The Second State of Natural Resources Report (SoNaRR2020)

Assessment of Biodiversity

Natural Resources Wales

Final Report

About Natural Resources Wales

Natural Resources Wales's purpose is to pursue sustainable management of natural resources. This means looking after air, land, water, wildlife, plants and soil to improve Wales's well-being, and provide a better future for everyone.

Evidence at Natural Resources Wales

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

We will realise this vision by:

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

Title: **SoNaRR2020** Assessment of the achievement of Sustainable Management of Natural Resources: Biodiversity

Lead Author: **K Collins**

Contributors: **N Bialynicki-Birula, S Bosanquet, H Garrett, L Halliwell, S Hearn, M Howe, J Latham, S Smith, E Wiik, J Woodman**

Review process: All content has been reviewed internally and by subject matter experts. Further independent peer review was arranged by the Environment Platform Wales. We would like to thank all academic and other external experts for critically reading the individual chapters and suggesting substantial improvements. We are very grateful for their help and advice.

We would also like to thank other experts who have provided evidence and advice during the chapters' development.

Restrictions: None

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

Recommended citation for this section of the report:

Natural Resources Wales. 2021. State of Natural Resources Report (SoNaRR): Assessment of the achievement of sustainable management of natural resources. Coastal Margins. Natural Resources Wales.

Copyrights

Contents

Tables and Figures

1. Summary

Biodiversity is essential to all ecosystems, with its complex interactions generating the services and benefits that human health, well-being and resilience depend on. This connection is so fundamental that the Sustainable Management of Natural Resources (SMNR) cannot be achieved until biodiversity is properly maintained and enhanced. An assessment of biodiversity is therefore crucial to any wider assessment of the success of SMNR.

The biodiversity assessment draws upon evidence from across other chapters in this SoNaRR plus other published material and global analyses to set Wales's situation into a broad context. It is supported by case studies aiming to illustrate the situation through the plight of some of Wales's key species and the conservation management underway.

The assessment picture is complex with both winners and losers for different aspects of biodiversity. However, the overall trend is one of serious decline, reflecting the global situation and internationally recognised nature emergency.

Biodiversity recovery is fundamental to sustaining the vital services that are provided by natural resources. Wales now has more regulatory and policy frameworks in place to help protect and support these resources and with the recent increasing focus and investment on action, all parts of society need to act faster and more cohesively to help deliver improvements at a better and larger scale. There is a need to work more collectively on the dual plight presented by the climate and nature emergencies to win further support for the transformational and behaviour changes required.

2. Headline Messages

- Biodiversity is essential to all ecosystems, underpinning their functioning, resilience and ability to deliver services.
- Biodiversity is fundamental to providing economic, social, environmental and cultural well-being. Our economies are embedded within nature, not external to it and investing in ecosystems as assets gives an annual rate of return far greater than most conventional economic assets.
- The loss of biodiversity is accelerating globally and at unprecedented rates in human history – around 1 million animal and plant species across the globe are now threatened with extinction, many within decades, at a rate of loss unparalleled for 65 million years.
- Pressure and demands include changes in land and sea-use, direct exploitation of organisms, climate change, pollution and the invasion of non-native species.
- Wales needs to build resilient ecological networks, where protected sites and other biodiversity hotspots can be brought to good condition and connected across the wider landscape to increase permeability for the movement of species and their genes within and between habitats by reducing fragmentation.
- Building on the approaches now being taken and increasing biodiversity related investment (through nature-based solutions for flood mitigation and carbon

sequestration for example) is key for restoring nature and developing a resilient economy. These also provide opportunities to secure many other benefits alongside improving climate change resilience and enabling biodiversity recovery.
- To complement these approaches and need for increased investment, more immediate and ambitious transformative changes are also required at a far-reaching scale to halt further loss and support biodiversity recovery.

3. Introduction

The vital role of biodiversity

Biodiversity is fundamental to all ecosystems by defining them, underpinning their functioning, resilience and their ability to deliver services that everyone benefits from. Biodiversity is inextricably linked to human existence; its decline will impact on the provision of food, the changing climate, and our own resilience as a species. It is therefore essential to economic, social, environmental and cultural well-being.

Biodiversity underpins ecosystem resilience and is integral to achieving SMNR. Biodiversity and resilient ecosystems with their suite of habitats and species, and genetic diversity provide the foundation for ecosystem services such as food, fuel, and flood prevention that support human well-being and help ecosystems adapt to the adverse impacts of climate change. SMNR is the delivery framework that ensures biodiversity is considered as an essential element to the resilience of ecosystems. Therefore, the state and trends of biodiversity are a critical measure of whether SMNR is being achieved.

Wales's biodiversity is also strongly influenced by its geodiversity, the underlying physical substrate, soil properties, geomorphological processes, topographic effects on microclimate, water availability, and disturbance during continual or episodic erosion. Varied patterns of micro- and meso-scale topography, soils and geomorphological process result in mosaics of habitats, corridors for species movement, and topographical variations for high species richness (Crofts, 2019).

Biodiversity and ecosystem functions are deteriorating worldwide

Recent reports from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) state biodiversity is declining globally at rates unprecedented in human history alongside an accelerating rate of species extinction.

Around one million animal and plant species across the globe are now threatened with extinction, many within decades. This is more than ever experienced before in human history (IPBES, 2019). Globally, the average abundance of native species in most major land-based habitats has fallen by at least 20%, mostly since 1900 (IPBES, 2019). The quality of habitats which support this biodiversity has also declined, with a 30% reduction in global terrestrial habitat integrity caused by habitat loss, fragmentation and deterioration (CIEEM, 2019). In marine systems, fishing has

had the most impact on biodiversity (target species, non-target species and habitats) in the past 50 years alongside other significant drivers (IPBES, 2019).

Globally the proportion of species currently threatened with extinction according to the International Union for the Conservation of Nature's (IUCN) Red List criteria averages around 25% across the many terrestrial, freshwater and marine vertebrate, invertebrate and plant groups (IPBES,2019).

In the UK, the abundance and distribution of species has also, on average, declined since the 1970s and the statistics published by the State of Nature report (Hayhow *et al.*, 2019) suggest this decline has continued over the past decade. A review of the drivers of change for over 300 species identified intensive management of agricultural land as the most important driver of biodiversity change over the past 45 years in the UK, having mostly negative effects on terrestrial and freshwater species (Burns *et al.,* 2016). Currently, 72% of the UK's land area is managed for agriculture; about one-third arable and two-thirds pastoral (grassland, moorland and heath), with crops treated with pesticides increased by 53% between 1990 and 2010 (Hayhow *et al.*, 2019). This, and changes to practices such as loss of mixed farming and increased use of fertilisers has caused populations of farmland birds to have more than halved on average since 1970, with similar declines in other taxonomic groups such as arable plants and pollinators (Hayhow *et al.*, 2019).

The diverse ecosystems of Wales support rich and varied wildlife. However, similarly to global trends, Wales continues to face biodiversity loss, with 1 in 6 species that have been assessed in Wales at risk of extinction. Of the 3,902 species assessed since rigorous scientific monitoring began in the 1970s in Wales, 73 have been lost already (Hayhow *et al.*, 2019) (Figure 1).

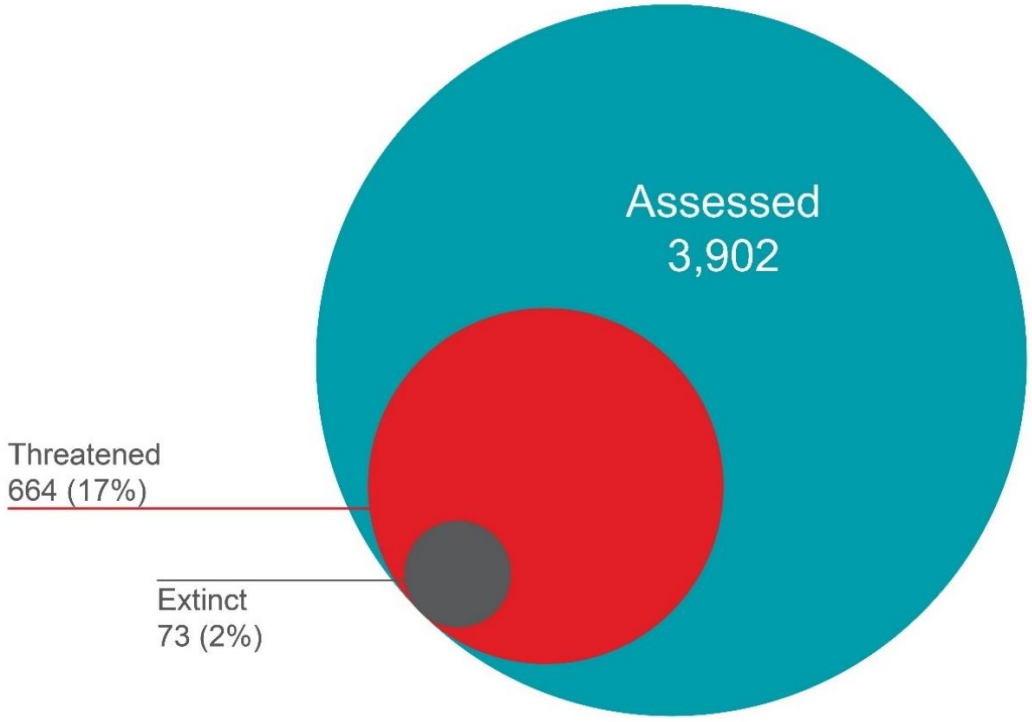

Figure 1 Species extinction risk assessment (Wales) (Hayhow et al., 2019).

Woodland cover in Wales has quadrupled to 15% since a low point of 4% in 1918. However, most of this increase has been due to the post-World War II planting of non-native conifers which support relatively little biodiversity compared to native woodland, and which in some cases, have been planted at the expense of more biodiverse habitats (Latham, 2010; Welsh Government, 2018). Only 48% of woodlands are considered native and just 14% are classed as ancient and semi-natural, recognised as the most important for woodland biodiversity (Hayhow *et al.*, 2019). The UK Forestry Standard (UKFS), first published in 1998, has set out best-practice guidelines to improve the sustainability and biodiversity of commercial woodland. Some elements are regulatory, such as the need to design new woodlands for habitat diversity and introducing more diverse age structures to existing even-aged woodlands (Forestry Commission, 2017). Many of the commercial woodlands that are diverse are like this because of the care and passion of individual landowners and foresters who go beyond the compulsory elements.

Wales's marine ecosystems are under pressure from a range of influences such as climate change, human activities, invasive non-native species (INNS) and inputs from freshwater catchments. Pressures are impacting variably on the status, extent, condition, and diversity of the marine environment. In some cases, such as coastal and marine water quality, there are significant issues that have ramifications for other aspects of the marine ecosystem.

Case Study: Saproxylic invertebrates pushed to the brink by loss of old trees

Saproxylic invertebrates rely on deadwood for survival and make up 6% of British invertebrate fauna. Despite Wales's high tree cover, most saproxylic invertebrates need ancient trees, so are very rare in managed ecosystems. Recent surveys commissioned by Natural Resources Wales (NRW) (Alexander, 2018; Alexander, 2019; Alexander, 2020) have demonstrated that some of the key Welsh woodlands support nationally significant species.

Castell y Waun a'i Barcdir / Chirk Castle and Parkland Site of Special Scientific Interest (SSSI) supports one of the best examples of ancient wood pasture and parkland in Wales, with numerous veteran and ancient trees of diverse species. These veteran trees support a nationally important saproxylic invertebrate assemblage, as well as a nationally important deadwood fungus assemblage. A survey of the fauna in 2018 (Alexander, 2019), funded by National Trust and NRW, brought the cumulative total of saproxylic invertebrates to 313 species including 207 beetles, 82 flies, and 12 bees & wasps. The Index of Ecological Continuity (IEC), which provides an assessment of the quality of the specialist beetle fauna associated with "old growth" conditions, has now reached 75 (an increase of about 10% compared to 1996) and places the parkland amongst the top 25 sites in Britain and the richest in Wales (Table 1).

The Wye Valley Woodland Special Area of Conservation (SAC), ranked as the second most important site in Wales, has reached 230 species, dominated by 144 species of beetles and 83 flies (Alexander, 2018). The IEC for this SAC is 65, and the Saproxylic Quality Index (SQI), which provides an assessment of the rarity of the beetle assemblage and can be used as a guide to current site condition, was 484 which is comparatively high compared to other key Welsh sites for saproxylic beetles (Alexander, 2020).

Table 1 Key Welsh sites for saproxylic beetles (Alexander, 2018; Alexander, 2019; Alexander, 2020).

Site	Number of saproxylic beetle species	Saproxylic Quality Index (SQI)	Index of Ecological Continuity (IEC)
Chirk Castle Park	207	439	75
Welsh Wye Valley Woodlands SAC	>150	484	65
Powis Castle Park	171	388.9	65
Dinefwr Park	157	380.9	57
Dingestow Court	119	457.1	48
Llanover Park	119	343.7	37
Carn Gafallt	85	368.2	28

Note: Any site with SQI of at least 500 or IEC of at least 25 is considered to be of national (UK) importance.

Figure 2 A black-spotted longhorn beetle (*Rhagium mordax*) on an oak near the banks of the River Wye. The larvae mature in moist rotting wood or recently cut dead trees/tree stumps for 2-3 years. Photo credit Robert Bacon.

Protected sites are essential for biodiversity

Protected areas maintain key habitats, provide refugia, allow for species migration, movement and gene flow, and ensure the maintenance of natural demographic and evolutionary processes across the landscape. Not only do protected areas secure biodiversity conservation, they also secure the well-being of humanity itself (CBD, 2021). While providing the highest level of protection for the best of Wales's wildlife, protected sites are adversely affected by a range of pressures and threats and require active management, restoration, and improved connectivity if their protected habitats and species are to remain in or reach favourable condition. However, the information to assess habitat and protected feature condition, which enables the assessment of existing and planned management effectiveness, has been flagged as an evidence need for many ecosystems in SoNaRR (the detailed evidence needs list can be found on the SoNaRR2020 webpage).

Protected areas are key to buffering unpredictable impacts of climate change: they are a natural fit to the ecosystem approach and contribute to ecosystem services in numerous ways, most notably in terms of supporting ecosystem function and resilience, enhancing regulating services, and certain cultural services. There is, therefore, an urgent need to improve the quality and management of Welsh protected sites as well as increase their scale and ecological connectivity (See Mountains, Moorlands and Heaths and Freshwater chapters). This will ensure that they are properly integrated within the wider environmental management of Wales so that nature conservation overall is strengthened.

Wales has 21 Special Protection Areas (SPAs) for rare and vulnerable birds and also migratory birds which visit Welsh shores. There are 95 Special Areas of Conservation (SACs) for other rare species and threatened natural habitats. Together they form part of the UK national site network (pre-Brexit known as the Natura 2000 network as per the original EU designation), which within Wales covers more than 700,000 hectares (8.5% of Welsh land area).

Terrestrial and freshwater sites within the UK national site network are underpinned by Sites of Special Scientific Interest (SSSIs). There are 1,078 SSSIs in Wales, covering just over 12% of the nation's land area, with 12 sites having been notified since SoNaRR2016 (NRW, 2016). SSSIs cover a wide range of habitats from small fens, bogs and meadows to sand dunes, woodlands and vast tracts of uplands. Most are in private ownership, although some are owned and managed by statutory agencies and conservation charities. There are also 76 National Nature Reserves (NNRs) in Wales that were set up to protect a wide range of wildlife, habitats or geological features of special interest.

Wildlife Sites and Sites of Interest for Nature Conservation (SINC) are areas of land recognised for their importance for wildlife, which fall outside the legal protection of the SSSI system. Wildlife Sites have an agreed management plan for wildlife whereas SINC sites generally do not. Together with SSSI sites, these form the core of a vital network of threatened habitats such as ancient woodlands, hay meadows, wetlands and neutral grasslands, providing space for many of Wales's declining animal and plant species.

In the Welsh marine environment, there are 139 Marine Protected Areas (MPAs), covering 69% of Welsh inshore waters (out to 12 nautical miles) and 50% of all Welsh waters (out to the median line). Work is underway to ensure this ecologically coherent network of MPAs is managed to provide greater benefits to the marine environment than individual MPAs, contributing to the sustainable management of marine natural resources. The network of MPAs comprises 15 SACs, 13 SPAs, one Marine Conservation Zone, 107 coastal SSSIs and three Ramsar sites. Ramsar sites protect internationally important wetland habitats and associated species, mostly birds, required by the 1971 international wetlands convention ('Ramsar Convention').

Case Study: Welsh stoneworts demonstrating the importance of protected sites

Stoneworts (for examples see Figure 3) are a group of mainly freshwater algae that occur primarily in clean water habitats, especially lakes and ponds as well as smaller water bodies in fen and dune habitats.

There are 19 species recorded from Wales (Stewart and Hatton-Ellis, 2020), with several species having been newly recorded in Wales over the last 30 years. Eight species are threatened (Stewart and Hatton-Ellis, 2020).

Stoneworts are threatened by multiple pressures including habitat loss, poor water quality and changes to land management. The protected site series is especially important: every stonewort species recorded from Wales occurs in one or more protected site. Additionally, data from surveys both inside and outside protected sites shows that several of the most threatened species have not been found outside protected sites (Stewart and Hatton-Ellis, 2020).

Figure 3 Examples of stoneworts (L-R): *Chara virgata* at Llynnau Cregennen, Gwynedd (Photo credit: Tristan Hatton-Ellis) and *Tolypella glomerata* at Cors Bodeilio, Ynys Môn (Photo credit: Tristan Hatton-Ellis).

The climate emergency and biodiversity crisis are two interlinked challenges

Climate change is one of the most significant threats to global biodiversity and is projected to become increasingly severe throughout the century. Average UK temperatures have increased by nearly 1°C since the 1980s with widespread impacts on nature evident. There is growing evidence that climate change is driving widespread and rapid changes in the abundance, distribution and ecology of the UK's wildlife, causing changes to species communities which are projected to continue for decades or even centuries to come (Hayhow *et al.*, 2019).

The Intergovernmental Panel on Climate Change (IPCC) report (IPCC, 2018) indicates that global warming in excess of 1.5^{o}C above pre-industrial levels will undermine life-support systems for humanity. It is predicted that if the world warms by 2^{o}C, one in twenty of all species will be threatened with extinction. Following on from the huge international attention now being given to climate change, the publication of the IPBES 2019 assessment (IPBES, 2019) helps to emphasise the strong connections between biodiversity loss and climate change. The drivers of climate change and biodiversity loss largely result from the same socio-economic activities and this connection to biodiversity loss needs equivalent recognition in terms of attention and policy action.

Biodiversity loss itself can fuel climate change; the destruction of biodiverse ecosystems, such as peat bogs, results in significant production of carbon dioxide and reduces ongoing sequestration, leading to a feedback effect of further climate change (CIEEM, 2019).

In spring 2019, the Welsh Government declared a climate emergency, recognised the impact on nature, and included the intention to update the Nature Recovery Action Plan to drive urgent action for both. The key is linking biodiversity recovery and climate change action together and seeking opportunities to combine climate mitigation and adaptation with nature-based solutions. For example, tree planting is promoted as a climate change mitigation tool. However, care needs to be taken to avoid direct conflict with biodiversity. The oak pictured (Figure 4) has been planted in invaluable meadow habitat that is now likely to be lost. A key learning process in tree-planting schemes has been to select planting sites where damage to other habitats crucial for biodiversity conservation is avoided.

Figure 4 Oak sapling planted in biodiverse meadow (Photo credit: Karen Rawlins).

4. Pressures and threats

Direct and indirect drivers of change have accelerated during the past 50 years. Globally, land-use change is the direct driver with the largest relative impact on terrestrial and freshwater ecosystems, while direct exploitation of fish and seafood has the largest relative impact in the world's oceans. Together with climate change (as mentioned already), pollution and INNS they form most significant drivers of biodiversity decline (IPBES, 2019).

These drivers result primarily from unsustainable human activities. To better understand and, crucially, address the main causes of biodiversity impact, society needs to understand the demographic, economic, and social value systems that interact in driving change at a local and global scale. These include consumption patterns, trade, technology, governance, conflicts, and epidemics. Although the rate of change of direct and indirect drivers differs among regions and countries, all have accelerated during the past 50 years (IPBES, 2019).

The State of Nature report (Hayhow *et al.*, 2019) identified the most significant pressures acting on terrestrial and freshwater nature in the UK as agricultural management, climate change, urbanisation, pollution, hydrological change, INNS, and woodland management. The range of issues and risks identified as adversely impacting SAC and SPA features in Wales, include inappropriate grazing type and levels, INNS, changes to hydraulic conditions, access and recreation impacts, air pollution and diffuse water pollution.

At sea, multiple pressures including climate change and poor water quality are impacting marine biodiversity, while agricultural intensification is identified as having

the greatest single impact on nature in the terrestrial and freshwater environments (Hayhow *et al.*, 2019).

In Wales, according to Welsh June Agricultural Survey data (Welsh Government, 2019) and a range of other sources, almost 90% of land over recent years is utilised for agricultural production, with most of that land intensified for food production (Blackstock *et al.*, 2010; Armstrong, 2016; Welsh Government, 2019). Semi-natural habitats and functioning ecosystems have reduced hugely in extent, becoming fragmented, and are often in poor ecological condition (See Enclosed farmland chapter). These changes have caused the loss of more than 90% of semi-natural grassland habitats since the 1930s, negatively affecting the many species that rely on this habitat (Hayhow *et al.*, 2019) (See Semi-natural grasslands chapter). For example, grasslands managed for maximum productivity of specific types of grass and clover are often ploughed (Figure 5). This is not only harmful to plant biodiversity but also fungal biodiversity, as, for example, waxcaps rely on low levels of soil disturbance. Biodiverse meadows have often traditionally been used as “hospital fields” (cae ysbyty) for poorly farm animals due to the health benefits of the more varied diet (while anecdotally evidenced, the science on this is incomplete) (Magnificent Meadows Partnership, 2017). Many species of wild pollinator such as bumble bees, solitary bees and hoverflies are under threat. Urban areas have become significant refuges for pollinators as the quality of the surrounding farmed countryside continues to decline (BTO, 2018) (See Urban chapter).

Figure 5 (L-R) Examples of a biodiverse meadow (left) and ploughed meadow for maximum productivity (right) (Photo credits: Stuart Smith).

Furthermore, intensive agriculture produces the majority of ammonia pollution in Wales. This causes impacts on nitrogen-sensitive ecosystems away from the land that is actually being managed: despite recent reductions, 62.7% of Welsh SSSIs partly or entirely exceed the ammonia Critical Level for their qualifying habitat or species features (Rowe *et al.*, 2019). Increases in atmospheric nitrogen deposition is known to be able to reduce biodiversity in natural and semi-natural ecosystems (See Air quality chapter).

Many coastal habitats and species are threatened by sea level rise and shoreline development. These coastal habitats are prevented from migrating inland due to natural or man-made barriers. This “coastal squeeze” could result in the loss of habitats, such as mudflats and saltmarshes, which are critical for wildfowl and wader species (See Coastal margins chapter).

5. State and trends in biodiversity

Since 1970, pressure on Wales’s diverse environment has resulted in devastating losses for biodiversity with many species at risk of extinction. The findings in the 2019 State of Nature report (Hayhow *et al.*, 2019) include:

- Of the 6,500 species in Wales with an IUCN Regional Red List assessment, 8% are threatened with extinction from Great Britain.
- The abundance indicator of 33 butterfly species has fallen by 52% in Wales since 1976. Across the UK moths have declined by 25% (1970-2016), with insects experiencing a 10% decrease in average distribution between 1970 and 2015.
- Since 1970, the UK abundance of priority species has declined by 60% and their distribution has declined by just over a quarter. Declines in farmland birds have been more severe than those for any other habitat, with a decline of 54% in the Farmland Bird Indicator since 1970.
- Over the period 1960 to 2018, INNS have become more prevalent, increasing the pressure on native biodiversity (See INNS chapter for further details on their impact).
- However, there are some positives: in Wales, monitoring of 37 wintering water bird species since 1970 shows a statistically significant increase in average abundance of 30% and the mammal abundance indicator (comprising 6 bats and rabbit) shows a 10% increase between 2006 and 2016.

Wales’s wildlife is undergoing rapid changes in species distribution, on average falling by 10% since 1970, and is 6% lower than in 2005 (covering 2,977 terrestrial and freshwater species) (Hayhow *et al.*, 2019). The extant terrestrial and freshwater species found in Wales, assessed using IUCN Regional Red List criteria, found 256 plants, 41 fungi, 208 lichens, 146 bryophytes and 13 mammals classified as being at risk of extinction from Great Britain (Hayhow *et al.*, 2019). Some of the most common species of bird have recorded serious declines for Wales; using British Bird Survey data (Harris, *et. al*., 2020) figures show a 72% decline in swift, a 71% decline in greenfinch and a 38% decline of chaffinch in between 1995 and 2018.

Biodiversity has also declined on the coastal margins in line with losses in extent, condition, and connectivity of habitats. Within the last 50 years there have been a number of extinctions of invertebrates, and lower and higher plants. There are further species on the brink of being lost from Wales, usually due to multiple pressures.

However, there is some good news. Polecats are recovering in Wales from a low point in the 1930s. They are still widespread in Wales, maintaining their range in their historical stronghold (Croose, 2016). The red kite suffered from intensive human persecution resulting in the species becoming extinct in several countries. At

the beginning of the 20th century, numbers reduced to just a handful confined to the uplands of mid-Wales. Following monitoring and conservation efforts in the 1990s, numbers increased to 350-400 pairs by 2003 rising to around 1,000 breeding pairs in Wales in recent times (RSPB, 2020). Furthermore, data from the National Bat Monitoring Programme indicate that populations of the species monitored are stable or recovering. It should be remembered, however, that these trends reflect relatively recent changes in bat populations (since 1999 for most species), therefore not taking into account historical, significant declines (Bat Conservation Trust, 2020).

The area of heathland and peatland in both upland and lowland has declined considerably due to management practices that modify plant communities and habitat type. Overall, there has been no improvement in bog plant biodiversity over the long-term, while the most recent data for heathland suggests some increases that would need longer-term monitoring to verify (Alison *et al.*, 2020). There is some evidence of improving condition in non-Glastir and Glastir priority blanket bog based on the Glastir Monitoring and Evaluation Programme (GMEP) (Emmett *et al.*, 2017). Among birds of upland farmed habitats in Wales, Balmer *et al.* (2013) show the breeding ranges of curlew, golden plover, black grouse, red grouse and ring ouzel have all contracted relative to the 1988-91 breeding bird atlas of Gibbons *et al.* (1993), with curlew now considered to be the most pressing bird conservation priority in Wales (Gylfinir Cymru/Curlew Wales, In prep.) and the UK (Brown *et al.,* 2015) (See Mountains, moorlands and heaths chapter).

Recent condition assessments of lowland grassland features on SSSIs and SACs indicate that most statutory protected lowland grasslands are in poor condition. More widely, across unprotected grasslands, there is a lack of consistent trends in floristic condition since 1990, although some improvement in the condition of marshy and acid semi-natural grassland has been detected since 2007 (Alison *et al.*, 2020). However, a recent assessment of marshy grassland on unprotected sites indicates that this form of grassland is still being lost (See Semi-natural grasslands chapter).

Species conservation status

Every six years, the UK's Joint Nature Conservation Committee (JNCC) assesses the conservation status of all species and habitats qualifying for protection under Article 17 of the EU Habitats Directive and Article 12 of the EU Birds Directive. These summarise the UK status and trends of the selected habitats and species and are important evidence sources.

The fourth Article 17 UK report (JNCC, 2019a), submitted to the EU in August 2019, found that 46% of listed species were in favourable conservation status at the UK level. The figure is the same for species occurring in Wales (Figure 6). In Wales, 44% of species are reported as stable, while 17% are shown to be deteriorating (Figure 7).

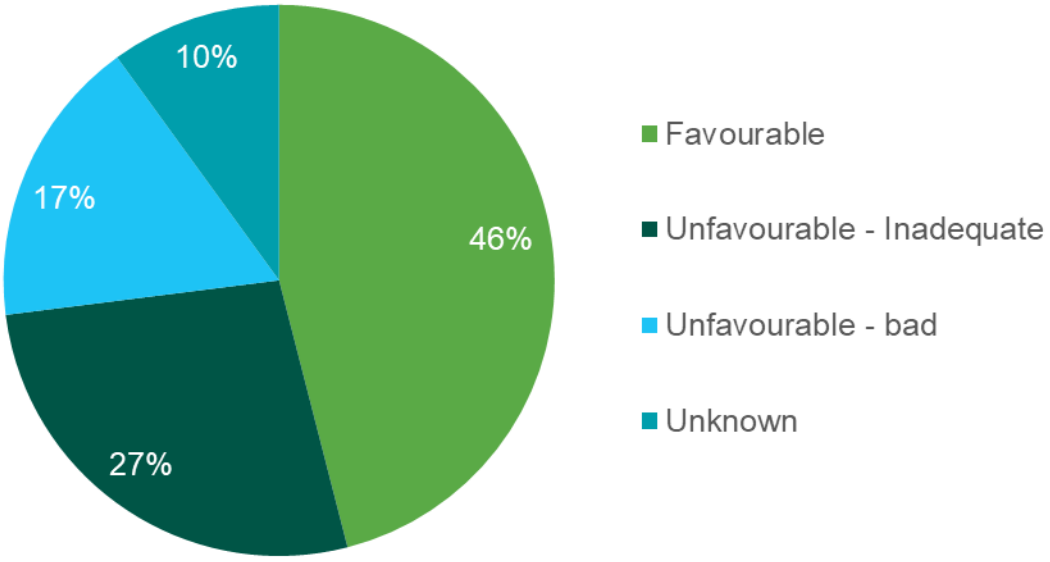

Figure 6 UK conservation status of Welsh species listed in the EU Habitats Directive. Excluding *Cladonia, Orthotrichum rogeri, Sphagnum* and all marine mammals (JNCC 2019a).

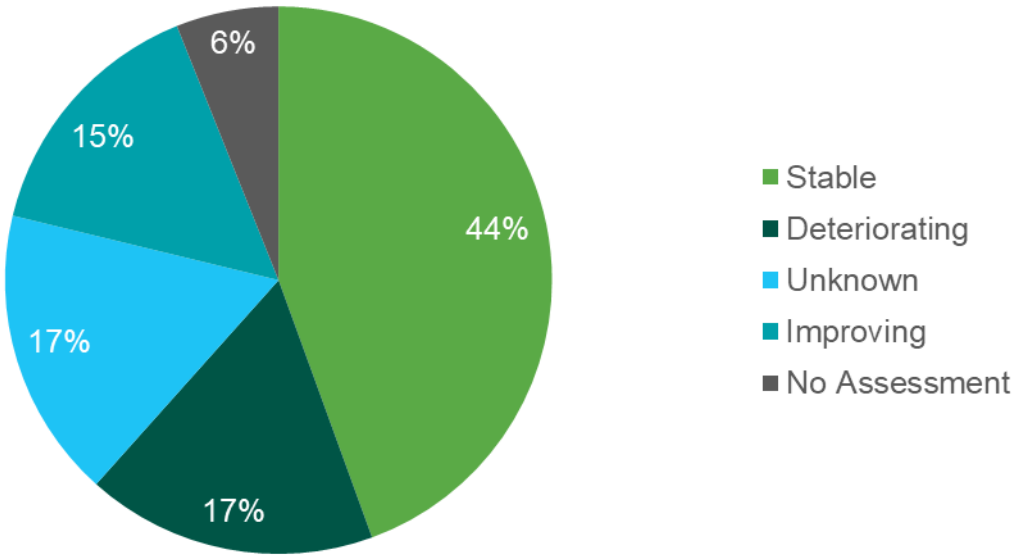

Figure 7 UK conservation status trends of Welsh species listed in the EU Habitats Directive. Excluding *Cladonia, Orthotrichum rogeri, Sphagnum* and all marine mammals (JNCC 2019a).

The recent UK biodiversity indicators report (JNCC, 2019b) has been revised to incorporate new data from the 2019 UK Habitats Directive Article 17 report to the European Union (JNCC, 2019a). It reveals that in 2007, 5% of UK habitats listed in Annex I of the EU Habitats Directive were in favourable conservation status; this figure decreased to 3% in 2013 before increasing again to 8% in 2019 (Figure 8).

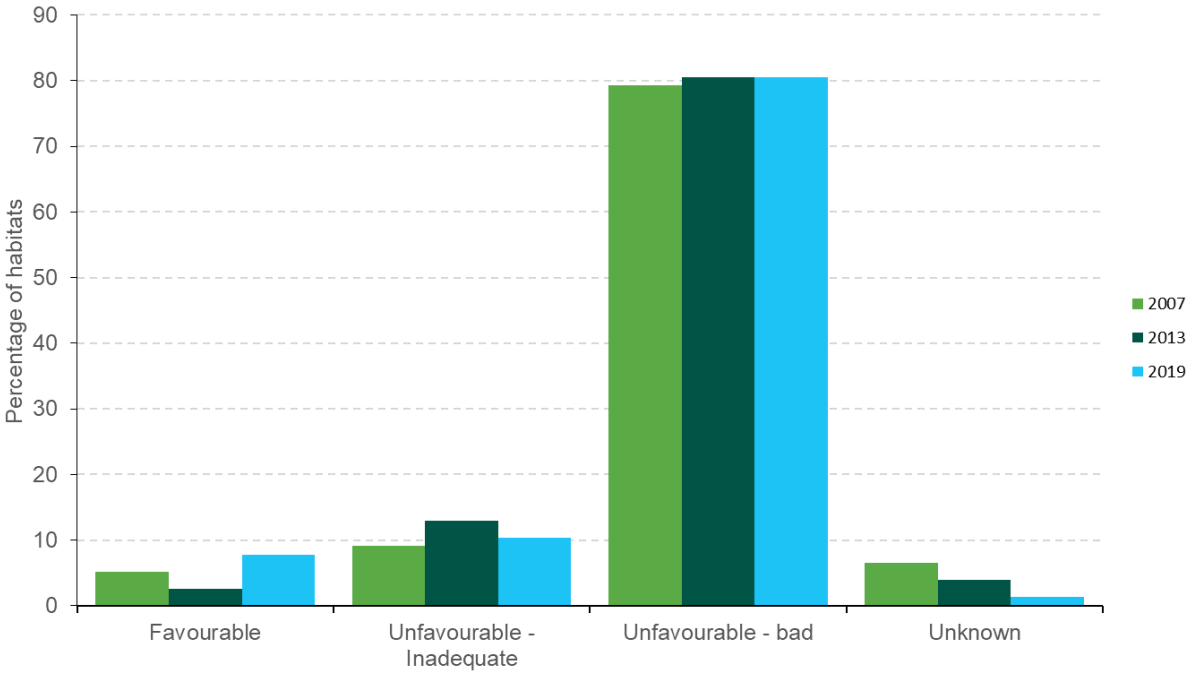

Figure 8 Conservation status of UK habitats of European importance, 2007, 2013 and 2019 (UK Habitats Directive (Article 17) reports to the EU, 2007, 2013 and 2019) (JNCC, 2019a; JNCC, 2019b).

In 2007, 26% of UK species listed in Annexes II, IV or V of the Habitats Directive were in favourable conservation status; this figure increased to 39% in 2013 before decreasing to 35% in 2019 (JNCC, 2019b).

The Wales species assessments which contributed to the UK Habitats Directive Article 17 report found that of the 52 species included, 25% have a stable population trend in the short term (c. 10 years) whereas in the long term (20-30 year) only 6 have stable population trends (Figure 9). The percentage of species with declining populations was similar in the short and long term, 23% and 25% respectively.

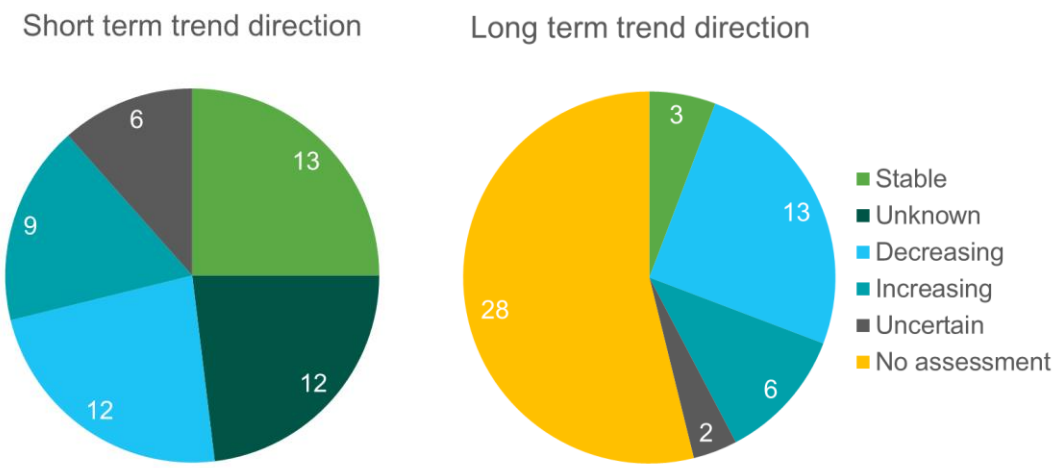

Figure 9 (L-R) Short term (left) and long-term (right) trends in population for 52 species in Wales (showing Welsh trends only) included in the UK Habitats Directive (Article 17) 2019 report (JNCC, 2019a).

Official lists of priority species (Section 7 for Wales) for each UK country confirm there are 2,890 species on the combined list. By 2016, the index of relative abundance of priority species in the UK had declined to 40% of its baseline value in 1970, which is a statistically significant decrease (JNCC, 2019b).

Protected sites management and monitoring in Wales

There are a range of protected sites in Wales, including SACs, SPAs, and SSSIs which NRW is responsible for managing and monitoring. These sites are designated for a range of species, habitats and earth science features. In order to ensure the continued viability of these features, NRW works together with owner occupiers and partners to further ensure geo- and biodiversity are protected for the future. For example, 5.47% of SSSIs are covered by management agreements between NRW and the owner occupiers. This work often requires site management to help maintain their condition, the assessment of which is delivered through NRW's monitoring programmes.

Where issues and risks are identified with regards to protected site features, NRW, together with partners, work to implement appropriate management. For example, restoration work evolving from a prioritised programme of actions as part of the EU LIFE Natura 2000 Programme. Progress towards bringing SAC and SPA habitats and species into favourable condition in Wales has been brought through the following EU-supported projects, alongside other action:

- Anglesey and Llŷn Fens LIFE project
- The Sands of LIFE project
- Welsh Raised Bogs LIFE project
- Pearls in Peril LIFE project
- River Dee LIFE project
- Celtic Rainforests Wales LIFE project

6. Ecosystem key headlines

Freshwater

All living things need water to survive, yet globally, freshwater ecosystems are among the most threatened (WWF, 2020). Freshwater ecosystems provide important ecosystem services including water supply, renewable energy production, flood management, fisheries, and recreation, yet their ability to do so is increasingly compromised.

There are an estimated 9,500-16,000 km of headwater streams in Wales. Using GMEP invertebrate data, nearly 83% of the headwater streams have good or high diversity. Comparison with results from 2007, reported by Countryside Survey, indicates an increase in biodiversity but a slight shift towards species more tolerant of degradation (Emmett *et. al*., 2017). This shift can affect the functioning and ecological resilience of the ecosystem. In terms of ecosystem health, there are problems downstream, with only 44% of river water bodies achieving Good Status, and no river water bodies in Wales achieving High Status, as reported by Water Framework Directive Interim 2018 classification (NRW, 2018).

The key issues affecting freshwater ecosystems in Wales include:

- Physical modifications which significantly reduce freshwater ecosystem resilience, particularly to climate change. These modifications (for example, bank reinforcement, dredging, bank modifications, weirs, culverts, channel straightening) have a detrimental effect on river and lake processes and ecosystem functioning.
- Pollution, which is currently the most acute issue facing freshwater ecosystems, specifically pollution from slurry, sewage, mine waters and soil erosion.
- Climate change, which is causing alterations to seasonal weather patterns resulting in more low flow and storm events and increased water temperatures. This influences all processes and pressures in freshwater ecosystems and reduces resilience.
- Lack of connectivity between rivers and their flood plains.
- Widespread deterioration of habitats due to INNS. INNS can have a devastating impact on native biodiversity through competition for resources, introduction of disease, and predation.

Cumulatively, these pressures threaten freshwater biodiversity with several species, such as salmonids and freshwater pearl mussel, requiring urgent action to prevent extinction or catastrophic declines.

Although water quality has been improving generally across Wales (NRW, 2018), most notably in the post-industrial rivers of South Wales, there remain areas of concern which must be addressed in the coming years if well-being goals are to be realised. These include prevention of ongoing unconsented damage to river channels, diffuse pollution from agriculture, local sewage issues, and the legacy of pollution from metal mines.

Additionally, issues such as the spread of INNS and the prevalence of anthropogenic pollutants such as microplastics are now impacting on freshwater ecosystems. The opportunities for sustainable management of Wales's freshwaters are based on three fundamental concepts: reducing pressures on freshwater ecosystems; building the resilience of freshwater ecosystems; and specific additional measures to tackle the biodiversity crisis (See Freshwater chapter).

Case Study: Freshwater pearl mussel – a species in peril

The freshwater pearl mussel *Margaritifera margaritifera* (Figure 10) can live over 100 years and has a complex life cycle that includes a parasitic phase on salmonids. In favourable habitat, it can form dense beds up to three mussels deep, acting as an ecosystem engineer by providing a refuge for many other animals and by filtering the water (Geist, 2010). Once widespread throughout Welsh rivers, it is now Critically Endangered in Wales.

Several factors have led to its dramatic decline. In the past, exploitation by humans was a serious problem, but more recently, damage to river habitat structure and poor water quality are the most significant pressures. Adult pearl mussels require stable but fast flows, such as when water is forced between boulders, or around a fallen tree. Juvenile mussels live buried in river sands or gravels for several years, during which time they need the habitat to be both stable and well-oxygenated (Geist and Auerswald, 2007; Moorkens and Killeen, 2014). These habitats also tend to occur close to features such as boulders and woody material, which prevent sands and gravels from being washed away in floods. This also helps to maintain faster current speeds even during dry weather, reducing siltation and increasing oxygen concentrations.

During the 20th century, many of these features were removed from Welsh rivers to improve land drainage, reduce flood risk, and create pools for anglers. As a result, this has caused declines in pearl mussels as well as harming other river organisms such as salmon and trout. In many areas, water pollution including increased silt load compounded these problems and has driven pearl mussel to the brink of extinction in Wales (Hatton-Ellis, 2018).

NRW has therefore developed and is implementing a Pearl Mussel Conservation Strategy for Wales (Hatton-Ellis *et al*., 2017) which will address these problems and seek to recreate conditions in Welsh rivers where pearl mussels can once again thrive. Using best practice guidance, a combination of habitat restoration, targeted captive breeding and release, and monitoring of sediment oxygen levels is being implemented in several key locations across Wales. This aims to restore freshwater pearl mussels and the ecosystem services they deliver to sustainable levels.

Figure 10 Three freshwater pearl mussels in Wales. Locations of freshwater pearl mussels are kept secret to protect them from illegal pearl fishing (Photo credit: Tristan Hatton-Ellis).

Marine

The Welsh inshore marine area extends from the mean high-water mark to 12 nautical miles, covering just under 15,000 km^2 or 41% of the territory of Wales. Wales has a rich and diverse marine ecosystem, with 69% of inshore waters designated as part of the network of 139 MPAs. These MPAs and wider seas contain a variety of habitats, benthic invertebrates, fish, extensive algal communities, and important populations of marine mammals and birds. Welsh waters are particularly important for habitats and species at the edge of their geographic range, such as horse mussel beds.

Marine ecosystems are under pressure from a range of influences such as climate change, certain human activities, INNS and inputs from freshwater catchments. Pressures are impacting variably on the status, extent, condition, and diversity of the marine environment.

The key issues affecting marine ecosystems in Wales include:

- **MPA feature condition and management** – covering 69% of Wales's inshore waters, the MPA network represents the best understanding of the resilience and diversity of the marine ecosystem. 46% of MPA network features are in favourable condition, but there is evidence that other features are not and more needs to be done to secure effective and consistent MPA management.
- **Climate change** – the changing climate is having physical, ecological, social and economic impacts on UK coasts and seas. There is clear evidence that warming seas, reduced oxygen, ocean acidification and sea-level rise are already affecting marine ecosystems, and further impacts are predicted.
- **Pollution and water quality including marine litter** – water quality issues (nutrient levels and chemicals) are impacting the marine ecosystem in a number of ways.

Having a clear understanding of the condition of sites and their features, and effective management of MPAs, is essential to achieving conservation objectives and securing an ecologically coherent and well managed network of MPAs in Wales.

Effective management of MPAs maximises their contribution to the health and resilience of marine ecosystems. There are various evidence gaps across social, economic (including development), and environmental uses of the marine environment that restrict the ability to ensure sustainable management of marine natural resources (See Marine chapter).

Case Study: Seagrass project fighting climate change and restoring important habitat

This case study is a great example of both a nature-based solution and where it is possible to optimise links between biodiversity and climate change.

Seagrasses are flowering marine plants found in shallow coastal waters and occur across the world in tropical and temperate regions. They have been declining globally at a rate of about 7% a year since 1990. In total, up to 92% of the plant may have disappeared from the UK's coast over the last century, due to algae-boosting pollution, anchor damage, and port and marina building.

Seagrass Ocean Rescue recently undertook the first major seagrass restoration project in the UK off Dale, within Pembrokeshire Marine SAC. The project by Swansea University and funded by WWF and Sky Ocean Rescue will monitor the growth of the seeds and infill with further seeds as required this year to hopefully produce a 2 ha meadow.

The marine environment plays a crucial role in climate regulation by acting as a sink for carbon in living tissue and oceans, and the longer-term sequestration of carbon in sediments (Armstrong, 2020). Seagrass beds and saltmarsh are good examples of “blue carbon” sinks (Armstrong, 2020).

Terrestrial

Changing agricultural management has had a major impact upon nature in the UK over recent decades (Hayhow *et al.*, 2019). Agricultural management therefore underpins the state of many terrestrial habitats in Wales, including mountains, moorlands, heaths, coasts, grasslands, and, implicitly, the state of woodland. For example, low-intensity grazing on grasslands with limited fertiliser and no ploughing can provide biodiverse habitat (Figure 11).

The key issues identified in SoNaRR chapters on terrestrial ecosystems in Wales affect all organisms, from bacteria and fungi, to plants, insects, birds and mammals. These include:

- Climate change: the risks are clearest for mountain habitats (to increased temperature), wetlands (to changes in water availability and deterioration in water quality) and coastal habitats (to sea-level rise).
- Land use management/change:
    - Intensive agricultural management has resulted in loss and degradation of habitats (for example, semi-natural grasslands, hedgerows, sand dunes, saltmarshes), and subsequently declines in species populations and habitat connectivity. Intensive agriculture also causes air pollution (such as

ammonia) which reduces biodiversity for example of lichens and mosses in ancient woodlands. Based on modelling, 61% of ancient semi-natural woodland in Wales are experiencing ammonia concentrations above the Critical Level for lichen- and moss-rich ecosystems. Similar exceedances occur in bogs, heathlands and acid grasslands.
    - Agricultural abandonment: While some farms have intensified and grown bigger, small farms and less productive areas have been abandoned. This has resulted in its own problems such as loss of biodiversity in increasingly shaded, wooded, and tall-growing grasslands. At the coast, scrub is also displacing priority species such as wild asparagus (*Asparagus officinalis* subsp. *prostratus*) and lichens.
- INNS: in Wales alone, 350 INNS have been identified as priority species that negatively impact the environment. They are found in most terrestrial habitats, in particular, woodlands, semi-natural grasslands, and urban areas. For example, American mink have had a devastating impact on water vole populations. Due to insufficient prevention measures in the face of complex introduction pathways such as the global transport and trade of goods and movement of people, new species are still arriving.

Many terrestrial plant species found in Wales but not elsewhere in Britain are characteristic of remote or agriculturally barren habitats like rocks and crevices, such as the Radnor lily *Gagea bohemica* (igneous rocks), the spotted rock-rose *Tuberaria guttata* (dry coastal rocks), and the Snowdon lily *Gagea serotina* (mountain rocks), found on the cool, north-facing slopes in Eryri. Some of the most important and richest examples of unimproved mesotrophic grasslands in Wales lie in the Elan Valley, in mid-Powys, but trends for grassland biodiversity nationally suggest little or no consistent improvement since the 1990s. Wales is globally important for grassland fungi, which are damaged both by cultivation and high nutrient levels; in recognition of this, grassland fungi habitats are excluded from Glastir Woodland Creation. Air pollution, especially ammonia from agriculture, limits mycorrhizal fungus growth in woodland to such an extent that some groups such as hydnoid fungi (Arnolds, 2010) are restricted to a handful of sites in the least polluted areas of Wales.

Figure 11 Examples of low intensity agricultural land use resulting in biodiverse habitat (photo credits: (left) Stuart Smith, (right) Julian Woodman).

Woodland, particularly ancient woodland, supports more threatened and vulnerable species than any other habitat (Welsh Government, 2018) but most of Wales's woods, both native and non-native, are in intermediate ecological condition (Forest Research, 2020). Ancient woodland comprises about 30% of all woodland in Wales. However, out of that aggregation, unperturbed woodland comprises approximately 41,800 ha, or 14% of all woodland (See Woodlands chapter and the Lle Geo-Portal for Wales for National Forest Inventory (NFI) and ancient woodland mapping data). As well as direct impacts of woodland management, much of the Welsh woodland resource is indirectly impacted by adjacent land management, especially agricultural air pollution.

Case Study: Whitebeam diversity is important

Whitebeams are small- to medium-sized trees in the genus *Sorbus* (along with rowan*, Sorbus aucuparia* and the service trees, Wild = *Sorbus torminalis* and True = *Sorbus domestica*). There are several species of whitebeam in the UK (38 at last count) and some of these are endemic in Great Britain. Some are endemic to Wales, for example, Leys whitebeam, *Sorbus leyana*, is only found in two locations north of Merthyr Tydfil.

This species diversity is mostly due to the way many of the whitebeams reproduce. Some have hybridised in the past and then gone through a process of doubling, tripling or quadrupling their chromosomes, a term known as polyploidy. All of these polyploid *Sorbus* species have then become apomictic; they produce fertile fruits without cross-pollination, and therefore produce clones, genetically identical to the mother tree. Some individuals are apomictic but can also be cross-pollinated by another species and hybridise.

The genetic and reproductive flexibility can make it difficult to separate the different species and hybrids, and this is where molecular studies help to confirm species identification. The process of polyploidy, apomixis and hybridisation has occurred over millennia and is still ongoing; new species have been identified in the last 20 years.

The Lower Wye Valley is the second-most diverse location for whitebeams in the British Isles with 19 taxa, second to the Avon Gorge with approximately 23 taxa (Rich *et al.,* 2019). The taxa of most conservation interest include *Sorbus anglica* (4 localities), *S. eminens* (7), *S. eminentiformis* (1), *S. porrigentiformis* (3) (Figure 12), *S. saxicola* (2) and *S. x tomentella* (3), with new species "Wyndcliff" found in Wyndcliff Quarry. *S. rupicola* and *S. x thuringiaca* are now extinct, with the single trees having died. The key *Sorbus* sites are Lady Park Wood and Highmeadow Wood, the Piercefield Park complex (Lover's Leap, Apostles' Rocks, Piercefield NE cliffs), Wynd Cliff and Wyndcliff Quarry.

The Lower Wye Gorge study refined the understanding of the most important sites for *Sorbus* diversity in the area, and important individual trees were georeferenced and marked on the ground to aid relocation. The study also revealed threats and areas requiring the most urgent conservation action.

The Lower Wye Gorge has high local species diversity, documented by various floras and studies since the 19th Century. Some of the Lower Wye Gorge is part of the Welsh Government Woodland Estate that was surveyed to map the individuals of this diverse but restricted group of trees (Rich *et. al*, 2019).

Figure 12 *Sorbus porrigentiformis*, Wintours Leap, Lower Wye Valley (photo credit: Dr Tim Rich).

Invertebrates

Entire groups of organisms can show coherent patterns of severe and wide-reaching declines in the health of habitats. The global decline of insects and other invertebrates has been in the spotlight since 2017, following the findings of a 76% decline in insect abundance on 63 nature reserves in Germany since 1989 (Hallmann *et al.*, 2017). Given their critical importance in nutrient recycling, soil development, pollination, pest control and the diet of many vertebrates, there have been calls for co-ordinated political efforts to address declines.

In the UK, Powney *et al.* (2019) reported widespread losses of pollinating insects. In Wales, there has been a 52% decline in butterfly species abundance since 1976 (Hayhow *et al.*, 2019). Recent insect extinctions from Wales are in habitats identified as threatened by land use change and management. These include the fly Barred Green Colonel *Odontomyia hydroleon* associated with seepages in meadows (last recorded in 2006), the Belted Beauty moth *Lycia zonaria* of herbaceous sand dunes and salt marshes (2012), the moth Orange Upperwing *Jodia croceago* of oak woodlands and hedgerows (1994), and perhaps the caddisfly *Limnephilus tauricus (*2008) of fens.

Other invertebrates are at risk of extinction, such as the Large Mason Bee *Osmia xanthomelana* of coastal grasslands, the Strandline Beetle *Eurynebria complanata* of sand dunes, Gipsywort Weevil *Datonychus arquatus* of wetlands, the beetle Red

Dune Crawler *Rhysothorax rufa* of sand dunes, and the stonefly Scarce Yellow Sally *Isogenus nubecula*. The Yellow Sally demonstrates how interlinked terrestrial and freshwater habitats are. Its larvae grow in water and, therefore, water pollution is threatening the entire species. A total of 15% of the 664 spider species in Great Britain are under threat of extinction (Harvey *et al.*, 2017), including *Agroeca dentigera* which in the UK is known only from the Ynyslas sand dunes in the Dyfi NNR. Geyer's Whorl Snail *Vertigo geyeri* is no longer found on Cors Erddreiniog SSSI and Cors Geirch SSSI following surveys in 2019 (Willing, 2020) and now only occurs at just a single Welsh locality. Some of these species which are at risk of extinction are entirely restricted to Wales in the UK.

Case Study: marsh fritillary butterfly, a species on the brink of extinction in Wales

The marsh fritillary *Euphydryas aurinia* is classed as Vulnerable in Great Britain and is an Annex II species. It is primarily associated with wet grassland in Wales (Figure 13), although the largest population is associated with limestone grassland on Castlemartin Range SSSI, with larvae feeding on Devil's-bit scabious *Succisa pratensis.* The butterfly exists as metapopulations, comprising groups of local populations connected by occasional dispersal. The butterfly requires between 76 and 104 ha of suitable habitat within a defined landscape for its long-term survival (Bulman *et al.*, 2007). The current NRW marsh fritillary landscape model considers 50 ha of Good and Suitable Condition habitat, of which 10 ha is in Good Condition, within a 2 km radius (functional landscape) as an appropriate target for achieving Favourable Condition (Fowles, 2005). However, only a few Welsh SACs and SSSIs achieve these thresholds. The marsh fritillary is a feature of 37 SSSIs and 13 SACs although it has either been lost or reduced to very small, isolated populations on many protected sites. For example, it was last recorded on Glaswelltiroedd Cefn Cribwr / Cefn Cribwr Grasslands SAC in 2003. Historic and contemporary losses (Figure 13) are the result of habitat loss, under-grazing or over-grazing and habitat fragmentation, severely impacting upon metapopulation functioning and isolating sites. Many of the remaining 38 occupied landscapes now contain less than the 50 ha threshold to support viable populations. Urgent action is required to safeguard remaining populations, providing enough suitable habitat in a connected landscape.

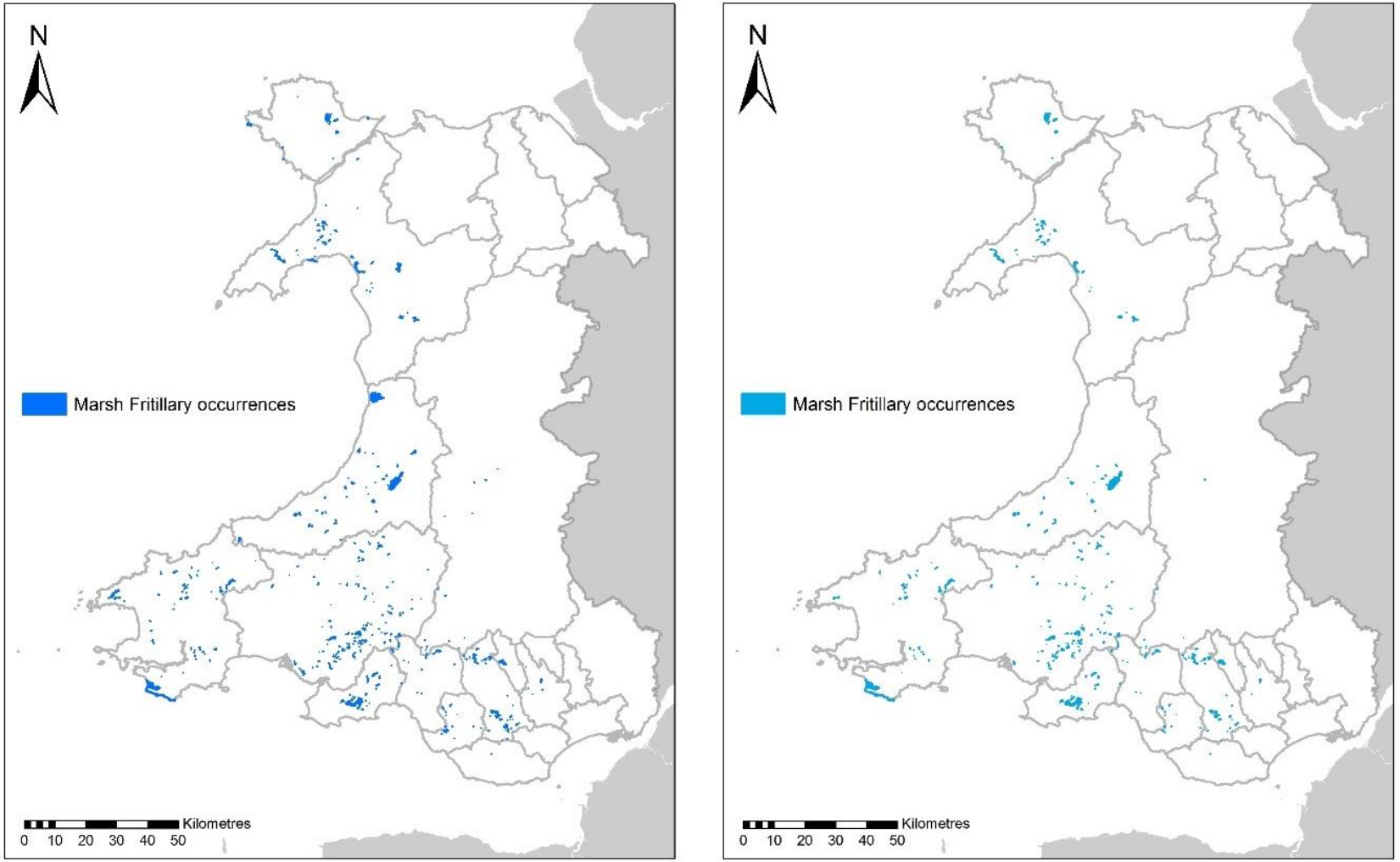

Figure 13 (L-R) Historic (2000) distribution of marsh fritillary in Wales (left); and current (2018) distribution of marsh fritillary in Wales (right) (Butterfly Conservation, 2021). Contains UK Butterfly Monitoring Scheme (UKBMS) data © Copyright and database right Butterfly Conservation, the Centre for Ecology and Hydrology, British Trust for Ornithology, and the Joint Nature Conservation Committee, 2021.

Vertebrates

From the coast and sea to woodlands and mountains, Wales supports a large proportion of the UK populations of several UK breeding and wintering bird species. These include seabirds such as Manx shearwaters and gannets; choughs on Welsh coasts and mountains; and woodland species, such as pied flycatchers and wood warblers. Welsh lowland farmland priority species show six declining in range by more than 25% over the longer term period (1970–2010) (Bladwell *et al.,* 2018) and the lowland farmland bird indicator has fallen by nearly 30% since 1994, due to continuing farm intensification and loss of seed and invertebrate food resources. Many species have declined for unconfirmed reasons and are under investigation (Massimino *et al.*, 2019). However, some of those that have declined the most between 1995 and 2018 involve confirmed human agency: swifts (modern building design); curlew (habitat loss; draining of grasslands); and yellowhammer (agricultural intensification in England and highly likely to apply in Wales also); based on the breeding bird survey which best captures trends in species that are not (yet) rare (See also Hayhow *et al.*, 2019). The Greenland white-fronted goose (GWfG) (*Anser albifrons flavirostris*), over-winters only in Britain and Ireland, feeding on saltmarsh and grazing marsh. In Wales, there remains only one regular over-wintering flock, on the Dyfi Estuary, which is declining rapidly (167 birds in 1998/99 to 26 birds in 2017/18) (Mitchell *et al.*, 2018). There is a real possibility that GWfG could be lost as an overwintering species from Wales within the next couple of decades (See Coastal margins chapter).

Amphibians and reptiles have also suffered declines in Wales and are particularly vulnerable to the effects of habitat loss, fragmentation and change in condition. The State of Mammals in Wales (Mathews *et al.*, 2020) reports that 1 in 3 species are threatened with extinction in Wales; hedgehog populations are estimated to have declined by 60% since 1995 and water voles continue to be the fastest declining species. Welsh dormouse populations have declined by 79% between 1993 and 2014 (McDonald, 2017) and analysis of factors affecting dormouse populations in England and Wales have highlighted the importance of woodland management to improve habitat quality (Goodwin *et al.*, 2018).

Case Study: Water vole, protecting one of Wales's most endangered mammals

The water vole *Arvicola amphibious* (Figure 14), is fully protected under the Wildlife and Countryside Act 1981 (as amended). They are the fastest declining mammal in Wales and a priority for conservation efforts. Habitat loss and fragmentation due to agricultural intensification and development habitat degradation due to poor land management and insensitive watercourse management continue to be significant threats to water voles. Populations have also suffered from predation by the introduced American mink.

The Living Levels Landscape Partnership Scheme is funded by the National Lottery Heritage Fund and led by the RSPB Cymru. Core partners include NRW and the Gwent Wildlife Trust. One of the objectives of the programme has been to restore the extensive network of field ditches that criss-cross the landscape. These ditches

support the interest features of the Gwent Levels' SSSIs and are a key part of the gravity fed system for managing water levels. The drainage system of reens and ditches extends to 1,629 km. Many of the field ditches have become so overgrown that landowners struggle to maintain them, affecting biodiversity, water quality and water flow. The aim of opening the ditches is to improve the ecology and resilience of the system by reconnecting important habitats, while enabling their ongoing management by landowners.

After an absence of many years, water voles were reintroduced to the Gwent Levels in 2012/13. More than 200 captive bred water voles were released at the Magor Marsh Nature Reserve. Since then, the population has established and spread westwards across the Levels using the network of drainage ditches and reens, reaching as far as Newport Wetlands NNR, some 10 km from the reintroduction site. This successful reintroduction has been assisted by careful management of reens by NRW and active control of mink numbers by the Gwent Wildlife Trust. The work of the Living Levels programme to restore field ditches will further support this reintroduction. Other successful water vole reintroduction projects include Ffrwd Farm Nature Reserve in Carmarthenshire and Cosmeston Park SSSI in the Vale of Glamorgan.

Figure 14 The water vole *Arvicola amphibius* (photo credit: NRW).

7. What is the future for biodiversity?

Biodiversity is linked through complex ecological webs: declines in one species or habitat may have knock-on effects to others that might be unexpected. As species depend on a diverse range of conditions and niches, their requirements vary with seasons and life-cycle stages and they will not all respond in the same way or over the same timescales. Biodiversity decline can be a very long process with impacts sometimes taking years, decades or even centuries to become fully apparent. For these reasons, while simple solutions or quick fixes help reverse some aspects of biodiversity decline, it is important to remember that recovery can take many decades for some species and complex ecosystems. Hence the need for more rapid action that is underpinned by strategic transformational ambition.

The Making Space for Nature report (Lawton, *et al.* 2010) advocated the development of a coherent ecological network to help counter the pressures and allow nature to re-establish and flourish. The report suggested that what is needed to enhance the resilience and coherence of ecological networks can be summarised as more, bigger, better, and joined up; these are still relevant today. Delivering long-term biodiversity improvement can be achieved by making space for and supporting natural processes that enhance landscape diversity. To work with nature, society needs to understand nature (Crofts, 2019).

The Interim Report (Dasgupta, 2020) calculated ecosystems as economic assets give an annual rate of return on investment of over 19%, far greater than most conventional assets. The final report of the Dasgupta review (Dasgupta, 2021) makes clear that our economies are embedded within nature, not external to it. It flags three broad and interconnected transitions that are needed to support biodiversity recovery: 1) ensure that our demands on nature do not exceed its supply, and that we increase nature's supply relative to its current level; 2) change our measures of economic success; and 3) transform our institutions and systems.

To deliver a regenerative economy that accommodates biodiversity's needs will involve systemic change across many interlinked social, economic and environmental systems. The IPBES global assessment report summary for policymakers (IPBES, 2019) describes the key levers for transformational change being:

- Incentives and capacity-building
- Cross-sectoral cooperation
- Pre-emptive action
- Decision-making in the context of resilience and uncertainty
- Environmental law and implementation

As highlighted by the Making Space for Nature report, the IPBES assessment (IPBES, 2019) and the Dasgupta Review, halting biodiversity decline means tackling the root causes and reducing human impacts. This applies not just in more typically rural or remote areas but also urban areas where much can be done to establish more nature-friendly green spaces for example. Designing plans and approaches

with these aspects in mind alongside wider landscape needs that implement effective nature-based solutions will maximise multiple benefits. This includes restoring existing precious habitats and creating new areas to improve overall habitat condition and delivering targeted action for declining species or those on the edge of extinction, such as curlew, Atlantic salmon, native oyster, the marsh fritillary butterfly, shrill carder bee, and red squirrel.

It is also important to consider genetic diversity which is the basis for evolutionary change and critical for species to successfully adapt to changing climate, habitats, and biotic interactions including novel diseases (Hoban *et al.,* 2020). There is abundant evidence about the substantial role of genetic diversity in ecosystem resilience, and for maintaining species diversity (Hoban *et al.,* 2020).

The response of biodiversity to climate change also requires an understanding about geodiversity and natural processes. Physical changes may include increased rates, intensity and seasonality of flooding, droughts, landslides, erosion and sediment supply, channel mobility and coastal erosion. The shape and location of landforms may change, for example, with more mobile river systems. Saltmarsh and sand dunes may migrate landward, and coastal slopes may steepen.

Some of these physical changes may occur faster than some species can adapt to them. Consequently, interventions need to accommodate the effects of changing physical processes and requires application of geoscience knowledge and geoconservation principles. Geodiversity conservation will also be important in preserving temporal records of environmental change and historical variability (for example, pollen spores, fossil landforms).

Supporting the Welsh policy context for improving biodiversity

The second goal of the Well-being of Future Generations Act is to have a resilient Wales that supports social, economic and ecological resilience through maintaining and enhancing a biodiverse natural environment and healthy functioning ecosystems.

The objective of SMNR as described in the Environment (Wales) Act 2016, outlines that NRW must maintain and enhance the resilience of ecosystems and the benefits they provide now and for future generations. Halting and reversing biodiversity loss is integral to this objective (See Ecosystem resilience chapter).

All public authorities who exercise functions in relation to Wales share the same duty to maintain and enhance biodiversity and in doing so, promote the resilience of ecosystems under Section 6 of the Environment (Wales) Act. Using the SMNR principles greatly enhances NRW's ability to meet its Section 6 biodiversity duty and for others, also embracing these principles would similarly enhance their biodiversity improvement contributions in Wales.

Section 16 of the Environment (Wales) Act enables NRW to enter into agreement with land managers that offers a significant partnership opportunity with a more diverse range of stakeholders for biodiversity enhancement that may not be possible

through other mechanisms. This can include for example, protecting SSSI qualifying features awaiting notification, non-agricultural land agreements, adopting specialist management techniques for sensitive species or habitats, habitat restoration or creating 'buffer' sites.

Alongside the Section 6 duty, the Section 7 habitats and species are those considered of principal importance for the purpose of maintaining and enhancing biodiversity in Wales. The interim Section 7 list has 557 species and 55 habitats of principal importance and once the new section 7 list is finalised, an appropriate mechanism will be established for future status reporting.

Section 23 gives NRW the power to conduct experimental projects to develop or apply new or modified methods, concepts or techniques, and to develop or test proposals for regulatory change. Wider adoption of adaptative management techniques would help with exploring new ways to achieve biodiversity recovery.

The Nature Recovery Action Plan (NRAP) (Welsh Government, 2015) has been refreshed (Welsh Government, 2020) to account for the growing evidence around the scale of biodiversity loss and the changing Welsh, UK and international policy context. It focuses on both spatial actions to deliver species and habitats benefits and transformative action to influence behaviour and investment decisions to help maintain and enhance biodiversity. It includes more immediate actions alongside longer-term commitments that will be determined through the post-2020 global biodiversity framework. Its five immediate priorities are: aligning climate emergency responses with the biodiversity crisis, addressing the post EU exit funding gap for agri-environment measures, providing spatial direction for targeted biodiversity action, improving condition of the Protected Sites Network and exploring new and sustainable funding mechanisms for biodiversity action.

Many mechanisms and actions to address biodiversity decline require collective input from across the public, private and third sectors alongside the work by any particular group or organisation. As highlighted by the recent Dasgupta Review (Dasgupta, 2021), building capacity at all levels is essential to enable more effective delivery and to expand the response needed to halt and reverse biodiversity decline. Local Authority Public Service Boards (PSBs) for example are a mechanism to enable a collective response by public authorities across Wales and similar mechanisms enabling this way of working across other sectors are equally important.

Area Statements have a key role in identifying biodiversity improvement opportunities that can be adopted or developed by for example public authorities to help with delivering their Section 6 biodiversity duty. Area Statements provide Local Authorities with biodiversity related information when producing Local Development Plans (LDPs) which influence local level development decisions. Local Authority Green Infrastructure Assessments are also a key mechanism for actions that will help deliver both well-being and nature-based improvement opportunities. These assessments have to draw on evidence provided through Area Statements.

The Welsh Government has worked with industry and others to look in more detail at the evidence and issues around pollinators and their conservation in Wales. The Action Plan for Pollinators in Wales (Welsh Government, 2013) was launched setting the strategic vision, outcomes, and areas for action to halt and reverse pollinator

decline in Wales. In 2018, this action plan was reviewed, and the actions updated. Additional strategic approaches to supporting other groups of species with, for example, similar functional traits would also be beneficial.

Opportunities for biodiversity enhancement

Building on the existing investment in biodiversity action, the opportunities for further action through those outlined in each of the ecosystem chapters will help Wales respond to the drivers behind biodiversity decline and with more immediate action for habitats or species under more rapid decline.

Recognising the accelerating rate of species extinctions, more immediate and ambitious transformative changes are needed at a far-reaching scale to halt further loss and support biodiversity restoration so Wales can fulfil Goal 2 of the Well-being of Future Generations Act as a socially, economic and ecologically resilient country.

Protected habitats and species

Create a coherent and resilient ecological network of protected sites: There is a real opportunity to improve the effectiveness and resilience of protected sites individually, as well as improving their position within the wider landscape through evidence-based spatial planning. Terrestrial and freshwater protected sites currently only occupy 12% of the area of Wales and often form a series of independent and usually fragmented sites. Protected areas which include SSSIs, Areas of Outstanding Natural Beauty (AONB) and National Parks cover nearly 30% of Wales land area which is close to the IUCN recommended target and represents “business as usual”. A recent paper published in Nature (LeClère *et al.*, 2020) advised that 40% was more appropriate for terrestrial biodiversity. This can be addressed by strategically increasing their number, area, connectivity, ecological quality and condition, so that they start to form functional ecological networks in which habitats and species populations can thrive and expand, adapt to change, and help confer resilience and improved ecosystem services to the wider environment. Additionally, sufficient monitoring data need to be collected. These data are vital for tracking biodiversity change, determining the effectiveness of biodiversity policy, delivering strategic outcomes, and providing alerts of changes to the environment. Technical advances like eDNA, opportunity mapping, and earth observation could assist in this delivery, but this must not displace invaluable on-the-ground expertise and observation.

Deliver targeted action for species: Delivering a prioritised and coordinated approach to species-level interventions will support many species threatened with imminent extinction or showing significant decline. This approach can include large-scale projects and partnership programmes as demonstrated by existing and planned programmes on the most threatened species. Examples include the LIFE Dee River project and RSPB’s Curlew LIFE project. The proposed species restoration partnership project ‘Natur Am Byth!’ will unite eNGOs, communities and NRW to boost populations for over 60 of Wales’s most threatened species. The multi-taxa approach will integrate conservation measures in 11 projects across Wales – uniting communities and volunteers to take action for wildlife on their doorstep. The ‘Natur Am Byth!’ national communications and engagement

programme will celebrate the intrinsic value of biodiversity and well-being benefits of connection to nature.

Working with others

Roll out nature-based solutions to drive forward the themes in the Area Statements: Area Statements establish opportunities for place-based, nature-based solutions in a local context. Collaborative working at a local level is an effective way to engender and harness the behaviour change needed to support national challenges as well as local biodiversity priorities. Natural flood management measures are an example of where implementing nature-based solutions helps reconnect flood plains, restore and improve habitats, increase biodiversity, and build resilience throughout Wales's river network.

Investing in biodiversity recovery: the Dasgupta Review (Dasgupta, 2021) highlights the economic significance of biodiversity and ecosystems for all sectors and at all levels. It highlights the need to explore how investment and funding mechanisms are and can be managed and used to support more sustainable, collaborative interventions to protect and enhance vulnerable species or habitats and for biodiversity more broadly. Longer-term funding for partnership programmes, for example, would encourage larger-scale and more ambitious projects providing multiple benefits.

Adapting Policies and Guidance

Planning, land use and agricultural systems need to adapt to work with nature as part of the transformative changes called for in the IPBES 2019 global assessment (IPBES, 2019): Transformative change is needed across all social, political and technological aspects including further investment from both public and private sectors. It will require advice and support, so businesses move beyond current regulatory baselines and for citizens and business to understand and change their demands for and use of natural resources. Some aspects of change may take time to develop even with this support, and increasing the extent of land under conservation management, restoring degraded land, and planning landscape-level conservation will deliver positive benefits for biodiversity trends by the mid-21st century (Leclère *et al*., 2020). Developing appropriate biodiversity targets could form a key policy instrument to support this.

More evidence is needed to understand renewable energy impact to ensure a low-carbon economy does not conflict with biodiversity targets: Renewable energy projects need to more actively benefit biodiversity, for example, by having the right development in the right place, employing nature-based solutions, and accounting for the entire life cycle of energy production (See Energy efficiency chapter).

Robust oversight and enforcement of environmental laws in Wales is needed: to make the most of environmental assessment, regulation, good practice, and standards

Agri-environment: Proposals for a post-EU exit land management scheme will see a move towards the delivery of key public goods and services through payment support, which offers potential for biodiversity. This approach would be enhanced by supporting collaboration, such as farm cluster projects, developing the ecosystem services marketplace and offering high-quality advice to each sector. The post-EU exit transition period and final scheme may not focus on species recovery so additional mechanisms will be required.

Transformative change is required from all sectors and this could be achieved through support mechanisms and guidance that build:

- Wider understanding of the importance of nature-based solutions and how they might be applied using the global standards (IUCN, 2020).
- The widespread adoption of good practice guidance and environmental standards.
- Integrated policy interventions that support desirable environmental behaviours and promote partnership working using the principles of SMNR.
- Ability for conflicting priorities to be resolved, for example, tree planting on existing semi-natural habitats.
- Regulatory and technological fixes that reduce and modify pressures.

Optimising opportunities for ecosystem resilience

Welsh Government's Natural Resources Policy and refreshed Nature Recovery Action Plan 2020-21 state the need to proactively develop resilient ecological networks (RENs) which are defined as "… *networks of habitat in good ecological condition linking protected sites and other biodiversity hotspots across the wider landscape, providing maximum benefit for biodiversity and well-being. Such nature networks have existing or potential for healthy resilient ecosystems which provide a range of important ecosystem services as well as allowing the movement of species across landscapes in response to climate change*."

RENs have two major components: protected sites and ecological networks. The latter component represents the spaces in between SSSIs that can be used to extend, buffer and connect their biodiversity. When adequately protected and managed, ecological networks not only contribute to the favourable condition of individual protected sites but also make significant contributions to the Favourable Conservation Status of habitats and species at a country level and beyond. The need to formally acknowledge ecological networks is recognised at an international level by the IUCN (Hilty *et al.*, 2020) because of their indispensable role as part of healthy functioning ecosystems.

Some examples of methods to develop RENs could include:

Increase wildflowers for roadside verges by 20%: Roadside verges account for approximately 10,000 ha of land in Wales, and provide a significant opportunity to benefit wildlife, especially pollinators, because many such taxa are highly mobile and thereby able to use small, isolated habitat patches across landscapes (Phillips *et. al.,* 2020). However, current verge mowing practices are harmful for wildlife and biodiversity. Many local authorities are doing their best to improve them, but ultimately a policy decision is required to enable them to stop cutting grass verges at

certain times of the year, while still meeting road safety requirements. Creating these wildlife corridors will complement action to maintain and enhance semi-natural habitats and result in improved connectivity and resilience of ecosystems. Improving connectivity has particular benefits because it allows species to move naturally between sites, thereby increasing genetic diversity and thus, allowing recovery from local extinctions.

Riparian buffer strips along every river in Wales: As well as providing important riparian corridors for wildlife and increasing connectivity, buffer strips of vegetation provide a physical barrier to slow water run-off and reduce riverbank erosion. As a result, they are important in reducing diffuse pollution thereby improving water quality. Improving these wildlife corridors will not only complement action to maintain and enhance habitats, but will ultimately improve diversity, extent, condition, connectivity and adaptability along Welsh rivers.

Provide buffer strips for every hedgerow and improve hedge cutting policies for wildlife: Look for opportunities to restore and create hedgerows, especially linking up existing hedges and woodland edges and provide buffer strips for hedgerows. Brown hairstreak butterfly is an example of a species that has undergone a substantial decline due to hedgerow removal and annual flailing which removes eggs (Butterfly Conservation, 2021). As a minimum, hedges should be left uncut every other year. This will also have benefits for other wildlife, especially birds.

Allow and promote natural regeneration of trees for biodiversity, connectivity, and the long-term development of functional ecosystems: From an ecosystem services point of view, woodlands are diverse, providing flood risk mitigation, carbon capture, recreation, and obviously, wood, to name a few. As such, tree planting and accelerated rates of new woodland creation deliver wide-ranging benefits. However, as with all wildlife management, it is vital that such schemes are carried out with care and knowledge. Schemes need to avoid damaging other valuable natural habitats and would benefit from complementing existing woodland cover to increase connectivity. Tree species selection is key, as, for example, native species have much more to offer for biodiversity than non-native conifers (Welsh Government, 2018). Natural regeneration is the process by which woodlands are (re)generated from trees that germinate from locally dispersed seeds, largely consisting of native tree species, instead of from artificial regularly spaced planting in plastic tubes (which furthermore tends to be saplings of the same age class). Natural regeneration within and adjacent to ancient semi-natural woodland is particularly valuable in buffering ancient woodland against pressures such as farming and infrastructure projects (See Woodlands chapter). Finally, it needs to be recognised that ecologically mature woodland habitat, which is intimately linked with biodiversity, may take centuries to establish and can have very little to do with the simple presence of trees. This is precisely why so many species of fungi, plants, invertebrates, and even birds, are used as indicator species for old forests, and why there are clear patterns to which species are becoming rarer (if not extinct) and which are thriving (Harkki *et al.*, 2003).

Large-scale habitat and targeted species restoration strategies for Wales

To mark the beginning in 2021 of the United Nations Decade of Ecosystem Restoration, NRW could develop integrated strategic large-scale restoration programmes for priority habitats.

A national strategy for identifying populations of priority species that require additional targeted interventions to re-establish population viability could be linked to habitat restoration programmes. Both of these approaches would deliver multiple benefits for people and biodiversity.

A considerable amount of work is being undertaken on the ground to tackle INNS in Wales, but the differing drivers, organisations and spatial scales involved demonstrate that there is capacity to improve coordination of these activities. This could be addressed by developing a strategic, coordinated, evidence-based steer for action to inform decision makers and funders to enable INNS issues in Wales to be addressed more effectively.

8. Evidence needs

Background

The biodiversity evidence needs identified below have been collated from the other SoNaRR chapters. NRW has further collaborated with the Welsh Biodiversity Partnership, which has collaborated with universities and other stakeholders to create the Biodiversity and Ecosystem Evidence Needs programme. The programme funds research and is linked with NRW's Marine Biodiversity Collaborative Research Priorities. Those interested in further detail on evidence needs can refer to these web resources as well as the full SoNaRR evidence needs list on our SoNaRR2020 webpage.

Summary

A common theme across SoNaRR ecosystems is the need to connect fundamental evidence gaps in the ecological condition of protected features and sites, as well as important habitats more widely, for example, semi-natural grasslands. This is because habitats need to be in satisfactory ecological condition to be able to support biodiversity more generally, as well as the rarest species which overall are continuing to decline in Wales (see other sections of this chapter).

Ecological condition evidence was raised as a priority specifically for:

- Enclosed farmland, which includes orchards, hedgerows, wood pasture, alongside arable land more generally;
- Ancient woodland, including historical ancient woodland sites that have been planted on and are being restored;
- Coastal margins;
- Mountains, moorlands and heaths; and

- Semi-natural grasslands, inside and outside statutory protected sites

Mapping needs, both historical and current, were raised for some habitats and species to fill in knowledge gaps in their extent – an exercise that would also benefit the development of restoration plans that support ecological connectivity. This evidence need was raised for enclosed farmland; soil erosion; semi-natural grassland (for example, for uncommon species trends); freshwater (to understand trends in connectivity); mountains, moors, and heath; planted ancient woodland sites under restoration and woodland pest and disease outbreaks; coastal margins; marine habitats, to support the delivery of the National Marine Plan, and to understand the effects of sea-level rise on important coastal habitats that already are fragmented; and for INNS which by definition have an evolving distribution and so ways to encourage people to report them are sought. Developing longer-term records of change in the extent and location of habitats and species is crucial for comprehending a landscape and its management needs at any one point in time. A better understanding how the spread of INNS is impacting Welsh habitats specifically is also needed.

Mapping needs were also highlighted for chemical compounds that can negatively impact biodiversity. These include ground-level ozone, which inhibits plant growth and occurs when nitrogenous exhausts from vehicles and industry react with heat and sunlight. In Wales, its potential effects are mostly unknown without more evidence of its concentration and spread. Ammonia, a nitrogenous compound released from manures, slurries and fertiliser, causes declines of nitrogen-sensitive plants, fungi and lichens especially in habitats near intensive agriculture. Impacts across Wales are mostly modelled, but there is a need for more measurement sites to improve the accuracy of the models. A need to understand the impacts of ammonia pollution on woodland and semi-natural grassland habitats was specifically raised.

With habitats and species being or becoming rare, the importance of **tracing genetic diversity** was highlighted, as it is fundamental to the long-term survival of most species. This includes tree species in Wales and repercussions on resilience; and whether animal and plant species in semi-natural grasslands are already suffering low genetic diversity.

In some cases, **evidence is needed to support recovery of habitats**. For example, some key habitats and species in the marine and coastal environment are declining for unknown reasons. Methods to successfully diversify greatly simplified mountain, moorland and heath habitats are sought. Methods to reverse the international trend of invertebrate declines are sought for enclosed farmland habitats, including scrutiny into pesticide effects on invertebrates living in soil.

Climate change is making winters increasingly likely to be wet, and summers dry. **More information is needed on current and projected water scarcity in Wales and its impacts on river ecosystems** (whether purely from climate change or a combination of climate change and excessive withdrawal of water for human consumption). This information will support better water consumption management and decision-making in the future.

For Wales's urban environments the focus on creating and maintaining green spaces plus the increasing appreciation of nature in the wake of COVID-19 provides an opportunity to ensure there are more biodiverse green spaces. These will also help promote long-term well-being and other socio-economic benefits. There is a need for **more co-ordinated socio-economic evidence gathering and information about the benefits that nature and biodiverse spaces provide**. This also applies more broadly about **information to increase awareness about the need for transformational change to deliver biodiversity recovery across all sectors.**

9. References

Alexander KNA. 2018. Saproxylic invertebrate survey of Wye Valley Woodlands Special Area of Conservation (SAC) in 2017. NRW Evidence Report No. 245. Natural Resources Wales, Bangor.

Alexander KNA. 2019. An assessment of the current condition of the saproxylic invertebrate assemblage at Castell y Waun a'i Barcdir/Chirk Castle and Parkland SSSI in 2018. NRW Evidence Report No. 317. Natural Resources Wales, Bangor.

Alexander KNA. 2020. Identification of saproxylic invertebrate samples collected in flight interception traps at Coppice Mawr and other sites in the lower Wye Valley in 2019. NRW Evidence Report No. 452. Natural Resources Wales, Bangor.

Alison J, Maskell LM, Smart SM, Feeney C, Henrys PA, Botham M, Robinson DA, Emmett BA. 2020. Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP). ERAMMP Report 30: Analysis of National Monitoring Data in Wales for the State of Natural Resources Report 2020. Report to Welsh Government (Contract C210/2016/2017). UK Centre for Ecology & Hydrology Project 06297. Available from: https://erammp.wales/en/gmep-data-analysis [Accessed December 2020]

Armstrong E. 2016. Research Briefing: The Farming Sector in Wales. National Assembly for Wales Research Service. Paper 16-053. Available from: https://senedd.wales/research%20documents/16-053-farming-sector-in-wales/16-053-web-english2.pdf [Accessed March 2021]

Armstrong S, Hull S, Pearson Z, Wilson R, Kay S. 2020. Estimating the Carbon Sink Potential of the Welsh Marine Environment. NRW Evidence Report No. 428, Cardiff.

Arnolds E. 2010. The fate of hydnoid fungi in The Netherlands and Northwestern Europe. Fungal Ecology 3: 81-88.

Balmer DE, Gillings S, Caffrey BJ, Swann RL, Downie IS and Fuller RJ. 2013. Bird Atlas 2007-11 the breeding and wintering birds of Britain and Ireland. BTO Books, Thetford

Bat Conservation Trust. 2020. The National Bat Monitoring Programme Annual Report 2019. Bat Conservation Trust, London. Available from:https://www.bats.org.uk/our-work/national-bat-monitoring-programme/reports/nbmp-annual-report [Accessed 4 February 2021].

Blackstock TH, Howe EA, Stevens JP, Burrows CR, Jones PS. 2010. Habitats of Wales: A Comprehensive Field Survey 1979-1997. University of Wales Press

Bladwell S, Noble DG, Taylor R, Cryer J, Galliford H, Hayhow DB, Kirby W, Smith D, Vanstone A, Wotton SR. 2018. The state of birds in Wales 2018. The RSPB, BTO, NRW and WOS. RSPB Cymru, Cardiff.

Brown D J, Wilson J, Douglas D, Thompson P, Foster S, McCulloch N, Phillips J, Stroud D, Whitehead S, Crockford N and Sheldon R. 2015. The Eurasian Curlew – the most pressing bird conservation priority in the UK? British Birds 108: 660–668

BTO. 2018. The Breeding Bird Survey 2018 incorporating the Waterways Breeding Bird Survey Population trends of the UK's breeding birds. BTO Research Report 717. British Trust for Ornithology. Thetford. 2018.

Bulman CR, Wilson RJ, Holt AR, Bravo LG, Early R, Warren MS Thomas CD. 2007. Minimum viable metapopulation size, extinction debt and the conservation of a declining species. Ecological Applications. 17: 1460-1473.

Burns F, Eaton MA, Barlow KE, Beckmann BC, Brereton T, Brooks DR, *et al.* 2016. Agricultural Management and Climatic Change Are the Major Drivers of Biodiversity Change in the UK. PLoS ONE 11(3): e0151595. Available from: https://doi.org/10.1371/journal.pone.0151595 [accessed March 2021]

Butterfly Conservation. 2021. Brown hairstreak *Thecla betulae* [online]. Available from: https://butterfly-conservation.org/butterflies/brown-hairstreak [Accessed March 2021]

Butterfly Conservation. 2021. UK Butterfly Monitoring Scheme (UKBMS) data.

CIEEM. 2019. Climate Emergency and Biodiversity Crisis: The Facts and Figures, CIEEM Briefing Paper. September 2019. Chartered Institute of Ecology and Environmental Management.

Crofts R. 2019. Linking geoconservation with biodiversity in protected areas. *International Journal of Geoheritage and Parks* 7: 211-217. Available from: https://www.sciencedirect.com/journal/international-journal-of-geoheritage-and-parks/vol/7/issue/4 [Accessed 4 February 2021]

Croose E. 2016. The Distribution and Status of the Polecat (*Mustela putorius*) in Britain 2014-2015. The Vincent Wildlife Trust.

Dasgupta P. 2020. The Dasgupta Review – Independent review on the economics of biodiversity, Interim Report, April 2020. Available from: https://www.gov.uk/government/collections/the-economics-of-biodiversity-the-dasgupta-review [Accessed March 2021]

Dasgupta P. 2021. The Dasgupta Review – Independent review on the economics of biodiversity, Final Report, February 2021. Available from: https://www.gov.uk/government/collections/the-economics-of-biodiversity-the-dasgupta-review [Accessed March 2021]

Emmett BE, Abdalla M, Anthony S, Astbury S, August T, Barrett G, Beckman B, Biggs J, Botham M, Bradley D, Brown M, Burden A, Carter H, Chadwick D, Cigna F, Collier R, Cooper D, Cooper J, Cosby BJ, Creer S, Cross P, Dadam D, Edwards F, Edwards M, Evans C, Ewald N, Fitton A, Garbutt A, Giampieri C, Gooday R, Grebby S, Greene S, Halfpenney I, Hall J, Harrison S, Harrower C, Henrys P, Hobson R, Hughes P, Hughes S, Illian J, Isaac N, Jackson B, Jarvis S, Jones DL, Jones P, Keith A, Kelly M, Kneebone N, Korenko J, Lallias D, Leaver D, Lebron I, Malcolm H,

Maskell L, McDonald J, Moxley J, Norton L, O'Hare M, Oliver T, Owen A, Parkhill KA, Pereira M, Peyton J, Pogson M, Powney G, Pritchard N, Pritchard S, Prochorskaite A, Prosser M, Pywell R, Rawlins B, Reuland O, Richards M, Robinson DA, Rorke S, Rowland C, Roy D, Scarlett P, Scholefield P, Scott A, Scott L, Scott R, Sharps K, Siriwardena G, Smart S, Smith G, Smith P, Stopps J, Swetnam R, Taft H, Taylor R, Tebbs E, Thomas A, Todd-Jones C, Tordoff G, Turner G, Van Breda J, Vincent H, Wagner M, Waters E, Walker-Springett K, Wallace H, Watkins J, Webb G, White J, Whitworth E, Williams B, Williams P, Wood C, Wright S. 2017. Glastir Monitoring & Evaluation Programme. Final Report to Welsh Government - Executive Summary (Contract reference: C147/2010/11). NERC/Centre for Ecology & Hydrology (CEH Projects: NEC04780/NEC05371/NEC05782).

Forest Research. 2020. National Forest Inventory. NFI Woodland Ecological Condition. Available from: https://www.forestresearch.gov.uk/tools-and-resources/national-forest-inventory/what-our-woodlands-and-tree-cover-outside-woodlands-are-like-today-8211-nfi-inventory-reports-and-woodland-map-reports/nfi-woodland-ecological-condition/ [Accessed March 2021]

Forestry Commission. 2017. The UK Forestry Standard. Forestry Commission, Edinburgh.

Fowles AP. 2005. Habitat quality mapping for marsh fritillary populations. CCW Natural Science Report No. 05/5/1. Countryside Council for Wales, Bangor.

Geist J and Auerswald K. 2007. Physicochemical stream bed characteristics and recruitment of the freshwater pearl mussel (*Margaritifera margaritifera*). Freshwater Biology, 52, 2299-2316.

Geist J. 2010. Strategies for the conservation of endangered freshwater pearl mussels (*Margaritifera margaritifera* L.): a synthesis of Conservation Genetics and Ecology. Hydrobiologia, 644, 69-88.

Gibbons DW, Reid JB and Chapman RA. 1993. The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991. T & A.D. Poyser, London

Goodwin CED, Suggitt AJ, Bennie J, Silk M, Duffy JP, Al-Fulaij N, Bailey S, Hodgson DJ and McDonald RA., 2018. Climate, landscape, habitat and woodland management associations with hazel dormouse *Muscardinus avellanarius* population status. Mammal Review. 48, 209‐223.

Gylfinir Cymru/Curlew Wales. In prep. A Wales Action Plan for the Recovery of Curlew.

Hallmann CA, Sorg M, Jongejans E, Siepel H, Hofland N, Schwan H, Stenmans W, Müller A, Sumser H, Hörren T, Goulson D, de Kroon H. 2017. More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLoS ONE 12(10): e0185809. Available from: https://doi.org/10.1371/journal.pone.0185809 [Accessed 4 February 2021]

Harkki S, Savola K, Walsh M. 2003. Palaako elävä metsä: Metsiensuojelun tavoitteita 2000-luvun Suomessa (A comprehensive conservation programme for

Finland’s forests in the 21st Century). Birdlife Finland/Greenpeace/Luonto-Liitto/Suomen luonnonsuojeluliito.

Harris SJ, Massimino D, Balmer DE, Eaton MA, Noble DG, Pearce-Higgins JW, Woodcock P. Gillings S. 2020. The Breeding Bird Survey 2019. BTO Research Report 726. British Trust for Ornithology, Thetford.

Harvey P, Davidson M, Dawson I, Fowles A, Hitchcock G, Lee P, Merret P, Russell-Smith A, Smith H. 2017. A review of the scarce and threatened spiders (Araneae) of Great Britain: Species Status No. 22. NRW Evidence Report No: 11, 101pp, Natural Resources Wales, Bangor.

Hatton-Ellis TW. 2018. IUCN Assessment for Freshwater Pearl Mussel Translocations in Wales. Volume 1: Strategic Case, Feasibility, Best Practice and Project Design. NRW Evidence Report 300, 68pp. Bangor, Natural Resources Wales.

Hatton-Ellis TW, Garrett H, Hearn S, Jenkins M, Jones HP, Taylor J, Watkin N. 2017. A Freshwater Pearl Mussel Conservation Strategy for Wales. Bangor, Natural Resources Wales.

Hayhow DB, Eaton MA, Stanbury AJ, Burns F, Kirby WB, Bailey N, Beckmann B, Bedford J, Boersch-Supan PH, Coomber F, Dennis EB, Dolman SJ, Dunn E, Hall J, Harrower C, Hatfield JH, Hawley J, Haysom K, Hughes J, Johns DG, Mathews F, McQuatters-Gollop A, Noble DG, Outhwaite CL, Pearce-Higgins JW, Pescott OL, Powney GD and Symes N. 2019. State of Nature 2019. The State of Nature partnership. Available from: https://nbn.org.uk/stateofnature2019/ [accessed March 2021]

Hilty J, Worboys GL, Keeley A, Woodley S, Lausche B, Locke H, Carr M, Pulsford I, Pittock J, White JW, Theobald DM, Levine J, Reuling M, Watson JEM, Ament R, Tabor GM. 2020. Guidelines for conserving connectivity through ecological networks and corridors. Best Practice Protected Area Guidelines Series No. 30. Gland, Switzerland: IUCN.

Hoban S, Bruford M, D'Urban Jackson J, Lopes-Fernandesc M, Heuertzd M, Hohenlohee P, Paz-Vinasz I, Sjögren-Gulvef P, Segelbacherg G, Vernesih C, Aitkeni S, Bertolaj L, Bloomerk P, Breed M, Rodríguez-Corream H, Funkn C, Gruebero C, Hunterp M, Jaffeq R, Ligginsr L, Mergeays J, Moharreku F, O'Brien D, Ogdenx R, Palma-Silvay C, Piersonaa J, Ramakrishnanab U, Simo-Droissartac M, Taniad N, Waitsae L, Laikreaf L. 2020. Genetic diversity targets and indicators in the CBD post-2020 Global Biodiversity Framework must be improved. Biological Conservation 248 (2020) 108654.

IPBES. 2019. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S. Díaz, J. Settele, E. S. Brondízio E.S., H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S.

Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany. 56 pages.

IPCC. 2018. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte V, Zhai P, Pörtner H-O, Roberts D, Skea J, Shukla PR, Pirani A, Moufouma-Okia W, Péan C, Pidcock R, Connors S, Matthews JBR, Chen Y, Zhou X, Gomis MI, Lonnoy E, Maycock T, Tignor M, and Waterfield T (eds.)] Intergovernmental Panel on Climate Change.

IUCN. 2020. Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS. Gland, Switzerland: International Union for Conservation of Nature (IUCN).

JNCC. 2019a. Joint Nature Conservation Committee. Article 17 Habitats Directive Report 2019. Available from: https://jncc.gov.uk/our-work/article-17-habitats-directive-report-2019/ [Accessed February 2021]

JNCC. 2019b. UK Biodiversity Indicators 2019 Revised, Available from: https://jncc.gov.uk/our-work/uk-biodiversity-indicators [Accessed March 2021]

Latham J. 2010. Woodlands and Scrub. In: Blackstock, T.H., Howe, E.A., Steven, J.P., Burrows, C.R., and Jones, P.S. (Eds). Habitats of Wales: A comprehensive field survey 1979-1997, pp 122-137. University of Wales Press, Cardiff.

Lawton JH, Brotherton PNM, Brown VK, Elphick C, Fitter AH, Forshaw J, Haddow RW, Hilborne S, Leafe RN, Mace GM, Southgate MP, Sutherland WJ, Tew TE, Varley J, Wynne GR. 2010. Making Space for Nature: a review of England's wildlife sites and ecological network. Report to Defra. Available from: https://webarchive.nationalarchives.gov.uk/20130402154501/http://archive.defra.gov.uk/environment/biodiversity/index.htm [Accessed March 2021]

Leclère D, Obersteiner M, Barrett M, Butchart SHM, Chaudhary A, De Palma A, DeClerck FAJ, Di Marco M, Doelman JC, Dürauer M, Freeman R, Harfoot M, Hasegawa T, Hellweg S, Hilbers JP, Hill SLL, Humpenöder F, Jennings N, Krisztin T, Mace GM, Ohashi H, Popp A, Purvis A, Schipper AM, Tabeau A, Valin H, van Meijl H, van Zeist WJ, Visconti P, Alkemade R, Almond R, Bunting G, Burgess ND, Cornell SE, Di Fulvio F, Ferrier S, Fritz S, Fujimori S, Grooten M, Harwood T, Havlík P, Herrero M, Hoskins AJ, Jung M, Kram T, Lotze-Campen H, Matsui T, Meyer C, Nel D, Newbold T, Schmidt-Traub G, Stehfest E, Strassburg BBN, van Vuuren DP, Ware C, Watson JEM, Wu W and Young L. 2020. Bending the curve of terrestrial biodiversity needs an integrated strategy. Nature 585, 551–556. Abstract available from: https://doi.org/10.1038/s41586-020-2705-y [Accessed March 2021]

Magnificent Meadows Partnership. 2017. Is the rye-grass always greener? An evidence review of the nutritional, medicinal and production value of species-rich grassland. Published as part of the Heritage Lottery Fund Save Our Magnificent Meadows consortium led by Plantlife.

Massimino D, Woodward ID, Hammond MJ, Harris SJ, Leech DI, Noble DG, Walker RH, Barimore C, Dadam D, Eglington SM, Marchant JH, Sullivan MJP, Baillie SR and Robinson RA. 2019. BirdTrends 2019: Trends in numbers, breeding success and survival for UK breeding birds. Research Report 722. BTO, Thetford. Available from: www.bto.org/birdtrends [Accessed March 2021]

Mathews F, Smith B, Harrower C and Coomber F. 2020. The State of Mammals in Wales. A report by the Mammal Society for Natural Resources Wales, produced in association with Wales Mammal Biodiversity Action Forum. The Mammal Society, London. ISBN: 978-0-9935673-6-0. Available from: https://www.mammal.org.uk/science-research/the-state-of-mammals-in-wales-cyflwr-mamaliaid-yng-nghymru/ [Accessed March 2021]

McDonald R. 2017. Trends in hazel dormouse populations in Wales. Unpublished letter to Natural Resources Wales. Available on request from NRW.

Mitchell C, Green M, Jones R, Lindley P and Dodd S. 2018. Year-round movements of Greenland White-fronted Geese (*Anser albifrons flavirostris*) ringed in Wales in winter 2016/17 revealed by telemetry. Birds in Wales Adar yng Nghymru. Vol. 51:1, pp. 38-48.

Moorkens EA, Killeen IJ. 2014. Assessing near-bed velocity in a recruiting population of the endangered freshwater pearl mussel (*Margaritifera margaritifera*) in Ireland. Aquatic Conservation: Marine and Freshwater Ecosystems, 24, 853-862.

NRW. 2016. The State of Natural Resources Report (SoNaRR): Assessment of the Sustainable Management of Natural Resources. Natural Resources Wales. Available from: https://naturalresources.wales/sonarr2016 [Accessed February 2021]

NRW. 2018. Water Framework Directive (WFD) Cycle 2 Interim Classification 2018 for Freshwater. Natural Resources Wales. Available from: https://naturalresources.wales/evidence-and-data/research-and-reports/water-reports/river-basin-management-plans/river-basin-management-plans-published/?lang=en [Accessed March 2021]

Phillips B, Wallace C, Roberts B, Whitehouse A, Gastona K, Bullock J, Dicks L and Osborne J. 2020. Enhancing road verges to aid pollinator conservation: A review. Biological Conservation ISSN (Print): 0006-3207 - ISSN (Online): 0006-3207. Available from: https://www.sciencedirect.com/science/article/pii/S000632072030745X?dgcid=rss_sd_all [Accessed March 2021]

Powney GD, Carvell C, Edwards M, Morris RKA, Roy HE, Woodcock BA and Isaac NJB. 2019. Widespread losses of pollinating insects in Britain. Nature Communications 10, 1018. Available from: https://doi.org/10.1038/s41467-019-08974-9 [Accessed March 2021]

Rich TCG, Houston L, Tillotson AC. 2019. Sorbus diversity in the Wye Valley Woodlands SAC, Wales. NRW [Report Series] Report No: 332,102pp, Natural Resources Wales, Cardiff.

Rowe E, Sawicka K, Mitchell Z, Smith R, Dore T, Banin LF, Levy P. 2019. Trends Report 2019: Trends in critical load and critical level exceedances in the UK. Report to Defra under Contract AQ0843, CEH Project NEC05708. Available from: https://uk-air.defra.gov.uk/library/ [Accessed 4 February 2021].

RSPB. 2020. Red kite [online]. Royal Society for the Protection of Birds. Available from: https://www.rspb.org.uk/birds-and-wildlife/wildlife-guides/bird-a-z/red-kite/ [Accessed March 2021]

Stewart NF and Hatton-Ellis TW. 2020. A Red List of Stoneworts in Wales. NRW Evidence Report No: 406, 105pp, Natural Resources Wales, Bangor.

Welsh Government. 2013. The Action Plan for Pollinators in Wales. Available from: https://gov.wales/action-plan-pollinators [Accessed March 2021]

Welsh Government. 2015. The Nature Recovery Plan for Wales – Setting the course for 2020 and beyond. December 2015. Available from: https://gov.wales/nature-recovery-action-plan [Accessed March 2021]

Welsh Government. 2017. Natural Resources Policy. Available from: https://gov.wales/natural-resources-policy [Accessed March 2021]

Welsh Government. 2018. Woodlands for Wales strategy. Available from: https://gov.wales/woodlands-wales-strategy [Accessed March 2021]

Welsh Government. 2019. Farming Facts and Figures, Wales 2019. Available from: https://gov.wales/sites/default/files/statistics-and-research/2019-07/farming-facts-and-figures-2019-492.pdf [Accessed March 2021]

Welsh Government. 2020. The Nature Recovery Action Plan for Wales 2020-21. Available from: https://gov.wales/nature-recovery-action-plan [Accessed March 2021]

Willing MJ. 2020. Surveys for Geyer's Whorl Snail *Vertigo geyeri* on Cors Erddreiniog SSSI & Cors Geirch SSSI and for Desmoulin's Whorl Snail *Vertigo moulinsiana* on Cors Geirch SSSI in 2019. NRW Evidence Report No: 404, 40pp. Natural Resources Wales, Bangor.

WWF. 2020. Living Planet Report 2020 – Bending the curve of biodiversity loss. World Wildlife Fund. [Almond, REA, Grooten M and Petersen T. (Eds)]. WWF, Gland, Switzerland.