollution capture was then calculated and the estimated percentages of pollution capture were used to obtain values of pollution capture for the missing years.

The health benefits were calculated from the change in pollutant exposure from the EMEP4UK scenario comparisons, that is, the change in pollutant concentration to which people are exposed. Damage costs per unit exposure were then applied to the benefitting population at the local authority level for a range of avoided health outcomes:

- respiratory hospital admissions
- cardiovascular hospital admissions
- loss of life years (long-term exposure effects from PM2.5 and nitrogen dioxide (NO2))
- deaths (short-term exposure effects from ozone (O3))

Some years generated negative values for the economic value of NO2 removal. In cases where a net disservice is presented the economic value is adjusted to zero.

Future flow projections used for asset valuation incorporate population projections and an assumed 2% increase in income per year (declining to 1.5% after 30 years and 1% after 75 years). Income elasticity is assumed to be 1. More work is being conducted in this area.

Recreation

The recreation estimates are adapted from the “simple travel cost” method developed by Ricardo-AEA. The methodological report Reviewing cultural services valuation methodology for inclusion in aggregate UK natural capital estimate is available.

The method looks at the expenditure incurred to travel to the natural environment and expenditure incurred during the visit. This expenditure method considers the market goods consumed as part of making the recreational visit (that is, fuel, public transport costs, admission charges and parking fees). This expenditure is currently assumed as a proxy for a marginal price for accessing the site.

The recreation estimates were produced using the Monitor of Engagement with the Natural Environment Survey (MENE). This survey ran between 2009 and 2017. Over 1,000 face-to-face interviews were undertaken each month, each interview was capped at 30 minutes and was undertaken through a weekly consumer omnibus survey. The UK estimates of recreation are upscaled from MENE to represent the UK population.

The MMH classification for the MENE survey is “mountain, hill or moorland”.

It should be noted that the survey focuses on short day-trips from home and misses out potentially large amounts of spending on outdoor activity from domestic tourism, which future reports will include.