The Second State of Natural Resources Report (SoNaRR2020)

Assessment of the achievement of sustainable management of natural resources: Mountains, moorlands and heaths

Natural Resources Wales

Final Report

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- 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.

Title: **SoNaRR2020** Assessment of the achievement of Sustainable Management of Natural Resources: Mountains, moorlands and heaths

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The Second State of Natural Resources Report (SoNaRR2020) contents

This document is one of a group of products that make up the second State of Natural Resources Report (SoNaRR2020). The full suite of products are:

Executive Summary. Foreword, Introduction, Summary and Conclusions. Published as a series of webpages and a PDF document in December 2020

The Natural Resource Registers. Drivers, Pressures, Impacts and Opportunities for Action for eight Broad Ecosystems. Published as a series of PDF documents and as an interactive infographic in December 2020

Assessments against the four Aims of SMNR. Published as a series of PDF documents in December 2020:

SoNaRR2020 Aim 1. Stocks of Natural Resources are Safeguarded and Enhanced

SoNaRR2020 Aim 2. Ecosystems are Resilient to Expected and Unforeseen Change

SoNaRR2020 Aim 3. Wales has Healthy Places for People, Protected from Environmental Risks

SoNaRR2020 Aim 4. Contributing to a Regenerative Economy, Achieving Sustainable Levels of Production and Consumption

The SoNaRR2020 Assessment of Biodiversity. Published in March 2021

Assessments by Broad Ecosystem. Published as a series of PDF documents in March 2021:

Assessment of the Achievement of SMNR: Coastal Margins

Assessment of the Achievement of SMNR: Enclosed Farmland

Assessment of the Achievement of SMNR: Freshwater

Assessment of the Achievement of SMNR: Marine

Assessment of the Achievement of SMNR: Mountains, Moorlands and Heaths

Assessment of the Achievement of SMNR: Woodlands

Assessment of the Achievement of SMNR: Urban

Assessment of the Achievement of SMNR: Semi-Natural Grassland

Assessments by Cross-cutting theme. Published as a series of PDF documents in March 2021:

Assessment of the Achievement of SMNR: Air Quality

Assessment of the Achievement of SMNR: Climate Change

Assessment of the Achievement of SMNR: Energy Efficiency

Assessment of the Achievement of SMNR: Invasive Non-native Species

Assessment of the Achievement of SMNR: Land use and Soils

Assessment of the Achievement of SMNR: Waste

Assessment of the Achievement of SMNR: Water Efficiency

Updated SoNaRR evidence needs. Published as a data table on web in March 2021

Acronyms and Glossary of terms. Published as a PDF in December 2020 and updated in 2021 as a data table on the web

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1. Headline Messages

This ecosystem provides key benefits including carbon storage, flood mitigation, food, fibre and some of Wales's most iconic species and landscapes.

The majority of MMH ecosystems occur in the uplands, the land lying above the upper limit of enclosure. This upland part of the ecosystem accounts for 19.3% of the Welsh land making it the largest continuous block of habitat. It includes large areas of acid grassland much of it resulting from overgrazing of heath and bog.

In contrast, the lowland peatlands and heathlands are frequently small, highly fragmented and impacted by neighbouring land uses. Decline in traditional grazing and other management practices are often apparent and lead to loss of valued features.

Problems are compounded in both upland and lowland MMH by aerial and groundwater pollution with high levels of reactive nitrogen.

2. Introduction

Mountains, moorlands and heaths (MMH) is a complex category which encompasses most of the iconic habitats of the Welsh uplands, including dwarf shrub-heath, inland cliff and ledge habitats, blanket bog, flush and fen and montane habitats (Table 1). Native woodland and wood pasture, are also integral components of this ecosystem, particularly on the ffridd, on steep ground, cliffs and gorges (see Woodlands chapter). Acid is also highly relevant here, due to its functional role as the 'matrix' within which many other upland habitats sit and its widespread status as a product of the degradation of dwarf shrub-heath grassland (see Semi-natural grasslands chapter), . In contrast to SoNaRR2016, SoNaRR2020 includes all peatland habitats such as alkaline fens and lowland raised bogs in the MMH assessment, reflecting the importance of peat bodies, which cross the upland/lowland boundary. MMH also includes lowland dwarf-shrub heath, including coastal dry and wet heath (but not maritime or dune heath).

The majority of MMH occurs in the uplands, defined here as land lying above the upper limit of agricultural enclosure, accounting for 401,500 ha (19.3% of the Welsh land area) (Blackstock et al., 2010). Much of this area is of moderate (circa. 300 – 600 m) altitude and regarded as sub-montane in character, with only circa 20,670 ha lying above 600 meters (Turner, 2011) meeting the definition of montane (Ratcliffe, 1977). MMH includes a proportion of the upland margins or ffridd, a distinct transition zone between intensively farmed lowlands and open hill habitats. Ffridd, covering approximately 135,000 ha (6.5% of the Welsh land area), comprises a mosaic of habitats: heath, grassland, peatland, bracken, rock and woodland (Blackstock et al., 2010).

It is important to appreciate the historical context of MMH to avoid "shifting baselines" as each generation accepts the losses of the past and looks only at recent changes. Much of the uplands once supported native woodland and scrub up to a natural tree-line (circa 600 meters Above Ordnance Datum), whilst lowland heaths and peatlands are fragments of their former extent (such as Stevens, 1992).

In Eryri, “the eagle’s nest”, a nesting eagle has not been seen for many centuries, and dotterel now make only fleeting visits on their migration to the northern tundra, but other species still characterise the Welsh uplands. Ravens, reflecting the abundance of sheep carrion, pivot across the high peaks. The eastern moorlands still produce red grouse for the gun, while on the slopes, ring ouzel and whinchat enliven the shattered screes and the mountain fringe or ffridd. High screes still retain populations of rainbow leaf beetle (the so-called Snowdon beetle) and the rare ground beetle *Leistus montanus* has recently been rediscovered here. On lowland peatlands, the rosy marsh moth thrives on Cors Fochno and southern damselfly responds to careful management in Pembrokeshire and Anglesey.

Relict arctic-alpine plants, including tufted saxifrage *Saxifraga cespitosa,* Alpine saxifrage*, S. nivalis,* and the ferns Alpine woodsia *Woodsia alpina,* oblong woodsia *W. ilvensis,* survive, mostly in Snowdonia, though some are found in the Brecon Beacons. Wet heathlands, for example, support three-lobed Water crowfoot *Ranunculus tripartitus*, restricted to the western fringes of Wales, while Ivy-leaved Bellfower *Wahlenbergia hederacea* is fairly widespread on heaths and ffridd.

In recent years, the importance of some uplands, like Migneint, for the rapidly declining water vole has been highlighted (Walsh and Hall 2005, Parry 2018) where they may avoid the non-native mink which have predated them elsewhere on lowland watercourses. They also retain strongholds in lowland wetlands on Anglesey where mink are still rare.

The dominant environmental factors in the Welsh uplands include a significant excess of rainfall over evapotranspiration and seasonally low temperatures, although in a European context the Welsh uplands are oceanic in character.

Hill farming is the principal land use in the Welsh uplands. Strong links remain between the agricultural community and the mountains, and the system of hefted livestock, cynefin, remains a deep-seated tradition in many areas, but livestock grazing has been a key driver of change in extent and condition of MMH habitats since 1945 (UK NEA, 2011). Management of moorland for grouse has been an important factor on eastern hills. Other factors include afforestation, airborne pollution (particularly nitrogen deposition), prescriptive burning and wildfires, tourism and recreation, and climate change.

In the lowlands, fragments of heathland and peatland surrounded by intensively managed farmland or restricted to the narrow coastal belt often suffer from agricultural neglect and abandonment (UK NEA, 2011). Recreational conflict with farming has sometimes led to further withdrawal of livestock. Habitat fragments suffer disproportionately from edge effects such as disturbance, invasive species, drainage and diffuse agricultural pollution from neighbouring land.

There is growing recognition of the crucial societal benefits which the uplands provide in addition to food and fibre. These include soil carbon storage, and thence climate change mitigation, within the peatland resource and wet soils. Uplands also provide the primary source of drinking water, water regulation, flood alleviation, energy production (wind and hydroelectric), recreation and tourism, along with scientific, educational, historical and archaeological services to non-use services, such as those provided by existence, cultural and altruistic values.

Sustainable management of this natural resource depends on increasing ecological resilience by improving the condition and connectivity of MMH habitats. A vision for the future would see functional peatlands occupying the entire deep peat footprint, structurally diverse heathlands expanding into some areas of upland acid grassland, habitats of the high mountains and rocky ledges protected from excessive grazing, and occupying the full extent of available substrate. There would be more native woodland and scattered trees in the uplands with natural regeneration occurring up to the natural tree-line, connecting to the mosaic of habitats that is the ffridd. In the lowlands, peatlands would be buffered from agricultural enrichment and the connectivity of lowland heathlands would be enhanced by actively increasing the area of semi-natural habitat, especially along the coast.

Table 1 MMH incorporates 21 terrestrial features listed in the Habitats Directive Annex 1.

Habitats Directive Annex 1 Reference	Habitat Feature (* = EU Priority)	Closest corresponding Phase 1 habitat (Blackstock et al., 2010)	Predominantly Upland or Lowland
4010	Northern Atlantic wet heaths with cross-leaved heath (*Erica tetralix*)	D2 Wet dwarf shrub heath D6 wet heath / acid grassland mosaic	Upland and Lowland
4030	European dry heaths	D1.1 Dry acid heath, D1.2 Dry basic heath D5 dry heath / acid grassland mosaic	Upland and Lowland
5130	Juniper (*Juniperus communis*) formations on heathlands and calcareous grasslands	D1.2 Dry basic heath	Lowland
4060	Alpine and boreal heath	D4 Montane heath	Upland
6150	Siliceous alpine and boreal grassland	B1.1 Unimproved acid grassland	Upland

Habitats Directive Annex 1 Reference	Habitat Feature (* = EU Priority)	Closest corresponding Phase 1 habitat (Blackstock et al., 2010)	Predominantly Upland or Lowland
7110*	Active raised bog*	E1.6.2. Raised bog	Mainly lowland
7120	Degraded raised bogs capable of natural regeneration	E1.7 Wet modified bog E1.8 Dry modified bog E4 bare peat	Mainly lowland
7130*	Blanket bogs*	E1.6.1 Blanket bog E1.7 Wet modified bog E1.8 Dry modified bog E4. Bare peat	Upland > lowland
7140	Transition mire and quaking bogs	E3.1.1. Valley mire E3.2.1. Basin mire E3.3.1. Flood plain mire	Lowland > Upland
7150	Depressions on peat substrates of the Rhynchosporion (*R. alba*, white beak-sedge)	D2 Wet heath E1.6.1 Blanket bog E1.6.2. Raised bog E1.7 Wet modified bog	Lowland and Upland

Habitats Directive Annex 1 Reference	Habitat Feature (* = EU Priority)	Closest corresponding Phase 1 habitat (Blackstock et al., 2010)	Predominantly Upland or Lowland
7210*	Calcareous fens with Cladium mariscus (great fen sedge) and species of the *Caricion davallianae**	E3.1.1. Valley mire E3.2.1. Basin mire E3.3.1. Flood plain mire	Lowland
7220*	Petrifying springs with tufa formation (*Cratoneurion / Palustriella commutata* Curled hook-moss), *	E2.3. Bryophyte-dominated spring	Upland > Lowland
7230	Alkaline fens	E2.2. Basic flush E3.1.1. Valley mire	Lowland
7240*	Alpine pioneer flush mire formations of the Caricion bicoloris-atrofuscae*	E2.2. Basic flush	Upland
8110	Siliceous scree of the montane to snow levels	I1.2.1 acid/neutral scree	Upland
8120	Calcareous and calcschist screes of montane to alpine levels	I1.2.2 basic scree	Upland
8210	Calcareous rocky slopes with chasmophytic vegetation	I1.1.2 basic inland cliff	Upland > Lowland
8220	Siliceous rocky slopes with chasmophytic vegetation	I1.1.1 acid/neutral inland cliff	Upland > Lowland
6430	Hydrophilous tall herb fringe communities of montane to alpine levels	I1.1.1 acid/neutral inland cliff I1.2. basic inland cliff	Upland

Habitats Directive Annex 1 Reference	Habitat Feature (* = EU Priority)	Closest corresponding Phase 1 habitat (Blackstock et al., 2010)	Predominantly Upland or Lowland
8240*	Limestone pavements*	I1.3 Limestone pavement	Upland and Lowland
8310	Caves	n/a	Upland > Lowland

Table 2 Notes on definition with regard to Mountains, Moorlands and Heaths.

Habitats Directive Annex 1 Reference	Notes
5130	Lowland examples only. Upland juniper populations are components of dry heath (D1.1) and montane heath (D4) habitat
6150	May occur as a degenerative form of montane heath (H4060)
7150	A discrete community found within pool systems on wet heath, blanket bog, raised mire and valley mires.
8110	Screes in the lowlands are excluded from the HD Annex I habitat definition. The habitat is largely mapped from the uplands of north Wales.
8120	HD Annex 1 definition limited to uplands
8210	The habitat occurs on base-rich rocks in both north and south Wales, and spans both the uplands and lowlands.
8220	This habitat is confined to inland cliffs and steep rocky slopes occurring in both the uplands and lowlands of Wales. Little attention has been paid to the lowland examples.

3. State and Trends (Aim 1)

Summary Assessment of State, Trends and Future Prospects

The following tables (Table 3 to Table 20) give a brief description of the past trends and future prospects for Mountains, Moorlands and Heaths. These are assessed to be:

- improving trends or developments dominate
- trends or developments show a mixed picture
- deteriorating trends or developments dominate

Further information is provided to put this in context.

Table 3 Key Message: Past Trends and Future Prospects of Habitat Extent in Lowlands Peatland

Time period	Indicative assessment	Description
Past trends – Second World War to present	Deteriorating	Huge historical losses have left a diminished lowland peatland resource, with habitat loss only slowing into the 21st century. The significance of this is that surviving areas are fragmented and the original peat body is compromised and more vulnerable to marginal drainage, reducing ecosystem resilience. For example, extant raised bog habitat in Wales is estimated to occupy no more than 60% of its original peatland footprint (Jones and Birch, 2019). NRW's Lowland Peatland Survey Programme has found frequent evidence for comparatively recent (post 1980) habitat loss. Such loss and fragmentation causes the continuing erosion of species over decades as small isolated populations fail.
Future prospects to 2030	Mixed picture	For the 7 core Annex 1 lowland peatland habitats (Table 1), the future prospects for habitat area have been scored as 'negative' for 3 habitats, 'unknown' for 1, 'overall stable' for 1 and 'positive' for 2 (JNCC, 2019). The positive assessments relate to the two raised bog Annex 1 habitats largely as a result of conservation actions underway or planned as part of the New LIFE for Welsh Raised Bogs project and the Welsh Government Peatland Action Programme. Negative assessments relate to alkaline fen, calcareous fen and petrifying springs and the ongoing vulnerability of these calcareous wetland habitats and associated species (Howe, 2019) is of particular concern.

Note on robustness: The confidence attached to the future prospects assessment for Article 17 habitats is low (3 habitats); medium (3 habitats) and high (1 habitat) (calcareous fens). There is an urgent need for a national peatland habitat surveillance programme to track habitat losses and gains.

Table 4 Key Message: Past Trends and Future Prospects of Habitat Extent in Upland Peatland

Time period	Indicative assessment	Description
Past trends – Second World War to present	Deteriorating	Substantial post-war losses – much of the 6,892 ha conifer plantation on deep peat in the uplands (Evans et al., 2015) would have been blanket bog habitat, and substantial losses are suspected to have occurred due to agricultural improvement at lower altitudes.
Future prospects to 2030	Mixed picture	For blanket bog (the dominant upland peatland) the future prospects for habitat area have been scored as ‘positive’ (NRW, 2018). Emmett et al. (2017) indicate that “initial analysis of land cover data suggests a recent increase in the area of blanket bog”, but this is likely due to restoration of afforested peatland and will be further enhanced by the Welsh Government Peatland Action Programme. These figures may be offset by some ongoing losses of habitat, but the overall trend is predicted to be positive. In the longer term, climate change will present a challenge to the extent of upland peatlands and may reduce the bioclimatic envelope of blanket bog but this may be tempered by managing for improved ecosystem condition and resilience.

Note on robustness: There is high confidence to the area lost to afforestation. The confidence attached to the future prospects assessment for extent of upland peatland is medium, given its dependence on achieving a more resilient condition.

Table 5 Key Message: Past Trends and Future Prospects of Habitat Extent in Upland Heathland

Time period	Indicative assessment	Description
Past trends – Second World War to present	Deteriorating	Substantial post-war losses of upland heathland have occurred, varying across Wales; Walker and Elias (1989) found 44% loss of heath on the Berwyn between 1946 and 1984, whilst Wheeler (1982) found a 24% decrease on the Preseli Hills and Carn Ingli between 1946 and 1980. Recent losses are likely to have been relatively small, although a large burn (250 ha) on Llantysilio Mountain in 2018 resulted in the loss of around 136 ha of peat and organic soils where dry heath may not recover (Longdon, 2019). There is some evidence of heathland restoration where grazing levels have been reduced, for example Cwm Idwal heath has recovered significantly since stock exclusions in 1999 (Turner, 2017). Expansion of heath has also been recorded at National Trust properties in the Ogwen Valley (Sherry 2019[a]) and Elan Valley (Sherry 2019[b]).
Future prospects to 2030	Mixed picture	Some upland heath could be lost as a result of native woodland expansion on lower slopes. In return, lower grazing levels should result in the restoration of heathland into areas of acid grassland, particularly where there are suppressed heathers within the sward. Where there is little remaining heather or bilberry, recovery will be slow.

Note on robustness: The confidence attached to the future prospects assessment for extent in Article 17 habitat is ‘medium’ for dry heath and wet heath depending on the achievement of measures to increase resilience.

Table 6 Key Message: Past Trends and Future Prospects of Habitat Extent in Lowland Heathland

Time period	Indicative assessment	Description
Past trends – Second World War to present	Deteriorating	Substantial loss of lowland heathland occurred before and after the Second World War. On the Llyn Peninsula, 51% of dry heath and 95% of wet heath were lost between the 1920s and the late 1980s (Stevens, 1992). On Anglesey, a 47% reduction in heath occurred between 1940 and 1993 (Norris and Stevens, 1999), although losses have slowed since the 1980s. In the ffridd, Gritten (2012) showed 6% loss of wet heath and 14% loss of dry heath between the late 1980s and 2009–11.
Future prospects to 2030	Deteriorating	There is little evidence of recovery of heath extent in coastal areas or within much of the ffridd and it is more likely that areas of lowland heath will continue to be lost to abandonment and scrub. However, in the Elan Valley ffridd, the situation is more complex with evidence of heathland expansion on acid grassland and loss of existing heathland to woodland and scrub (Sherry et al., 2019). There is a large scale lowland heathland project in Pembrokeshire where 30 ha of dry heath has been created (Hayes and Spiridonova, 2009).

Note on robustness: The confidence attached to the future prospects assessment for extent in Article 17 habitat is ‘medium’ for dry heath and wet heath and ‘low’ for *Juniper communis* formations on heath and calcareous grasslands.

Table 7 Key Message: Past Trends and Future Prospects of Habitat Extent in Silicious Alpine and Boreal Heath and Grassland

Time period	Indicative assessment	Description
Past trends _ Second World War to present	Deteriorating	There is little information on extent prior to 1996, making it difficult to determine trends. It is likely that these habitats were more extensive on places such as Plynlimon where they have now started to expand since grazing was reduced in the last decade. Small patches have been lost to erosion by sheep and people on Glyderau plateau and Carneddau ridge.
Future prospects to 2030	Deteriorating	There is a limited potential to increase the area of habitat if its apparent suppression by overgrazing could be addressed. However, there is a significant risk that it could shrink further due to heavy grazing, nitrogen deposition and the long-term impacts of climate change as the bioclimatic envelope for this habitat is elevated

Note on robustness: The confidence attached to the future prospects assessment for extent in Article 17 habitat is ‘low’ for montane heath and ‘medium’ for Siliceous alpine and boreal grasslands.

Table 8 Key Message: Past Trends and Future Prospects of Habitat extent in Upland Rock Habitats

Time period	Indicative assessment	Description
Past trends – Second World War to present	Deteriorating	There is no comprehensive dataset to indicate trends in the extent of rock-based habitats. It is highly likely that areas of natural scree and cliff have been lost to quarrying since 1945, although in the long term quarry faces may develop natural vegetation. Limestone pavements have traditionally been used for drystone walling and local building. It is estimated that only 3% of UK pavements remain undamaged. In Wales, two areas of limestone pavement were lost to quarry expansion in the mid 1990s (Deacon, 1997). While the discovery of new cave systems increases our knowledge of the extent of the subterranean habitat, the actual extent of cave systems will have remained the same since the Devensian glaciation.
Future prospects to 2030	Improving	Within the protected site system, the extent of rock-based habitat is unlikely to change significantly. However, outside the Sites of Special Scientific Interest (SSSIs), it is likely that quarrying activities will continue to impact on areas of scree and cliff, although the significance of this in the context of the whole resource is not known and some recovery may be possible in the long term. Legislation (Limestone Pavement orders) has largely halted the loss of that habitat by rock removal, so future loss is likely to be limited.

Note on robustness: Article 17 reports only provides confidence assessments for 3 of the 6 habitats; 2 are ‘low’ and 1 is ‘medium’.

Table 9 Key Message: Past Trends and Future Prospects of Pressures and Threats in Lowland Peatland

Time period	Indicative assessment	Description
Past trends – 2012 – present	Deteriorating	The most prevalent pressures based on the 2019 Article 17 assessment are: mixed source air pollution, extensive grazing/undergrazing by livestock (and the linked pressure of management neglect), drainage, and diffuse pollution.
Future prospects to 2030	Mixed picture	Grazing and drainage can be addressed using Section 16 Management Agreements within SSSIs, though implementation is reliant on sufficient staff resource. Experience suggests that, to date, agri-environment schemes are of limited effect for lowland peatlands, with little evidence of effectiveness for water quality improvements in lowland catchments (Emmett et al., 2017). More focussed action is required to address agricultural enrichment of Groundwater Dependent Terrestrial Ecosystems. The high greenhouse gas (GHG) emissions from drained lowland peatland under intensive management (improved pasture or horticulture) is a cause for particular concern (Evans et al., 2017).

Note on robustness: medium. Assessment of pressures based on the peer reviewed 2018 Article 17 assessment (JNCC, 2019) utilising a range of evidence, including NRW’s Actions Database.

Table 10 Key Message: Past Trends and Future Prospects of Pressures and Threats in Upland Peatland

Time period	Indicative assessment	Description
Past trends – 2012 – present	Deteriorating	The most prevalent pressures are mixed-source air pollution, extensive grazing by livestock, and drainage (JNCC, 2019). In uplands, drainage largely refers to historic moor-gripping. Whilst >770km of grips have been blocked, an estimated 1,500km still remain (Williamson, 2019).
Future prospects to 2030	Mixed picture	There are opportunities to reduce drainage impacts by further blocking of moor-grips though peat shrinkage effects persist for many decades, causing ongoing drainage. Grazing issues, (mostly overgrazing) are likely to remain a threat, partly dependant on post-Brexit agricultural support systems. Impact from past blanket bog afforestation remains and is a continuing threat from self-seeding conifers. In the longer term, climate change threatens the integrity of upland peatlands, particularly where resilience is compromised by past and present management.

Note on robustness: medium. Assessment of pressures based on the 2018 Article 17 assessment (JNCC, 2019) which utilised a range of evidence sources, including NRW's Actions Database.

Table 11 Key Message: Past Trends and Future Prospects of Pressures and Threats in Upland Heathland

Time period	Indicative assessment	Description
Past trends – 2012 – present	Deteriorating	The most prevalent pressures, based on 2018 Article 17 assessment, are agricultural and land management, with grazing being of the highest significance. S16 Management Agreements and Glastir Commons Agreements have had some positive outcomes for upland heath, particularly resulting from reduced winter grazing (Sherry, 2019[b]), but securing the correct grazing stock and appropriate grazing regime remains a significant issue (NRW Actions Database). Frequent/intensive prescribed burning and wildfire is an issue on upland sites (Longdon, 2019). Other pressures include reactive-nitrogen pollution, invasive non-native species (particularly rhododendron). and access/recreational issues.
Future prospects to 2030	Mixed picture	Post-Brexit changes to agricultural policy and practices could offer an opportunity for more sustainable grazing, including rebalancing the numbers of sheep and cattle. Nitrogen deposition and climate change will continue to be major drivers of change on upland heath (Fagúndez, 2013). Potential management to mitigate these impacts has been identified (Natural England, 2013), (Barker et al., 2004). Impacts from afforestation remain including a continuing threat from self-seeding conifers. Climate change and associated drought increase the risk of wildfires.

Note on robustness: medium. Assessment of pressures based on the 2018 Article 17 assessment (JNCC, 2019) which utilised a range of evidence sources, including NRW's Actions Database.

Table 12 Key Message: Past Trends and Future Prospects of Pressures and Threats in Lowland Heathland

Time period	Rating	Description
Past trends _ 2012 – present	Deteriorating	Under-grazing, leading to gorse and scrub invasion, is the most significant pressure on lowland heathland. This is compounded by high recreational pressures on small lowland sites, resulting in the withdrawal of livestock to avoid conflict. Experience suggests that targeted projects and Section 16 Management Agreements can help to secure appropriate grazing and resolve conflicts.
Future prospects to 2030	Mixed picture	Grazing may continue to decline on lowland heathlands (depending on agricultural policy and increasing access pressure). Lowland sites need targeted intervention and financial support to integrate agricultural, habitat and recreational management to deliver multiple benefits. There are opportunities to increase connectivity and resilience following models from Pembrokeshire and Llŷn. There is a long-term threat to heathland particularly in the upland margins from the pathogens *Phytophthora ramorum* and *P. kernoviae* which can impact *Vaccinium* species (JNCC, 2010). Climate change and associated drought may increase the risk of wildfires.

Note on robustmess: medium. Assessment of pressures based on the 2018 Article 17 assessment (JNCC, 2019) which utilised a range of evidence sources, including NRW’s Actions Database.

Table 13 Key Message: Past Trends and Future Prospects of Pressures and Threats in Silicious Alpine and Boreal Heath and Grassland

Time period	Rating	Description
Past trends – 2012 – present	Deteriorating	Two principal pressures on both alpine and boreal habitats are grazing and air pollution. Despite generally reduced grazing levels, localised heavy grazing on high ridges and summit plateaux continues to have a significant impact on the habitat. Furthermore, high precipitation result in very heavy reactive-nitrogen deposition. Recreation has a more limited impact on the habitat through localised footpath erosion.
Future prospects to 2030	Deteriorating	Grazing reduction can lead to the slow recovery of the habitat (Miller, 2010). However, reactive nitrogen deposition and climate change will continue to be serious threats to the habitat and, in combination, may result in the spread of grasses which outcompete montane species. With climate change, wetter, warmer winters will impact species which normally thrive under extended snow cover (Natural England, 2013).

Note on robustness: medium. Assessment of pressures based on the 2018 Article 17 assessment (JNCC, 2019) which utilised a range of evidence sources, including NRW's Actions Database.

Table 14 Key Message: Past Trends and Future Prospects of Pressures and Threats in Upland Rock Habitats

Time period	Rating	Description
Past trends – 2012 – present	Deteriorating	The two principal pressures on rock habitats are air-borne pollutants and grazing. Special Area of Conservation (SAC) monitoring has found areas where more than 50% of the chasmophytic vegetation has been removed by grazing. However, the problem is not uniform as some areas are inaccessible to sheep, so impacts occur in “hotspots”. Grazing impacts are compounded where feral goats browse on the less accessible cliffs and scree fields. Heavy grazing is also a significant pressure on limestone pavement. The impact of nitrogen deposition on these habitats is poorly understood, however recent evidence found an increase in algae impacting sensitive lichen and bryophyte communities, which is possibly linked to reactive-nitrogen deposition (Hodd, 2018). Climbing (including, occasionaly, ice climbing) is an issue locally but is largely restricted to defined routes. Footpath erosion impacts locally on scree and chasmophytic vegetation on rocky slopes (BMC,2011). Caving can increase CO^2 levels (from respiration), temperatures, light levels and disturbance, impacting on cave formations and cave fauna including bats (Baker and Genty, 1998).
Future prospects to 2030	Mixed picture	Where grazing has been reduced, for example at Cwm Idwal National Nature Reserve (NNR), rocky ledge vegetation has been able to recover (Turner, 2017). Recovery in the wider uplands has been limited by the inability to secure appropriate grazing regimes on the large upland commons. This may change with future agri-policy. Feral goats will likely remain an issue in Eryri. Recreational pressures are likely to at least remain the same and some (climbing and bouldering) may continue to increase.

Note on robustness: Article 17 reports (JNCC 2019) provide confidence assessments for 3 of the 6 rock habitats; 2 are low and 1 is medium.

Table 15 Key Message: Past Trends and Future Prospects for Condition and Connectivity in Lowland Peatland

Time period	Rating	Description
Past trends – 2012 – present	Deteriorating	Condition is based on the assessment for Annex 1 habitats amounting to 3,050 ha, 36% of the total lowland peatland (excluding blanket bog) resource of 8,370 ha. Of this, 379 ha was assessed as being in good condition 1,833 ha as not good and the remainder (838 ha) as not known. Connectivity is generally poor, given that many of these habitats are fragments in intensive agricultural landscapes.
Future prospects to 2030	Mixed picture	The future prospects for structure and function based on the 2018 Article 17 reporting is positive for two of the habitats, negative for three, and unknown for two. Reductions to nutrient loads depend on addressing local aerial emissions and groundwater diffuse pollution. Prospects for increased connectivity are assessed as very limited given the competing land use demands. In the longer term, climate change, particularly drought, may lead to damaging hydrological changes. Measures to increase the hydrological integrity of drained peatlands will increase the resilience of these systems.

Robustness: The confidence attached to the future prospects assessment for Article 17 is low, 2 habitats; medium, 5 habitats and high, 1 habitat (calcareous fens).

Table 16 Key Message: Past Trends and Future Prospects for Condition and Connectivity in Upland Peatland

Time period	Rating	Description
Past trends – 2012 – present	Mixed picture	Common Standards Monitoring (CSM) describes the overall condition of the entire feature within a protected site (which can be very extensive), covers thousands of hectares, and will typically encompass significant variation in quality. Condition assessments are available for all blanket bog SAC features in Wales covering 19,900 ha of blanket bog (37% of the Welsh resource). All the features were assessed as being in unfavourable condition. Monitoring results from the Glastir Monitoring and Evaluation Programme (Emmett et al., 2017) indicate a statistically significant improvement in the condition of blanket bog between the 2013–16 data collection round and both 1990 and 2007 baselines. Expert assessment (Heppingstall, 2019 pers.com.) of recent trends in the condition of blanket bog for 5 upland sites in Ceredigion, covering over 5,738 ha, indicate improvements in condition for over 92% of the area. Habitat connectivity is relatively high except where broken by past afforestation or peatland habitat in poor condition.
Future prospects to 2030	Mixed picture	The future prospects for structure and function were recorded as positive for the 2018 Article 17 reporting round. However, these assessments need to be seen in context: the resource was assessed as being in unfavourable or unknown condition in 2018 and significant investment in restoration remains essential and will continue to do so for the foreseeable future. The removal of old forest plantations from deep peat will increase connectivity. In the longer term, climate change, particularly drought, may lead to damaging hydrological changes. Measures to increase the hydrological integrity of drained peatlands will increase the resilience of these systems.

Robustness: The confidence attached to the future prospects assessment for Article 17 is low, 2 habitats; and medium, 5 habitats.

Table 17 Key Message: Past Trends and Future Prospects for Condition and Connectivity in Upland Heathland

Time period	Indicative assessment	Description
Past trends – 2012 – present	Mixed picture	Recent SAC monitoring records 2,201 ha of dry heath in favourable condition on the Rhinogau. All other areas of upland wet/dry heath within Special Areas of Conservation (SACs) are unfavourable with recovery indicated on only two sites. Unit-based assessments of SACs give a more detailed picture, for example 1,800 ha upland heath was mapped as favourable on the Carneddau (Turner, 2018 and Sherry, 2018). Most upland heathlands are relatively well connected.
Future prospects to 2030	Mixed picture	Future prospects for structure and function were recorded as poor for both wet and dry heath in the 2018 Article 17 reporting round. Actions to address management issues are underway on only 27% of dry heath units and 10% of wet heath units. SAC monitoring recorded 3,118 ha as recovering and 17,159 ha as unchanged/unclassified. Climate change may lead to increased fire risk.

Robustness: The confidence attached to the future prospects assessment for Article 17 is low for both wet and dry heath since the coverage of protected site monitoring is low.

Table 18 Key Message: Past Trends and Future prospects for Condition and Connectivity in Lowland Heathland

Time period	Indicative assessment	Description
Past trends – 2012 – present	Deteriorating	The most recent SAC monitoring dataset recorded no lowland heathland in favourable condition and the loss of 24 ha of wet and dry heath on one SAC. The National Trust desktop property review records favourable condition on 3 SSSIs and 3 SAC units of 84.9 ha. Connectivity is generally poor in the lowlands, given that much of this habitat comprises fragments in intensive agricultural landscapes. There is higher cover and larger habitat patches in the ffridd (upland fringes).
Future prospects to 2030	Mixed picture	Future prospects for structure and function were recorded as poor for wet and dry heath in the 2018 Article 17 reporting round. Actions to address management issues are underway on only 13% of dry heath units, and 7% of wet heath units. SAC monitoring records recovery on 3,118 ha and decline on 186 ha, while a National Trust desktop review logged recovery on 391 ha and decline on 40 ha. Some reconnection of coastal heathlands (in particular) may be possible following the Llŷn and Pembrokeshire models addressing the first field back from the cliff-top. Climate change may lead to increased fire risk.

Robustness: The confidence attached to the future prospects assessment for Article 17 is low for wet heath, dry heath and low for *Juniper communis formations* on heath and calcareous grasslands.

Table 19 Key Message: Past Trends and Future Prospects for Condition and Connectivity in Silicious Alpine and Boreal Heath and Grassland

Time period	Indicative assessment	Description
Past trends – 2012 – present	Deteriorating	97% of alpine and boreal heath and 94% of grassland is found within SACs; the most recent monitoring shows both to be in unfavourable condition (Turner, 2020). These habitats are inherently poorly connected, and isolated on the high summits and ridges.
Future prospects to 2030	Deteriorating	Future prospects for structure and function were recorded as poor in the 2018 Article 17 reporting round (JNCC, 2019). Turner (2012, 2020) has shown some recovery is possible. However, growth is extremely slow in this environment, and despite previous grazing agreements in parts of the Eryri SAC, the habitat remains in poor condition and action is needed to enable recovery. Climate warming, plus overgrazing and exceedance of nitrogen critical load, will challenge the survival of this feature.

Robustness: The confidence attached to the future prospects assessment in Article 17 is low for montane heath and high for siliceous alpine and boreal grasslands.

Table 20 Key Message: Past Trends and Future Prospects for Condition and Connectivity in Other Upland Rock Habitats

Time period	Indicative assessment	Description
Past trends – 2012 – present	Mixed picture	There is no historic information on the condition of these habitats; the most recent SAC monitoring dataset shows eight features in favourable condition, two described as unfavourable recovering, and six as unfavourable unclassified. On Cadair Idris, all upland rock features are favourable, while on the Brecon Beacons and Eryri SACs, all are unfavourable. However, assessments at a unit level are more encouraging. Turner (2018) mapped 613 ha of rock habitat within the Carneddau units of the Eryri SAC as favourable. In Cwm Idwal, the higher ledges were recorded as favourable and the lower (sheep-accessible) ledges as unfavourable by the National Trust in 2016. No data is available for the current condition of limestone pavement. Rock habitats are inherently isolated by the disjointed nature of the outcrops, by differences in lithology and further constrained where heavy grazing limits their natural expression to the most inaccessible areas.
Future prospects to 2030	Mixed picture	Managing grazing pressure, including goats, can have a positive impact on these habitats, and therefore, their future condition. Recreational pressures will continue to have local impact which may increase. Good communication with user bodies and management of the recreational resources, such as through footpath work, can resolve local issues. Climate change will challenge the relict arctic-alpine flora and fauna, which may be compromised by genetic erosion and requires intervention to boost genetic resilience and habitat space.

Robustness: Article 17 only provides confidence assessments for 3 of the 6 habitats; 2 are low and 1 is medium.

Habitat Extent

MMH habitats cover an estimated 240,610 ha (Table 21); this figure includes areas of upland marshy grassland and bracken but excludes extensive areas of other semi-natural grassland (mainly upland acid grassland) which form part of the upland matrix. There have been substantial areas of habitat loss and change since 1945; for example, the conversion of upland heathland to acid grassland (Walker and Elias, 1989), the loss of lowland heath (Norris and Stephens, 1999), and the afforestation of upland peatlands (Evans et al., 2015). These losses have slowed in recent decades and there is evidence of some increase in upland habitat extent (due to restoration), for example, upland blanket bog (Emmett et al., 2017).

Table 21 Areas based on Blackstock et al. (2010) with recent revision of montane heath extent from Article 17 reporting (2013 and 2019).

Habitats	Extent in Hectares
Upland peatlands	68,800
Lowland peatlands	10,100
Upland heath	79,100
Lowland heath	12,500
Alpine and boreal heath and grassland	100
Upland rock habitats	8,210
Upland marshy grassland	29,200
Upland continuous bracken	32,600
Other upland semi-natural grasslands	114,100

Other upland semi-natural grasslands areassessed in the Semi-natural grasslands chapter

Designated sites represent the best of our natural areas, selected according to rigorous standards (JNCC 1989–2019). The designated sites series has been critical in controlling further wholesale loss of MMH habitats, particularly heathlands and peatlands, by controlling agricultural improvement in the lowlands and further afforestation in the uplands. Approximately 60% of upland and 30% of lowland MMH habitats are protected by designation; in part reflecting the many areas of undesignated heath and peatland scattered in the ffridd, below the upland boundary (Table 22).

Table 22 Habitat areas (ha) and percentage of each habitat within welsh designated sites.

Habitat	Total extent of habitat in Wales (ha)	Extent of habitat within designated sites (ha)	% of habitat within designated sites
Upland peatlands	68800	47557.44	69.12
Lowland peatlands	10100	4329.28	42.86
Upland heath	79100	40505.39	51.21
Lowland heath	12500	2491.23	19.93
Montane heath	100	100.00	100.00
Upland rock habitats	8280	5614.92	67.81

Note on data in Table 22: Extent is expressed in ha and rounded to the nearest 100 if greater than 1,000, otherwise to the nearest 10; totals are calculated from unrounded values (from Blackstock et al., 2010). It has been calculated by multiplying the totals of Blackstock et al. by proportions calculated from from NRW's existing Phase 1 data.

Note on upland and lowland peatland: these data relate to habitat classes, not soil classes; areas of converted peatland are not included.

Condition and Connectivity

The condition of MMH habitats is extrapolated from limited datasets which include SAC monitoring data, several SSSI/non-SSSI data surveys and Glastir monitoring data. It should be noted that although SSSI and other protected sites are selected as the best *examples* of their features, they are not necessarily in favourable *condition*. In many cases they are the remaining damaged fragments of formerly extensive and resilient features and in need of active conservation. Here a distinction between current *condition* (a snapshot in time) and overall *status* is made (which also includes an assessment of relevant factors and the likely prospect for the feature available in Table 3 to Table 20).

The most recent SAC monitoring dataset (2013–18) presents a picture of unfavourable status for all Annex 1 habitat features with the exception of cave features (which were recorded as favourable status); the rock-based scree, ledge and rocky slope habitats fare best with 6 features (42%) in favourable condition.

Montane habitats are in the poorest condition with no features reported as favourable (Turner, 2020) In the Carneddau, Turner (2012) shows a complex pattern of change in montane vegetation structure since the 1950s with serious decline in habitat quality followed by a recent, but very slight, recovery. The cover of

Racomitrium moss has shown a slight (but statistically not significant) increase at Pen yr Ole Wen between 1993 and 2011 following a significant decrease between 1953 and 1993; macro-lichens have decreased significantly since 1951.

Lowland heathlands show no features in favourable condition and only one feature (6%) is reported as favourable in the uplands.

Similarly for peatlands, two features (5%) are favourable in the lowlands and four features (22%) in the uplands. Trends are difficult to detect within the SAC monitoring data as for a large number of assessments the trend is recorded as 'unclassified' (often where an earlier baseline cannot be established). However, for all the Annex 1 MMH habitat types there are only four management units within the uplands which support habitat classified as 'unfavourable recovering'; there are four in the lowlands.

Other datasets provide more nuanced information at an individual site or unit level, which may give a more positive message; for example, within the Eryri SAC, European Dry Heath is classified as unfavourable overall but Turner (2018) mapped 1,800 ha of favourable habitat within the Carneddau units and the National Trust. (Sherry, 2018) has recorded 839 ha of favourable condition heath on units under this ownership. For SACs as a whole, these features are at unfavourable conservation status because parts of the feature are in poor condition. However, within these there are areas in good condition depending on the scale being considered.

The Glastir Monitoring and Evaluation Programme (GMEP) final report (Emmett et al., 2017) provides a more general overview with some key headline messages; for example, an improvement in the condition of blanket bog. Initial assessment also suggested an increase in the extent of blanket bog (due to restoration from plantation) but a decline in the extent of heathland.

Among the iconic birds of upland farmed habitats, the ranges and numbers of curlews, golden plovers, black grouse, red grouse and ring ouzels have all contracted relative to the 1970 Atlas (Harris et al., 2016). In common with much of Europe and many other parts of the world, Wales's upland breeding wader assemblage is in significant decline. In the uplands, afforestation, grazing pressures and predation are the likely key drivers of change.

The catastrophic decline in golden plover and curlew (Figure 1) raise questions about the health of these blanket bog and moor habitats. Golden plover breeding in the Welsh uplands are among the most southerly populations in the global range; this decline may be due to climate change and the loss of synchronicity with invertebrate prey (Pearce-Higgins et al., 2005), or changes in grazing practice and vegetation structure (Johnstone et al., 2017).

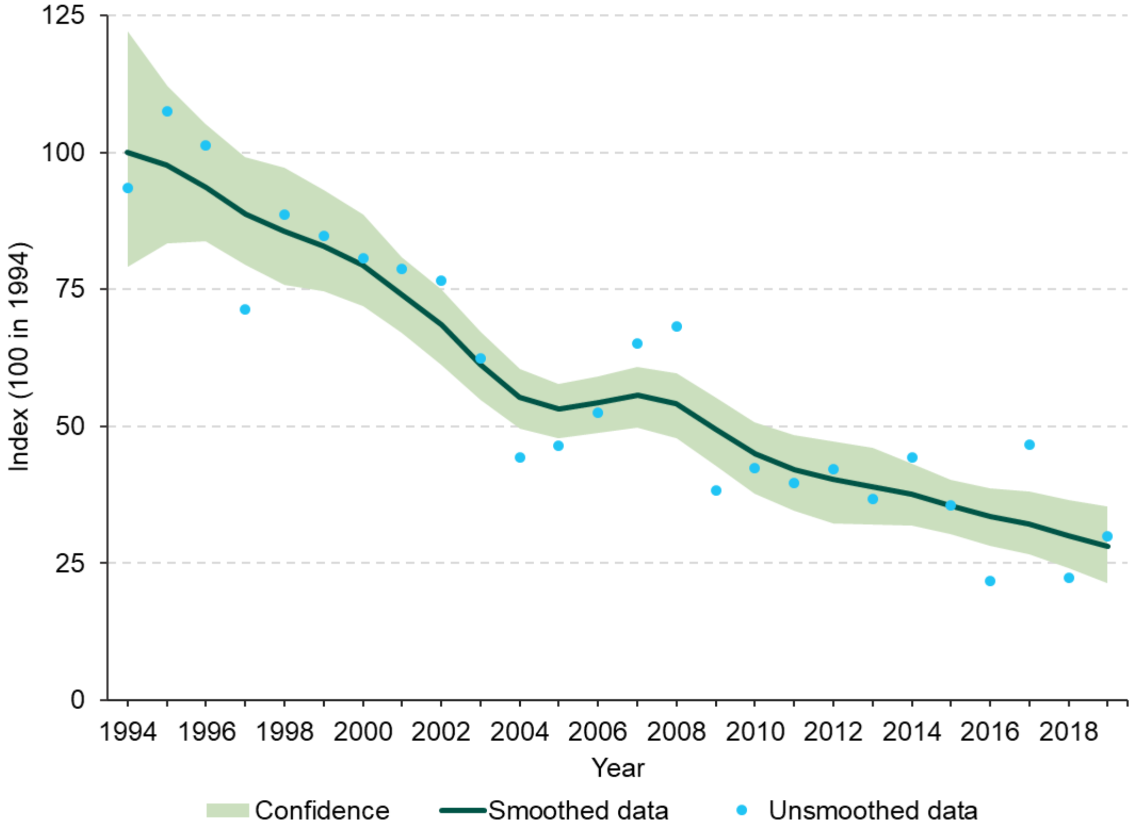

Figure 1 Wales National Breeding Bird Survey Trend Data for Curlews, 1994–2019 (Source: British Trust for Ornithology)

The number of breeding hen harriers in Wales had been slowly recovering since re-colonising in the late 1950s but the latest survey figures show that the population fell by 39% between 2010 and 2016, from 57 to 35 territorial pairs, after earlier increases from 1998 to 2010. Over recent years, poor productivity has been attributed to a combination of poor spring weather, lack of prey availability and changes in land management around some regularly used sites (possibly linked to a lack of prey). There are similar concerns with declining merlin populations, although the drivers for population change are unknown.

To combat these declines, various land-management interventions are used to improve the condition of MMH ecosystems; Table 23 outlines some of these, although it should be noted that there is some overlap and that some positive interventions by may be undertaken by land managers independent of these incentives.

Table 23 Sympathetic management of Mountains, Moorlands and Heaths

Habitat	Area within Glastir (ha)	Area within Section 16 Agreements (ha)	Area within Non-government Organisation Management (ha)
Upland peatlands	50291.28	6146.67	13499.78
Lowland peatlands	2633.75	166.87	502.58
Upland heath	51194.34	6296.29	6920.41
Lowland heath	3559.80	208.69	1023.66
Montane heath	43.03	0.00	56.99
Upland rock habitats	5401.97	136.91	1547.15
All MMH habitats Total	113,124.2	12,955.43	23,550.57

Notes: Data excludes upland grassland, bracken or wood areas.

1. Some s16 agreements (under s16 of the Environment (Wales) Act 2016) are additional to underlying Glastir agreements (such as applying additional obligations).
2. Some eNGO land also benefits from either Glastir or s16 agreements or both.
3. Data does not record incidental sympathetic management by other owners or occupiers

Source: NRW GIS data 2020

Connectivity means the characteristics of the landscape that affect movements of organisms (sometimes described as the relative “permeability” of a habitat to species) and functioning of natural processes. Upland MMH habitats form the largest unfragmented semi-natural landscapes in Wales. However, even here, habitats become fragmented as a result of poor habitat condition; for example, parcels of upland heathland isolated within blocks of acid grassland due to grazing pressures. Ffridd provides connectivity between the uplands and lowlands. Landscape permeability is reduced if the ffridd becomes too uniform, that is, if it becomes bracken dominated, widely afforested or agriculturally improved. Therefore, managing or restoring habitat mosaics is fundamental to connectivity.

Lowland MMH habitats are highly fragmented with poor connectivity. Lowland peatlands often occupy a fragment of their original footprint, and are typically surrounded by intensively managed agricultural land making them vulnerable to drainage and diffuse pollution. Lowland heathlands occur in small patches; for example, mean patch size for dry heath in the coastal zone is 4.3 ha, while in the managed lowlands it is 9.9 ha, compared to 25.7 ha in the uplands (Blackstock et al., 2010). Small patches of habitat suffer disproportionate “edge effects”, further reducing condition and effective area of habitat.

Pressures and Threats

Article 17 (Habitats Directive) reports assess the extent to which a standard suite of existing pressures and future threats affect habitat features (DG Environment, 2017). The recent assessments for Wales identifies 47 pressures affecting Annex 1 MMH habitats (JNCC, 2019).

The main pressures (by number of Annex 1 habitats affected) for all MMH habitats are shown in Table 24.

Table 24 Number of Mountains, Moorlands and Heaths Annex 1 Habitats with High, Medium or Low Impacts from Various Pressures

Pressure	High	Medium	Low	Total
Mixed source air pollution, air-borne pollutants	17	2	0	19
Intensive grazing or overgrazing by livestock	14	0	0	14
Extensive grazing or under grazing by livestock	11	0	0	11
Sports, tourism and leisure activities	4	8	2	14
Problematic native species	6	5	3	14
Other invasive alien species	1	9	3	13
Drought/decreases in precipitation due to climate change	0	5	6	11
Change of either habitat location, size, or quality or all three due to climate change	0	5	4	9
Temperature changes (such as rise of temperature and extremes) due to climate change	0	2	7	9
Conversion into agricultural land or forestry	1	5	2	8
Agricultural activities generating diffuse pollution to surface or ground waters	3	4	1	8
Burning for agriculture	1	3	2	6
Drainage	4	2	0	6

Note: Sources: JNCC. 2019. Article 17 Habitats Directive Report 2019. https://jncc.gov.uk/our-work/article-17-habitats-directive-report-2019/ and associated habitat reports.

Mixed Source Air-pollution

Mixed source air-pollution was assigned a pressure score of 'high' for 18 of the 21 Annex 1 MMH habitats (Table 1) and is the highest ranked pressure across all categories (JNCC, 2019). Nitrogen pollution is the most widespread pressure on MMH habitats, with 95% of bog, 98% of dwarf shrub heath and 100% of montane habitats exceeding their critical load (Rowe et al., 2020), some by a very wide margin. While there has been some improvement in average annual exceedance values (such as total nitrogen load) in all these habitats, the *extent* of the impact shows little change.

Despite projected reductions in the overall deposition loads of reactive nitrogen in the UK, air pollution is expected to remain a high pressure and threat to MMH habitats in Wales. For example, analysis using projected exceedance data to 2030 indicates that the area of blanket bog where deposition is above the relevant critical load will not fall at all from the 2013–2015 estimate (JNCC, 2018).

In peatlands, nitrogen deposition is associated with a reduction in plant species richness, changes to vegetation structure and changes in carbon cycling, which may accelerate carbon loss (Kivimäki et al., 2013). It is estimated that nitrogen will continue to accumulate in peat until at least 2030 (Payne, 2014).

Research on heathlands shows strong evidence of a link between nitrogen deposition, the decline of species diversity and changes to habitat structure and function (Southon et al., 2013) With heavy grazing, nitrogen deposition can result in the spread of grass-dominated vegetation (Alonso et al., 2001). An interaction between grazing pressure and nitrogen deposition (from aerial deposition and animal emissions) on montane habitats results in the decline of key species such as woolly hair moss and grass domination, which attracts further grazing (Van der Waal et al. (2003), Armitage et al. (2005), Britton and Pearce (2004), Britton and Fisher (2007).

An assessment (Hodd, 2018 and 2020) of six north Wales sites supporting liverwort-rich scree slope vegetation (H8110 silicious scree) recorded algal masses ('algal gunk') smothering rare and scarce bryophyte species on 67% of 42 surveyed plots thought to be attributable to nitrogen deposition. Similar accumulations of algae are notable on calcareous lowland flushes across the Anglesey Fens SAC.

Livestock Grazing

Livestock grazing is essential to maintain the structure and floristic composition of many MMH habitats. However, too much or too little – or at the wrong time of year or an unsuitable livestock – cause the decline of habitat structure and composition and increase species-poor vegetation, for example upland acid-grassland or *Molinia*-dominated peatlands. (See also the Land use and soils chapter).

Recent declines in grazing levels in the uplands have initiated the slow recovery of vegetation in some areas (Sherry 2019[a],Sherry 2019[b], Turner 2017, Turner 2020) though many habitats still show impacts of heavy grazing, including the suppression or loss of heathers, the prevalence of grasses and loss of plant species diversity. These impacts may result from continuing high grazing levels, localised over-grazing or the long time-lag between reduction in grazing and recovery of vegetation in the harsh upland environment; modelling suggests that upland vegetation response takes 10–23 years after management change (Emmett et al., 2017).

In the lowlands insufficient grazing is the key problem on both heathland and peatland. On heathlands, it leads to species-poor gorse, bracken and scrub and a negative feedback loop with rank vegetation becoming difficult to graze, resulting in localised over-grazing of open habitat or abandonment. On lowland peatlands, insufficient grazing typically results in scrub invasion and over-dominance of graminoids (grasses, rushes, sedges), particularly *Molinia,* to the detriment of low-growing short-sedges, forbs and bryophytes. On calcareous fens, lack of grazing or mowing can lead to the over-dominance of the great fen sedge. The impacts of under-management are amplified by drainage, groundwater nitrogen enrichment and atmospheric nitrogen deposition (Tomassen et al., 2004). This also impacts on a wide range of invertebrate species, particularly those requiring exposed wet substrate such as southern damselfly.

Precise historical information for habitat change within ffridd is lacking, but analysis of available data (Milsom et al., 2003) clearly show that there has been widespread loss of semi-natural vegetation and net replacement by improved grassland. Another threat appears to be abandonment and reduced management. A study in north Wales (Gritten, 2012) looking at heathland in ffridd found that the condition of dry heath, in particular, appears to be declining with a loss of heather and spread of western gorse. This is likely due to reduced management. Abandonment of grazing land in the south Wales valleys has resulted in rank vegetation, leading to regular uncontrolled fires.

Sports, Tourism and Leisure Activities

Access and recreation pressures have been recorded on heathlands.;Impacts include footpath erosion, vehicle damage, disturbance, especially by dogs, to livestock and breeding birds, and fouling which causes localised soil enrichment. Some of these effects are positive; for example, footpaths can create firebreaks and maintain open ground micro-habitats on heathland, but dogs can discourage graziers. Taylor et al. (2005) found that 25–50% of walkers on lowlands (but only 5–7% on uplands) are accompanied by dogs. Most fouling occurs close to car parks and access points, but the resulting nitrogen and phosphorous enrichment can locally exceed levels of intensive agricultural soils and alter vegetation. Training dog owners to pick up after their pets can help to reduce conflict and the normalisation of “pooper scoopers” should be welcomed.

Impacts on rock-based habitats include footpath erosion across scree fields and localised damage to sensitive cliff and ledge vegetation from climbing and (occasionally) ice climbing (BMC, 2011). Caves have more specific issues which include the impact of increased CO_2 levels associated with respiration on delicate cave formation (Baker and Genty, 1998). Recreational impacts on subterranean fauna are generally poorly understood, but hibernating bats are particularly sensitive to human disturbance.

Problematic Native Species and Other Invasive Species

Problematic native species are largely associated with other pressures, particularly inappropriate grazing, burning, drainage and reactive nitrogen pollution. On peatlands, *Molinia* and scrub invasions are the primary concerns, whilst on heathlands gorse, bracken and scrub invasion are the most significant threats, usually associated with abandonment of traditional grazing.

Significant invasive non-native species (INNS) include rhododendron and some conifers (such as Sitka spruce and western hemlock) on ffridd, upland heathlands and peatlands (see INNS chapter). On rock-based habitats and alpine flush mires, New Zealand willowherb has continued to spread, Himalayan balsam spreads readily on neglected ffridd in parts of south Wales and on lowland peatlands more widely, threatening the integrity of key areas such as Crymlyn bog. Feral goats in parts of north Wales damage existing trees and prevent regeneration.

Climate Change

Climate change in Wales will be characterised by greater unpredictability and variability of weather pattern, including rainfall events. Droughts and floods will become more common, imposing greater stress on ecosystems. A rise in temperature may alter the bio-climatic envelope for many species and their associated habitats, so a rise in the natural tree-line and an influx of more southerly species can be expected. Habitats that are dependent on high or intermittently high water tables are likely to suffer disproportionately. (See also the Climate change chapter)

There is clearly a wide range of potential impacts on MMH habitats as a result of climate change. The inherent variability and complexity of MMH habitats – and the range of potential responses – makes accurate prediction of climate change effects difficult.

A review for Welsh Government (2020) notes the likely effects of climate change on Welsh habitats as:

- a shift in many species further north and to higher altitudes
- warmer springs leading to potential phenological mismatches (flowering times, for example)
- lack of frosts (coupled with unseasonal frosts) with consequent effects on bud dormancy
- changes in the composition of plant communities
- different species responses to changes in precipitation
- vulnerability of individual habitats to climate change such as montane;
- increased risk of spread of Invasive Non Native Species (INNS)

Direct impacts include summer drought on peatlands and heathlands. These impacts are likely to be most significant on soils which are prone to desiccation, such as thin peats (on wet heath and *Rhynchospora* depressions) and skeletal mineral soils (dry heath and juniper heath), and a more general decline in soil organic matter as wetness declines. Habitats which are in poor condition as a result of other pressures, such as drained and degraded bogs, are also likely to be sensitive to drought.

Montane and alpine habitats are most susceptible to high temperatures as their bioclimatic envelope diminishes. However, other pressures, notably grazing and nitrogen deposition are currently considered more significant in reducing the resilience of these habitats to the impact of climate change. Climate change will become an increasing threat with wetter, warmer winters, more surface run-off and erosion, and impacts on arctic-alpine species of the high summits (Natural England, 2013).

Climate change can also have indirect effects, such as uncontrolled damaging wildfires on moorland vegetation in dry periods, as seen in the case of Llantysilio mountain in 2018 (Longdon, 2019).

Habitats that are already under stress through sub-optimal management are more likely to suffer detrimental impacts from climate change (Welsh Government, 2020). A key action for many of the Section 7 Habitats is that of maintaining the quantity and quality of water. This is particularly applicable to groundwater dependent terrestrial ecosystems (GWDTE) which rely on a seasonally high water table, such as wet woodland, lowland fen, purple moor-grass and rush pasture and reedbeds.

The Welsh Government review notes:

> *"it is likely to be of greater benefit to Wales' biodiversity to address existing land management issues before tackling issues of climate change. Appropriate grazing is of particular relevance to these habitats. Tackling these issues first will not only provide great overall benefit to these habitats, it will also make them much more resilient to the effects of climate change".* (Welsh Government, 2020).

Conversion to Agricultural Land or Forestry

This pressure refers primarily to the legacy impact of past conversion of lowland raised bog and fen habitats to agricultural land which continues to impact the remaining peat body. However, the last Article 17 report also recorded three cases of agricultural intensification on alkaline fen, contrary to EIA (Agriculture) (Wales) Regulations 2017. Peatland under such improved pasture or cultivation emits extraordinary levels of greenhouse gases (Evans et al., 2017). (See also the Enclosed farmland chapter and Land use and soils chapter).

Continuing loss of small fragments of lowland heathland occurs; for example, there is anecdotal evidence on Anglesey of habitat fragments on rocky hummocks within improved fields being converted to agricultural grassland by targeted stock feeding.

Woodland was historically present in the mountain landscape but the natural tree-line (about 600m Above Ordnance Datum) is now virtually absent. Experiments such as Cwm Idwal NNR stock-exclusion demonstrate that recovery is possible, but slow (Turner, 2017).

In the uplands, afforestation historically occurred on blanket bog, with an estimate of nearly 7,000 hectares of conifer planting since the Second World War. Though the UK Forestry Standard does not support planting on deep peat, planting may still occur on shallow peat (<50cm) and wet heath where questions remain about the carbon benefits of planting on organic soils (Friggens, 2020). A net increase in the area of blanket bog habitat (Emmett et al., 2017) is likely due to the removal of conifers from blanket peat. NRW's Afforested Peat Programme has removed plantation from 689 ha of afforested peat, with another 197 ha in progress and 1,162 ha planned. However, whether this achieves restoration (in the sense that peatland structures and functions are restored) has yet to be verified.

Welsh Government has adopted a policy of ensuring "all peatlands with semi-natural vegetation are subject to favourable management/restoration and to restore a minimum of 25% (circa. 5,000 ha) of the most modified areas of peatland (such as those currently under conifer/improved grassland) to functional peatland ecosystems (Welsh Government, 2019a) and the Peatland Action Programme (Natural Resources Wales, 2020) will implement this policy.

Self-seeding conifers from plantations is a continuing threat to upland heath and peatlands (such as Berwyn, Migneint, Cadair Idris) and requires regular intervention. While trees and woodlands are a natural component of the mountain environment, there are differing views as to what this might comprise in a restored landscape; from scattered scrub through wood-pasture to solid canopy. The National Forest Inventory definition of woodland as ≥20% canopy (or the potential to achieve this) encompasses a broad range of woodland and wood-pasture and may enable a naturally regenerating native woodland to be regarded as an integral component of this ecosystem. (See also the Woodlands chapter).

Diffuse (Surface and Groundwater) Pollution

Excess inorganic nitrogen in groundwater is an issue on all lowland peatlands (groundwater dependent terrestrial ecosystems). The impacts of diffuse (groundwater) pollution are similar to those from aerial deposition: increased growth of aggressive species, particularly grasses such as purple moor grass *Molinia* or common reed *Phragmites* which smother more delicate species, and increased susceptibility of some species to physical damage or frost. The usual source of diffuse pollution is agricultural run-off, particularly where peatlands are surrounded by intensively managed farmland. (See also the Freshwater and Enclosed farmland chapters).

Burning

Heather and grass burning is a traditional heathland management tool both to improve livestock grazing and to provide habitat for game birds, particularly red grouse. Conservation organisations sometimes burn for habitat and species management, though cutting is often preferred. The impacts of burning on MMH habitats are complex, with both positive and negative outcomes depending on the objective.

The debate on burning has become highly polarised in recent years. Davies et al. (2016) suggested that there has been a shift in public opinion against fire, without sufficient understanding of the science. A review of burning (Harper et al., 2018) found fire to have complex, varied impacts on a range of ecosystem services. Fire has the potential to affect the physicochemical and ecological status of water systems, alter several aspects of the carbon cycle (such as above- and below-ground carbon storage), and trigger changes in vegetation type and structure. Harper et al. suggest that water supply catchments risk water quality impacts from fire and that prescribed burning over inappropriate timescales reduces faunal and floral diversity.

There is a policy presumption against burning blanket bog, which damages the *Sphagnum* moss component essential for its function and growth. While perception of increasing fuel loads on drier habitat or on drained blanket bog has led to calls for more regular controlled burns to avoid catastrophic wildfire, other evidence (Glaves et al., 2020) suggest that fuel load or firebreak management may have limited benefit. Fires follow people and this is where fire prevention efforts should be focussed.

Drainage

Drainage and related activities remain as either high or medium priority pressures and threats for eight of the nine peatland and related Annex 1 types (JNCC, 2019), with agricultural drainage cited for the six priority habitats most closely associated with deep peat deposits (Table 1). Impacts are the result of both past drainage activity, such as internal drainage channels, and current drainage activity, which largely refers to the management of marginal drains where peatlands abut agricultural land.

An estimated total length of open drainage channels of 1,512 km remains across the Welsh peatland landscape (Williamson et al., 2019). This poses significant adverse impacts on floristic quality and hence peatland feature condition. Furthermore, a study of the drained Migneint peatlands (Migneint-Arenig-Dduallt SAC, north Wales) suggests that drainage may have resulted in the loss of 3t CO_2-e yr^{-1} /ha (Tonnes of CO2-equivalent GHG per year per hectare) (Williamson et al., 2017). Assuming that this estimate can be scaled up to all drained peatlands, and that drainage exerts an effect 10 meters either side of a ditch, this would result in a total carbon loss estimate of 9,073 t CO_2-e yr^{-1} for the remaining drained resource. The current open drainage channels have marginal agricultural benefit and result in frequent loss of livestock in ditches. The effects of this past drainage will be accentuated by climate change since the hydrological resilience on these areas is compromised.

4. Assessment of Resilience (Aim 2)

This assessment of resilience is split between key elements of this expansive ecosystem. Table 25 provides an analysis of the component attributes of resilience for these elements, with more general perspectives provided below. This assessment is heavily based on evidence submitted for the 2018 Article 17 report (JNCC, 2019).

Diversity

Overall, the diversity of habitats in the Welsh uplands is higher than in the lowlands (Blackstock et al., 2010). This reflects the high cover of semi-natural habitat in the uplands and predominance of improved pasture in the lowlands. But these scores only give a relative impression of diversity; the reality is that many upland landscapes are dominated by large, often rather species-poor and relatively homogeneous semi-natural vegetation, reflecting the influence of a range of long-standing environmental and land management pressures. In contrast, lowland heathland and peatland habitats often have high inherent species diversity. Ffridd is often composed of distinctive habitat mosaics and provides unique structural and vegetation diversity not found elsewhere in the Welsh landscape.

Extent

Information on extent is based largely on the Habitat Survey of Wales (Blackstock et al., 2010), with limited information available on earlier losses leading up to the survey and changes since the survey. It is significant that MMH habitats occupy circa 218,080 ha of the total upland area of 401,500 ha recorded by Blackstock et al. (2010). Acid grassland accounts for 113,200 ha of the remainder (see Semi-natural grasslands chapter), some of which could be restored to heathland and blanket bog. Conifer plantations occupy 43,700 ha in the uplands, with nearly 6,900 ha on deep peat (Evans et al*.,* 2015) though nearly 900 ha of this will have been cleared to restore peatland with a further 1,162 ha programmed for restoration (Chamberlain, 2020 pers. com.). A large proportion of the resource of several priority habitats is found in the ffridd, in particular, lowland dry acid heath, lowland wet heath, lowland marshy grassland, lowland acid grassland and upland oakwood (Blackstock et al., 2010).

Condition

The collated results of 2018 Article 17 assessment for the 21 Annex 1 habitats falling within MMH (JNCC, 2019) suggest that only 2,997 ha (1.9%) of the resource of these habitats is in good condition and achieving its conservation objectives, with 44,783 ha (30%) in 'not good' condition, and the remainder of 102,719 ha (68%) in unknown condition (Figure 2).

Monitoring undertaken by the Glastir Monitoring and Evaluation Programme (GMEP) shows no overall change in either habitat condition or plant species richness for MMH between 1990 and 2013–16 but a significant increase in both metrics between 2007 and 2013–16. Maskell et al. (2019) suggests that, despite long-term decline, a corner may have been turned in the latter period.

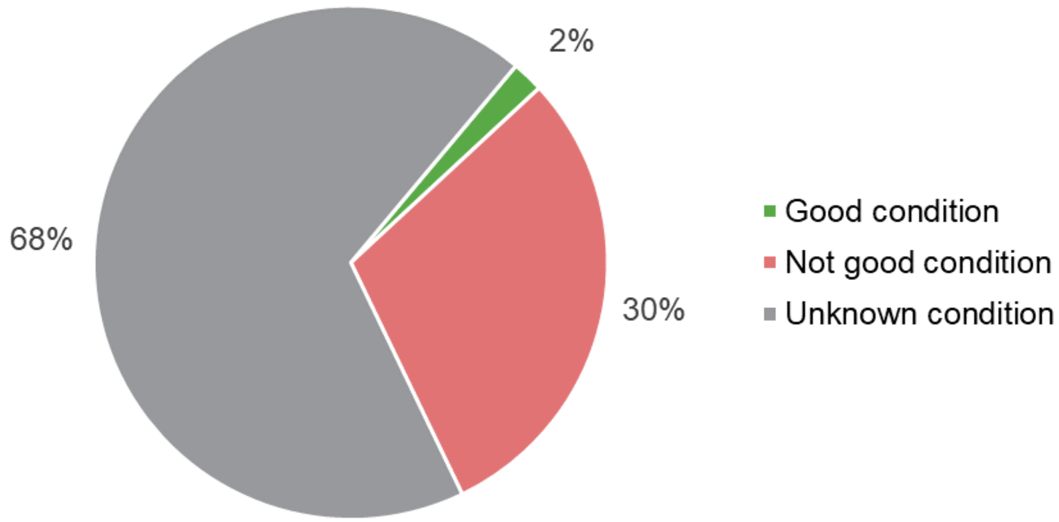

Figure 2 The collated results of 2018 Article 17 assessment for the 21 Annex 1 habitats falling within MMH (Source: JNCC, 2019)

Connectivity

Connectivity has been assessed qualitatively, although Latham et al. (2013) have provided tools for a more detailed assessment of the connectivity of broad habitats within a particular landscape. As extensive blocks of semi-natural habitat, the uplands might appear to have good connectivity, but for its component habitats, due to their unfavourable condition or intervening unfavourable habitats, this is not always the case. Lowland MMH habitats have very poor connectivity; in semi-natural peatlands this can be gauged by the area of habitat occupying the peat footprint. Peatland habitats occupy only 55.4% of the total peat soil area overall; based on the Unified Peat Map (Evans et al., 2015). The difference between lowland (30.6%) and upland (63.7%) peatlands reflects extensive loss, modification and fragmentation of lowland peatlands. Many peatlands are associated with drainage pathways and therefore benefit by connection via freshwater habitats.

Habitats that have become increasingly rare and fragmented in the lowlands remain at higher cover and larger blocks in the ffridd (Blackstock et al., 2010). Networks produced to examine ecological connectivity in the landscape (Watt et al., 2005; Latham et al., 2008) show that there is a correlation between high connectivity and ffridd. Ffridd provides connections both between upland and lowland habitat patches and also, as a continuous band below the uplands, creating an ecological sequence between the lowlands and uplands.

This assessment of resilience differs from that in SoNaRR2016, which presented a more positive picture for mountains, moorlands and heaths as a whole, based on the extensive cover of semi-natural habitats in the uplands. Cconsideration of resilience at the scale of the ‘functional’ suite of habitats employed for Table 25 reveals a more nuanced assessment.

This assessment suggests that the resilience of Welsh mountain, moorland and heath (including peatland) ecosystems is generally quite poor, with significant intervention needed across all four resilience attributes (in suggested rank order these would be: condition, extent, connectivity and diversity). There are significant gaps in the supporting evidence base for this assessment, most notably a lack of recent information on habitat condition and trends in condition and extent. Ecosystem diversity is arguably the least well understood of the four attributes, particularly with respect to mountain, moorland and heath habitats where large tracts of relatively homogenous and species-poor vegetation may meet standard current definitions of good condition.

Table 25 Ecosystem Resilience Assessment: Attributes of resilience of each mountains, moorlands and heaths habitat unit

Practical habitat	Diversity	Extent	Condition	Connectivity
Upland peatlands (blanket bog, upland topogenous fen and upland soligenous fen)	Low – the range of morphological and ecological variation has been impacted by past management, with certain key elements (such as hummock/hollow systems) less well represented than they should be.	Medium – historic losses have occurred to forestry (and replanting on deep peat), with more recent losses to wind-energy generation and suspected losses due to agricultural improvement. There is some evidence of recent increases in area due to plantation removal. Blanket bog 54,500 ha. Fen and flush 14,300 ha.	Low – Article 17 reporting concluded only unknown or poor condition for the Welsh blanket bog resource, with significant areas of degraded bog and species-poor fen and flush.	Medium – upland peatlands are the most interconnected of the peatland resource, primarily due to extensive development of blanket bog. However, of the upland peat resource based on the Unified Peat Map (67,695 ha), only 43,156 ha (63.8%) is mapped as bog, fen and flush, indicating a significant cover of non-peat-forming habitats on deep peat and thus, potential for large-scale improvements in connectivity.

Practical habitat	Diversity	Extent	Condition	Connectivity
Lowland peatlands (including raised bog, lowland topogenous fen and lowland soligenous fen)	Medium – our lowland peatlands exhibit a wide range of NVC plant communities and sub-communities, some very species-rich, but significant functional and vegetation elements are absent – such as bog pools and lag fen systems.	Low – 10,100ha Short and long-term trend magnitudes are generally unknown based on Article 17 evidence, but historic and piecemeal ongoing loss are key issues. Many sites are now much diminished, with an average lowland wetland site size of just 3.1 ha, with only 18.3% of sites > 10 ha and 1.2% (7 sites) > 100 ha based on the 1977–1982 Wales Wetland Survey of 584 sites (Ratcliffe and Hattey, 1982).	Low – the proportion of the Annex 1 peatland habitat resource (minus blanket bog to give an approximate figure for lowland peatlands) in unknown or poor condition is 87.5%.	Low – poor connectivity between habitat blocks (Latham et al., 2013) – which partly reflects inherent isolation due to the location of water supply mechanisms and topography, but also widespread historic loss of lowland wetland habitats. For example, semi-natural habitat (including peatlands) account for just 17% of our inland flood plain area (Jones et al., 2009).

Practical habitat	Diversity	Extent	Condition	Connectivity
Upland heathland	Medium – while many upland heathland sites exhibit limited floristic and structural diversity as a result of past management, the more atlantic heaths are typically species-rich and support a rich bryophyte flora.	High – despite historic declines, dwarf shrub heath accounts for a variable, but often significant proportion of the 6-upland habitat biogeographical groupings defined by Yeo and Blackstock (2002), with figures ranging from 9% for the Southern Uplands to 48% for the Western Hills.	Medium – the condition of the Annex 1 resource at a SAC level is poor but masks the variability within large upland sites with some units supporting heath in favourable condition. GMEP monitoring indicates recent improvements for MMH as a whole, of which dry dwarf shrub heath is the single largest component.	Medium – this is one of the most extensive of our upland habitats and is often relatively well interconnected, though links between lowland and upland stands are often lacking. Grass/heath mosaics make up 26% of the total dwarf shrub heath resource, indicating significant potential for enhancing connectivity between heathland blocks.

Practical habitat	Diversity	Extent	Condition	Connectivity
Lowland heathland	Medium – coastal dry and wet heaths support the most diversity both in species composition and structure. Many of the inland heaths and heathland within the ffridd are more impoverished.	Low – the lowland heathland resource is small with the largest areas being found along the coast and in the ffridd.	Low – a high proportion of the resource is in poor condition, often undergrazed, with some local improvements particularly on the coast	Low – lowland heathlands are highly fragmented and survive in unconnected parcels. Lowland heathland connectivity in the coastal zone is limited on the landward side by intensively managed agricultural land.
Alpine and boreal heath and grassland	Low – many Welsh stands are impoverished in terms of both the expected complement of species and structural diversity, mainly due to reactive nitrogen deposition and overgrazing .	Medium – alpine and boreal habitat extent is estimated at 100 ha with the grassland area significantly larger than the heath. While extent of the habitats is limited by substrate, climate and altitude, there has been loss of extent as a result of pollution, grazing pressure and erosion.	Low – the condition of the Annex 1 resource overwhelmingly (99.2%) poor or unknown due to reactive nitrogen deposition, overgrazing and the possible effects of climate change.	Low – montane habitats are inevitably tightly restricted to bioclimatic envelope, but further constrained by pollution and over-grazed acid grassland and scree/boulder fields.

Practical habitat	Diversity	Extent	Condition	Connectivity
Upland rock habitats	Medium – the Annex 1 inland rock habitats within the SACs have high species diversity, particularly the ungrazed ledges (hydrophilous tall herb vegetation). Scree habitats can have a rich bryophyte flora and specialised fauna but few higher plants. Habitats with heavy grazing tend to have poor species and structural diversity.	Medium – around 9,900 ha of rock habitat is recorded in the uplands. The extent of the rock substrate is largely unchanging at a broad scale but the area of Annex 1 habitat is, to some extent, limited by past and current management practices.	Medium – condition within the Annex 1 resource is fair, but is variable between sites and largely determined by grazing regimes.	Medium – the occurrence of the rock substrate, which supports the various habitats, is governed by geological and geomorphological processes and connectivity; therefore, it is not relevant. However, connectivity of the Annex 1 habitats is influenced by management and there are opportunities to improve connectivity by improving condition.

Practical habitat	Diversity	Extent	Condition	Connectivity
Wider upland matrix (for example bracken, semi-natural grasslands)	Low – large areas of relatively uniform habitat with poor structural and species diversity are seen. Associated species of interest, particularly upland birds, such as wheatear and chough foraging on dry grassland; snipe, curlew and other waders on rush and *Molinia* grassland; stonechat and whinchat on bracken.	High – semi-natural grasslands (including upland acid grassland – see Semi-natural grasslands chapter) cover over 140,000 ha and continuous bracken around 3600 ha.	Low – no monitoring data available but the habitat is known to occur in large uniform blocks lacking structural heterogeneity. Species which use these habitats, such as stonechat, prefer a more varied mosaic of grassland, bracken for example.	Medium – very large areas but poor condition limits connectivity.

5. Healthy Places for People (Aim 3)

The MMH ecosystem supports the largest areas of semi-natural terrestrial habitats and landscapes in Wales. In addition to the provision of food and fibre, the uplands are crucial in supplying clean drinking water, sequestering carbon and providing renewable energy. MMH landscapes have huge cultural and heritage value, are key areas for access and recreation and play important roles in physical, mental and spiritual well-being.

The regulating and cultural ecosystem services for well-being provided by mountains, moorlands and heaths are outlined in Table 26 and Table 27 below and are developed from the set of services and definitions of the UK NEA Conceptual Framework (UK NEA, 2011). The Wales assessment is our current interpretation based on expert opinion.

Table 26 Relative importance of regulating ecosystem services delivered by Welsh MMH

Regulating services	Level of importance
Climate – carbon sequestration	High
Hazard – flood regulation	High
Disease and pests	Low
Pollination	Medium-high
Noise	Low
Water quality	High
Soil quality	High
Air quality	Medium
Waste breakdown and detoxification	Not provided

Note: This table is adapted from that in UKNEA Chapter 11 (Jones et al., 2011)

Table 27 Relative importance of cultural ecosystem services delivered by MMH

Cultural services	Level of importance
Environment settings: local places	High
Environment settings: landscape	High
Environment settings: religious, spiritual, cultural heritage, media	Medium
Environment settings: aesthetic, inspirational	High
Environment settings: enfranchisement and neighbourhood development	Medium
Environmental settings: recreation/tourism	High
Environmental settings: Physical/mental health and security and freedom	High
Environmental settings: Education/ecological knowledge	High

Note: This table is adapted from UKNEA, Chapter 11 (Jones et al., 2011)

MMH has a critical role in protecting people from environmental risk. Indeed, because the Welsh uplands encompass the head waters of river catchments such as the Dee, Severn and Wye, this role extends beyond Wales into the English lowlands. The floods of early 2020 demonstrated the impact of run-off from the Welsh uplands on communities in south Wales and the West Midlands. More intense rainfall as the climate changes also increases the challenge of soil erosion and run-off, creates greater instability on slopes and leads to more widespread and frequent landslides.

Water Quality and Flow Regulation

The uplands have a crucial role in regulating the quality and quantity of water reaching lowland river systems. MMH habitats, particularly on peat and organic soils, retain large amounts of surface water, slowing discharge and regulating flow; damage leads to more rapid run-off.

Restoring peatlands and increasing vegetation density contributes to natural flood management and improvements in water quality by increasing surface roughness, infiltration and the time for water to flow across the catchment. Revegetating eroded peat attenuates run-off and reduces peak flows. These effects are roughly doubled if gulley blocking is also undertaken (Shuttleworth et al., 2018).

Restoration of eroding peat reduces particulate loss (Shuttleworth et al., 2015) and dissolved organic carbon (Artz et al., 2019). Peat erosion in Wales is modest, with the total extent of exposed peat estimated at <100 ha across 180 sites (NRW, 2016) and the wider area of peatland affected by erosion estimated at between 225 ha (Evans et al., 2017) and 542 ha (NRW, 2016).

In a Welsh context, the repair of drained peatlands is probably more pressing; ditch mapping across the Welsh peat resource suggests that there are at least 1,500 km of open ditches still to be blocked. Restoration work has revegetated an estimated 1000 ha of peatland in Wales (Williamson, 2017).

Lowland peatlands also have flow regulation functions, in some cases, as source areas and for flood allieviation on flood plains.

Climate Change – Carbon Storage and Sequestration

Peatlands play a vital role in climate regulation through carbon storage and sequestration, occupying around 4% of the land mass in Wales but storing between 30 and 15% of the carbon, depending on evidence source (ECOSSE, 2007; Williamson et. al., 2019). However, due to habitat damage (drainage, afforestation, overgrazing), Welsh peatlands (including areas converted to other land cover types) currently release around 500 kt CO_2-equivalent (CO_2eq) every year (Evans et. al., 2017). The highest emissions come from those areas of peat converted to intensive grassland. Near-natural bog is a small GHG sink but crucially a huge carbon store and net carbon sink. While forests can be important in sequestering carbon, peatlands must retain their existing role in storing carbon; getting the balance right is challenging (Crane 2020; Alison et al., 2019). In order to retain these carbon stocks, reduce emissions and restore their carbon-sequestering function it is necessary to restore peatlands to favourable condition.

Most peatland restoration efforts to date are regarded as achieving biodiversity improvements, which has been the general motivation for restoration. Few restoration projects have been subject to before and after measurements of carbon flux. Published emissions factors (Evans et al., 2017) suggest that rewetted bog has significantly lower emissions, in terms of CO_2eq, than its modified precursors. Peatland restoration also has potential to contribute to natural flood risk management and also to reduce water treatment costs.

Afforestation on peatland, and deforestation without functional peatland restoration, are very risky for soil organic carbon (SOC) . Following afforestation, increases in carbon stored above ground are likely for the growing period of the timber crop.This may not balance carbon losses from the peat which now greatly exceed the losses of SOC and CO_2eq from unafforested peatlands. Any carbon benefit would also depend on timber end-use and whether it continues to store carbon for long after harvesting. On deep peats, defined as a peat layer more than 50 cm, current guidance (UK Forestry Standard) does not allow new forest establishment. But at the time of writing re-planting on deep peat is not prohibited.

In the last decade, considerable work has been undertaken to block peatland drains and restore hydrological processes. It is estimated that 771 km of ditches have been blocked in Wales, with a predicted GHG emissions reduction of 6,030 t CO_2-eq (Williamson et al., 2019).

On upland heath, heather (*Calluna*) dominated heathlands sequester twice as much atmospheric carbon as grass-dominated heathland communities, with potential rates of carbon sequestration comparable to those of woodland (Quin et al., 2015). This is reflected in higher soil carbon stocks in heathland (including areas restored from former graminoid dominance), and larger stocks of recalcitrant (stable) carbon (Quin et al., 2014). Restoring *Calluna* dominance from grass dominated precursors is technically feasible (Mitchell et al., 2008) and there is huge scope for this activity with circa19,300 ha of dry heath/acid grassland mosaic recorded in Wales (Blackstock et al., 2010). *Calluna* restoration could be funded by Capital Works options under Glastir Advanced (Welsh Government, 2019b).

Increasing woodland cover within the MMH ecosystem requires attention to such detail; the right tree in the right place. While young plantations sequester carbon rapidly, there is often a greater and deeper carbon-store in old broadleaf woodland (Xiong et al., 2020), so much depends on the fate of harvested timber in calculating the carbon benefit. There is also evidence that although trees grow faster with elevated CO_2 levels, they also age faster (Brienin et al., 2020), further complicating the model of woodland carbon benefits.

Pollination

The importance of MMH for pollination is poorly documented compared to flower-rich habitats such as semi-natural lowland grasslands. Habitats with a high proportion of heathers provide a nectar source for pollinators over a long season. Heathlands have long been an important resource for beekeepers and ‘heather honey’ has twice the value of other domestic honeys (UKNEA 2011). Recent research into the antiparasitic effects of nectar plants against the bumblebee pathogen *Crithidia bombi* found heather the most bioactive species tested, suggesting the importance of heathlands in the provision of this natural bee ‘‘medicine’’ to combat pollinator declines (Koch et al 2019).

Cultural Ecosystem Services

In 1911, Augustus John, the most important post-impressionist artist of his age, established, with James Dickson Innes, the Arenig School of Painters. He spent two years in the wild mountainous landscape producing a vast body of work capturing the Arenig Fawr massif in every light and at every season. Over the centuries the mountains, moorlands and heaths of Wales have inspired artists, historians, poets, scientists and explorers. Today, ever more people enjoy these landscapes, engaging in a range of artistic, educational, cultural and sporting activities.

Almost all the land area included within the MMH ecosystem is Open Access as defined by the Countryside and Rights of Way Act 2000 (CRoW Act). The ecosystem is therefore of paramount importance as a recreational resource, particularly for energetic outdoor activities such as hill walking, fell running, climbing and mountain biking. The two most popular mountain areas, Snowdonia and the Brecon Beacons, attracted 4.27 and 4.15 million visitors per year respectively (Arup 2013). Visitors to the three National Parks spend over £1 billion annually on goods and services, supporting the local economy and providing local employment.

The cultural and historical significance of the Welsh MMH resource is enormous. Less intensive agriculture and the absence of tillage at higher altitudes leaves an extensive archaeological resource from pre-Mesolithic to present times (Browne and Hughes, 2003). In peatlands, past land-use has left a rich heritage of ground-based and documentary evidence, with over 930 peat cutting and possible peat cutting locations recorded, and a further 517 records for other physical remains, including peat stacks and peat stands (RCHAMW, 2019). Peatlands play a unique role in preserving archaeological remains and recording the development of the landscape and the influence of humans (Hughes, 2010).

The first poem (actually an englyn, a traditional Welsh or Cornish short poem form) composed at the age of 11 by the famous poet Hedd Wyn (Ellis Humphrey Evans, 1887–1917) is called ‘Y Das Fawn’ (The Peat Stack) (Llwyd, ed., 1994) and reflects the local importance of peat cutting in Trawsfynydd (Gwynedd), his birthplace. The Cyfoeth ein Corsydd project run by the Snowdonia National Park (2017–2019) celebrated the cultural significance of peatlands to rural communities with a travelling exhibition pack. Contemporary poetry reflects the ongoing strong cultural and spiritual inspiration provided by Welsh peatlands (such as Rhys, 2007).

6. Economy (Aim 4)

The provisioning services described in Table 28, along with the regulatory services (Table 26) and cultural services (Table 27), make a significant contribution to the economy of Wales. However, it is clear that these services are not optimised and there is conflict between land management for different purposes resulting in inefficient use of resources.

Table 28 Relative importance of provisioning ecosystem services delivered by Welsh MMH

Provisioning services	Level of importance
Crops	Not applicable
Livestock and aquaculture	Medium
Fish (for example salmon, trout)	Medium
Trees, standing veg, peat	Medium
Water supply	High
Wild species diversity	High

Note: This table is adapted from UKNEA, Chapter 11 (Jones et al., 2011)

Livestock and Agriculture

Agriculture in the uplands typically consists of extensive sheep grazing, and to a lesser extent, cattle for lamb and beef. There has been a general reduction in livestock numbers in upland areas since the late 1990s (Silcock et al., 2012) from the extraordinary livestock numbers of 11.8million sheep present at that time. Clark et al. (2019) suggest that further reduction in stock levels to natural carrying capacity, and associated reduction in variable costs, can increase profitability whilst improving other upland ecosystem function and services. MMH habitats in the lowlands are also used for rough grazing, but there has been a much greater decline in livestock production with abandonment in some areas. The harvesting of excess herbage (sedge, heather and gorse) from these habitats can provide low-cost animal bedding, reducing straw imports and transport costs (PONT, 2017) (see Land use and solis chapter).

Fish

Upland rivers and streams provide important spawning and nursery habitat for salmon *Salmo salar* and trout *Salmo trutta*. Management of MMH habitats can have a profound impact on fish populations by affecting water quality and structural heterogeneity of riparian vegetation; for example, moorland burning can increase fine particulate organic matter suspended sediment concentration, aluminium, iron and dissolved organic carbon (Ramchundar et. al., 2013). This impacts on aquatic invertebrate populations (stoneflies and mayflies), which are important food sources for salmonids. Riparian broadleaf woodland may reduce water temperatures, provide in-stream woody material and improve channel morphology (Broadmeadow et al., 2011), delivering improved provisioning (fisheries) and regulatory (flood) services (see also freshwater chapter).

Forestry

The role of woodland, wood-pasture and scattered native trees in the upland fringe and ffridd landscape is recognised, particularly where this reflects the natural altitudinal treeline. There are synergies to be had from judicious use of shelter belts, hedges, scattered trees and riparian woodlands (of appropriate species) for animal husbandry, improved infiltration, reducing and delaying flood peaks, reducing water temperatures, providing in-stream woody material and diversifying channel morphology (Marshall, 2014; Ford et al., 2016; Broadmeadow et al., 2011).

Past upland afforestation continues to compromise the function of some areas of deep peat and by the spread of conifer propagules into sensitive habitats. An assessment has been carried out and the “Top 10” afforested deep peat sites have been identified on the basis of greatest potential for a range of ecosystem service delivery and these are a high priority for open habitat restoration.

Areas of dense bracken cover 32,600 ha in the uplands and 30,100 ha in the lowlands (Blackstock et al., 2010). These often provide habitat for woodland understorey species such as wood sorrel and bluebell; on relatively good mineral soil, they offer opportunities for woodland expansion to connect woodland habitat fragments. Choices will need to be made between forestry plantation to deliver softwood production (and limited biodiversity value), agroforestry intervention for shelter, soil protection and landscape, and native woodland expansion, by natural or assisted regeneration for carbon storage, biodiversity, water resource management, landscape and tourism (see Woodlands chapter).

Drinking Water

Over 75% of the UK’s drinking water is sourced from MMH ecosystems (NEA, 2011); around 93% of the water supplied to consumers in Wales originates from surface water or abstracted from rivers with large upland catchments (Dee, Usk, Severn, Tywy and Wye). These are impacted by flood, drought, dissolved and particulate organic matter and pathogenic agents such as *Cryptosporidium* (DWI, 2016). Both the quantity and quality of supply depends on catchment management, therefore water-holding capacity of peat and roughness and hydrological behaviour of vegetation are important factors in optimising societal benefits. Peatland restoration offers a potentially cheaper and more sustainable option to improve the quality of raw water arising from peaty catchments, avoiding costly treatments and the use of chemicals. (See Freshwater chapter and Water efficiency chapter).

7. Synergies and Trade-offs

Given the variety of land management activities and interest groups within the mountain, moorlands and heaths ecosystem, it is unsurprising that there are benefits, costs, synergies and trade-offs (Table 29) that are relevant to the management of this ecosystem.

Table 29 Synergies and Trade-offs for Welsh MMH Habitats.

Management options or activities	Synergy	Trade-off
Blanket bog restoration Grip/ditch blocking (hydrological restoration)	Restores hydrological processes. Carbon storage/sequestration. Grip blocking in upland blanket bog appears to result in reduced losses of livestock through entrapment in grips, with losses dropping from an average of 0.18 corpses/km to 0.03/km after grip blocking. No increase in tick or liver fluke following drain blocking at Lake Vyrnwy (Berwyn SAC) (RSPB, 2011). Increases in *Tipulid* (cranefly) abundance observed following grip blocking is expected to support increases in populations of curlew and golden plover of conservation and economic interest (Carroll et al., 2011).	On some sites ditches are used by water voles; grip blocking therefore results in a loss of habitat. Increased methane (GHG) emissions for a period in some circumstances.

Management options or activities	Synergy	Trade-off
Forestry, tree planting and natural regeneration	Provision of timber. Shelter for livestock. Stabilisation of hill-slopes. Restoration of natural treeline and riparian woodlands to restore structure and function; cool waters improve fish habitat. Diversification of bracken monocultures and defragmentation of native woodlands.	May reduce and fragment the area of other semi-natural habitat. Can impact on hydrological processes and carbon storage of peatland. Can aggravate acidification and sedimentation of catchments. Provides seed for further conifer invasion of MMH (especially heathland and bog). Release of soil carbon due to disturbance and drying.
Agriculture and land management	Appropriate agricultural management is essential for the maintenance of good ecological status for many MMH habitats. Wetlands provide forage, especially during drought. Food and fibre production. Land management for specific species for conservation or sport. Lower intensity farming may be more profitable if variable costs (such as fertiliser, feed) are lowered while improving other ecosystem functions and services. Biomass harvesting can reduce farm bedding costs.	Optimal management for biodiversity *may* decrease economic returns for agriculture and *may* not be economically viable without subsidies. Moorland burning may have impacts on aquatic systems and can reduce carbon storage and raw water quality. Intensive agriculture (improved pasture) on peatland emits very high levels of greenhouse gases.

Management options or activities	Synergy	Trade-off
Energy	Opportunities for low-carbon renewable energy development. such as windfarms and hydroelectric. Increased surface roughness could extend run-off and generation time. Timber firewood displaces fossil fuels.	Damage to peatlands by infrastucture can outweigh the carbon benefits of renewable energy. Impacts of windfarms on upland bird and bat populations. Rapid run-off from bare hillsides may limit the period of hydroelectric generation.
Recreation and tourism	Well-being benefits (health, spirit, culture). Important for rural economy and employment. Provides opportunity to educate people about the MMH environment. Inspires people to support/get involved with conservation efforts.	Direct damage to habitats such as loss of vegetation through footpath erosion, or nest disturbance for example. Indirect impacts such as loss of grazing on sites with high visitor pressure. Loss of “wilderness” value if areas are over-used.
Management for specific species	Many species once widespread in the lowlands are now largely confined to the uplands and upland margins as a result of agricultural intensification in the lowlands. Some species such as breeding curlew and black grouse have undergone such dramatic declines that, unless they are protected in the uplands/ffridd in the short to medium term, it is unlikely that they will survive in the long term.	Intensive management for species can be at odds with requirements for habitat restoration; for example, cutting and burning management for red grouse in the uplands may undermine blanket bog recovery. Management for specific species or groups of species may be at the expense of others. Difficult balances.

8. Opportunities for action to achieve the sustainable management of natural resources

Manage protected sites towards favourable conservation status, allowing these sites to 'function as core areas of a resilient ecological network' (Vital Nature, NRW 2018b).

- The protected area system is the seed-corn of biodiversity, providing refuge areas but also the innoculant for the restoration of functional networks across the wider landscape.
- Improve condition monitoring of protected areas to understand change in status at individual management unit. Develop simple, robust assessment tools to enable land managers to self-monitor against habitat standards.
- Ensure that the appropriate management of protected areas is prioritised with adequate resources supported by advisory services. Much of this can only be achieved in partnerships with private landowners, environmental bodies and statutory authorities.
- Land ownership by Welsh Government, NRW and non-government organisations such as RSPB, National Trust, the Wildlife Trusts and Elan Valley Trust provide particular opportunities to improve the MMH habitat condition and connectivity of MMH habitats. Whilst sometimes constrained by tenancy agreements, they can forge close working relationships with tenants, secure funding and deliver landscape scale habitat restoration and management projects, for example, the Elan Links Scheme, and the National Trust Upper Conwy Catchment Project.

Maintain and enhance habitat outside protected sites, particularly Priority Habitat, (s7 Environment (Wales) Act 2016) which must, at the very least, be protected from further loss and damage.

- Increase resilience by restoring priority habitat, including blanket bog and heathland, where these contribute to coherent ecological networks.
- Support the development of sustainable farming and forestry scheme(s), including climate change mitigation and adaptation measures and measures to address the nature emergency. The Glastir agri-environment scheme and Environment (Wales) Act 2016 Section 16 Management Agreements have been important mechanisms for supporting appropriate management on MMH habitats. New sustainable land management schemes should build on that investment. Glastir includes management options which cover MMH habitats, such as blanket bog, lowland heath, upland heath and the management of open country. The Glastir Commons scheme is particularly important as much of the MMH resources lies within common land. Section 16 Management Agreements support management to address specific issues identified in the NRWR Sites Actions

Database. This is a more targeted mechanism but it is limited by financial and staffing resources.

- Establish appropriate grazing regimes (including no grazing where necessary) to promote the recovery of degraded habitats and improve connectivity. Grazing is the single most important, and most malleable, factor in determining the condition of MMH ecosystems (Keenleyside et al., 2019). Mixed grazing regimes, particularly the use of cattle on upland areas, can benefit biodiversity and improve forage utilisation (Fraser et al., 2014). Pulse grazing and periodic management in the ffridd zone could maintain and enhance habitat mosaics.
- Restore functional peatlands to as much of their original ecological footprint (such as deep peat area) as possible to enhance ecological connectivity and resilience, reduce GHG emissions and restore carbon sequestration function. Manage ditches and moor grips to restore the hydrological integrity of peatland. An estimated >48,465 ha of potentially restorable peatland habitat exists within the main Welsh river catchments (Williamson et al., 2019). It is estimated that 1,512 km of peat drainage ditches remain, a high proportion in upland blanket bog. Protection and restoration of peatlands is vital in the transition towards a low-carbon and circular economy (IUCN, 2017).
- Continue to remove plantations from deep peat areas (as crop matures) to restore bog habitat function. Some 6,900 ha plantation on peat was identified (Evans et al., 2015), of which nearly 900 ha will soon have been removed, and a further 1162 ha is programmed for removal from the Welsh Government woodland estate.
- Require statutory bodies (water companies, The Crown Estate, Welsh Government, the Ministry of Defence) to restore peatland under their control. Require internal drainage boards to maintain optimal water-table levels to sustain peat resources.
- Ensure that there is no peat extraction in Wales (revoke existing permits) and ban peat import and sale. The UK Government target to voluntarily phase out use of peat by 2020 has failed.
- Avoid rotational burning on upland peatlands. Controlled burning may have a role in dry heathland management but is generally damaging to *Sphagnum*-dominated habitat; upland peatland and wet heathland.
- Establish appropriately funded strategic approaches to the management of non-native conifer and rhododendron regeneration (such as Celtic Rainforest LIFE project). Reduce feral goat populations to levels consistent with the most sensitive habitats (woodlands and upland species-rich ledges). Establish long-term biosecurity solutions to prevent further establishment of invasive non-native species.
- Establish incentives to encourage cooperation between neighbouring holdings on peatlands. Many peatlands straddle landholdings which can create conflict if hydrological changes are required, creating a disincentive to recovery and improvement.
- Raise public and land manager awareness of peatland value and function and provide skills training to support adoption of sustainable management practices on peatland.
- Increase upland heathland recovery from acid grassland/heathland mosaic to reduce fragmentation, increase carbon sequestration and biodiversity, and attenuate water flow. Reduced grazing pressure and use of mixed stocking can

increase farm profitability by lowering variable costs while optimising use of natural forage (Frazer et al., 2014).

- Encourage expansion of woodland and re-establish natural treelines (semi-natural broad-leaved woodland covers just 2300 ha (0.5%) of the Welsh upland area) by natural colonisation, where appropriate (see Woodlands chapter).
- Promote trees on dense bracken areas; steep slopes can support native woodland to give ground stability, biodiversity, carbon, timber, hydrological, agricultural, recreational and landscape benefits.
- Extend native woodland and wood-pasture onto ffridd and streamsides. Ffridd depends on a small scale patchwork of habitats, including woodland, heath grass and transitions. Riparian woodland creates in-stream woody material and stabilises banks (see Woodlands chapter)..
- Restore lowland ecological networks, including broadening the coastal zones on cliff tops one field back from the cliff edge to restore coastal heath and grassland (see Coastal margins chapter)
- Address contractual arrangements that may constrain uptake among farms that are tenanted or on designated Common Land. Some 22% of land in Wales is tenanted, with an average tenure of just 2.9 years. Commoners, rather than the landowner, largely determine the use and management of that land, which may deter a willing landowner from making sustainable changes. Consider changes to the Commons Act 2006 to require sustainable management appropriate to the climate and nature emergencies.

Use Upland Ecological Options and opportunity maps in Area Statements to suggest appropriate areas where land management changes and habitat development, including woodland, can have multiple benefits.

- Ensure that Area Statements explore more detailed land cover and land management options to marry international obligations and national priorities with local opportunities. Such an upland management framework was trialled for the protected sites (CCW, 2007) but a revision should extend this beyond protected sites, utilising, for instance, peat distribution (Evans et al., 2015) habitat connectivity (Latham et al., 2013), Land Capability Assessment (Welsh Government), Important Upland Bird Areas (RSPB), Important Plant Areas (Plantlife) and local knowledge to signpost opportunities to deliver SMNR. ‘
- One size does not fit all. Ensure flexibility of policies to enable solutions to be tailored to local conditions and opportunities, empowering communities to add local priorities, reflecting the diversity of the landscape while recognising and delivering national priorities and international obligations.

Manage the conflicts between increasing levels of public access and land management for agriculture and conservation.

- Establish an integrated approach to managing recreational pressures to ensure sustainable use of the MMH habitat resource, for example, strategic assessments for sensitive habitats/species to identify problem areas and solutions with user groups, rather than a piecemeal approach, such as climbing or footpath erosion.
- Assess the impacts of large challenge events and specific activities on key habitats and species to inform decisions and management. Work with recreational

providers to deliver engaging information on the environment and provide better advice on reducing impacts.
- Address public access issues which are discouraging grazing of lowland peatlands, heathlands and coastal slopes, such as pinch points and lack of escape areas for livestock, lack of availability of traditional breeds, and support for additional care and handling facilities on difficult ground. Seek to resolve issues between the public and farmers such as livestock harassment by dogs.
- Seek to reduce fragmentation and abandonment on coastal and lowland heath caused by recreational conflicts by widening the coastal belt, for example, Pembrokeshire Coast National Park Authority (2003). Conserving the Coastal Slopes Project 1999-2002 and the Tir a Môr Llŷn SMS project. Consider the first field from the coast as multi-functional to deliver agricultural, biodiversity, recreational and sea-defence (roll-back) functions (see opportunities for action in Coastal margins chapter)

Actively pursue measures to reduce pollution, particularly reactive nitrogen (NH3 & NOx) emissions.

- Reactive nitrogen air pollution and the resulting eutrophication of habitats is a pernicious threat to all MMH habitats. Measures to address this threat are challenging, as the sources reflect widespread lifestyle choices (transport, housing, agricultural emissions) and the wider economy. But these impacts need to be recognised and accounted as externalised costs of these processes and choices. As carbon emissions have become recognised as having real consequences and costs, so too should NOx and other pollutants which exceed critical levels and loads, impact on natural habitats and processes and increase greenhouse gas emissions. While major emitters may be addressed by current regulatory processes, death by a thousand (small) emissions continues unabated, unaccounted and largely unregulated. (See Air quality chapter)
- Reduce diffuse water pollution to groundwater dependent terrestrial ecosystems from surrounding farmlands to improve overall resilience of the ecosystem. This pollution not only degrades the biodiversity value but also alters the peatland function, facilitating peat breakdown and greenhouse gas emissions. (See Freshwater chapter).
- Assist land managers to minimise nutrient leakage from their production cycle. If plant nutrients are the lifeblood of food production, their loss must be seen as unacceptable waste. (See Land use and solis chapter)
- Buffer zones around lowland peatlands can be converted to low input land-cover such as semi-natural grassland or heathland. Even hedges, wooded shelter-belts and grass swales can help reduce the near-surface inflow of nutrients.

The UK's departure from the EU presents many challenges but also an opportunity to define new ways of managing the countryside for multiple ecosystem services beyond the underlying assumptions of the Common Agricultural Policy. The uplands have long suffered from a singular focus on production measured by food and fibre, but not necessarily agricultural profit (Clark et al., 2019), and consequential external costs in biodiversity, water resources and climate are not included in the account. A multifunctional approach to land resource planning and management offers new opportunities to redress the balance.

9. Evidence Needs Summary

The evidence needs for MMH are broad and often complex reflecting the diverse nature of these habitats, the gaps in our understanding of condition and pressures and the long-term outcomes of conservation measures.

Effective management firstly requires a better understanding of the condition of existing MMH habitat, particularly in protected area land management units but also more widely, alongside the causes of poor habitat condition and the direction of change.

To improve the function of MMH, we need to identify where there are opportunities, particularly for peatland and heathland ecosystem restoration. Many lowland heathlands are fragments of their previous extent and many former upland heaths are reduced to acid grassland. Target areas for restoration and reconnection should be identified.

Mechanical techniques are sometimes used to manage vegetation, such as mowing heathlands in lieu of controlled burning or where grazing inadequate. But this can smother the ground in a mulch of cuttings and the long term effect of mowing dwarf scrub heath on ecosystem resilience needs to be identified. Similarly, we do not understand the long-term impact of mowing blanket bog or how to address the purple moor-grass *Molinia caerulea* or heath rush *Juncus squarrosus* monocultures on blanket bog. Investigation is needed of appropriate mechanical or chemical mechanisms of control to use alongside grazing.

We need a better understanding of the relative carbon-sequestration benefits of open habitats on shallow peat and organic soil versus forestry and how this varies according to timescale (multiple crops) and assumptions on timber after-use. Better understanding is needed on where areas of shallow peat (<50cm) and organic soils are found in Wales.

Effective restoration of peatland habitats requires an understanding of the socio-economic and practical barriers for landowners and managers and how these can be addressed.

With regards to soils, there is a need for understanding of the long-term trend of soil fertility and base-status in upland habitats and the drivers of change. Is there a role for restoration of liming in ffridd and upland meadows?

We want to see an increase in woodland cover, but how biologically rich are new woodlands in the uplands?. Can we predict the development of woodland biodiversity with time or are other factors such as antecedent and micro-habitats, micro-climate, location and proximity to ancient woodlands more important? Upland woodland expansion could damage upland riverine lichens as many are shade intolerant; though dappled shade from sparse tree cover may be tolerated shade from dense woodland could destroy this resource. Where are the important locations for river lichens so that appropriate safeguards can be put in place?

Ffridd or coed-cae, on the boundary between upland and lowland is a complex, dynamic habitat mosaic. What are the key elements of ffridd and what guidelines can we suggest for securing an appropriate balance of these habitats?

Diffuse pollution affects many lowland wetlands but the pathways vary. Are buffer zones effective and how extensive should they be? This is likely to be site-specific due to varying hydrological conditions.

We seek the recovery of Wales’s arctic-alpine plants from tiny refuges but we need to understand if there are genetic bottlenecks to overcome, a need to boost or migrate populations or change our land management.

"Challenge Events" such as mountain marathons which add to quality of life for many people may impact upland habitats and species. This could include direct impact (erosion, soil compaction) and indirect impacts (disturbance, changes in land management, ancillary effects such as GHG emissions). We have little evidence either way but need to understand these effects in order to manage and mitigate any damage.

Wales’s MMH is of high importance for people’s physical and mental health. Maintaining health reduces demand on health services, and thus contributes to the circular economy in line with SMNR Aim 3. Recreation, tourism, aesthetics and inspiration are cultural ecosystem services. Estimates of the economic value of these services would help us to better assess the costs and benefits of expenditure on this ecosystem to increase well-being and provide a healthy environment for all in line with SMNR Aim 4.

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