The Second State of Natural Resources Report (SoNaRR2020)

Assessment of the achievement of sustainable management of natural resources: Freshwater

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: Freshwater

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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

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Tables and Figures

1. Headline Messages

Key Issues

Climate change

Climate change is altering 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. Examples include:

- Inadequate flows/water levels to maintain water quality and aquatic biodiversity.
- Raised levels of fine sediments entering rivers, increased river channel erosion and wash-out of species.
- Altered population dynamics and disturbance to life cycles of species as a result of changes to flow and temperature regimes.
- Altered distribution of Invasive non-native species and increased risk of establishment due to temperature increases.

Opportunities:

- Implement water efficiency measures and control abstraction to reduce impacts of low flows.
- Widespread implementation of sustainable drainage approaches throughout catchments to adapt for climate change and reduce impacts of flooding.
- Reconnect rivers with flood plains for water and carbon storage (see below), to reduce impacts of excessive scour and erosion during high flows, and aid recovery of flood plain habitats.
- Planting of riparian corridors to help offset future temperature rises and control soil/nutrient loss in storm events.
- Address physical modification of freshwater ecosystems (see below) to improve resilience.
- Address pollution (see below) to improve resilience.
- Address invasive non-native species (see below) to improve resilience.

Physical modification

Physical modifications have a significant impact on reducing freshwater ecosystem resilience, particularly resilience to climate change. These modifications (for example bank reinforcement, lowered river beds, weirs, culverts, channel straightening) have a detrimental effect on river and lake processes and ecosystem functioning.

Unconsented gravel removal is a significant issue on many catchments, destroying fish spawning habitat and interfering with geomorphological processes. Physical modification of freshwater ecosystems as a result of development and infrastructure schemes is ongoing.

Physical modification is a significant reason why freshwater ecosystems are failing to reach Good Ecological Status under the Water Framework Directive (WFD), and

Favourable Condition under the Habitats Directive.

Opportunities:

- Use the Regulatory Principles to improve implementation of legislation and policy around in-river works (and strengthen it where necessary).
- Deliver an integrated River Restoration Programme.
- Deliver WFD measures.
- Deliver collaborative projects through the Area Statement process.

Pollution

Pollution is a key issue currently facing freshwater ecosystems, specifically pollution from slurry, sewage, mine waters, and soil erosion.

This issue results in excessive nutrient, sediment, and metal loadings in rivers, lakes and groundwaters which in turn disrupts ecological processes. Pollution is another important reason why freshwater ecosystems are failing to reach Good Ecological Status under the WFD, and Favourable Condition under the Habitats Directive.

Opportunities:

- Work with Welsh Government (WG) on the new Sustainable Farming Scheme and the Water Resources (Control of Agricultural Pollution) (Wales) regulations.
- to deliver adequate protection and restoration of freshwater ecosystems.
- Introduce policy instruments or legislation that improve the design of landscapes so that pollution is less likely to enter rivers, lakes, and groundwater.
- Work with WG and stakeholders to deliver interventions for land management to meet the challenges of the climate and nature emergencies.
- Develop new technologies for the management of pollutants for example mine water treatments and investments in sewage treatment and infrastructure.
- Use the Regulatory Principles to improve implementation of legislation and policy around pollution of surface water and groundwater (and strengthen it where necessary).

Decline in freshwater biodiversity

Freshwater biodiversity is under severe pressure and several species require urgent action to prevent extinction or catastrophic declines. The issues affecting these species are complex and include impacts of climate change which are not well understood.

- Salmonid populations are in decline; stocks in all rivers assessed are classed as at risk or probably at risk.
- Formerly common invertebrates such as freshwater pearl mussel and white-clawed crayfish are both critically endangered in Wales.
- The once-common water vole is classed as critically endangered in Wales.
- The condition of lowland lakes is seriously threatened.
- The number and quality of ponds has seriously declined.

Opportunities:

- Deliver the plan of action for salmon and sea trout.
- Deliver the eel management plans across Wales.
- Deliver NRW's Freshwater Pearl Mussel Strategy
- Identify measures to reverse the decline of other seriously endangered freshwater species via collaborative projects such as Back from the Brink Cymru.
- Identify a mechanism to significantly increase the number and quality of lowland ponds.

Lack of connectivity between rivers and their flood plains

Rivers in Wales are now poorly connected to their flood plains. This has resulted in the landscape-scale loss of various flood plain habitats (neutral and marshy grassland, swamp, wet woodland, fen and bog), loss of associated ecological networks, disruption to natural riparian processes and vastly reduced resilience to flood risk.

Opportunities:

- Support the Welsh Government National Strategy objectives (WG, 2020) and Wales's Planning Policy (TAN15) to take a catchment approach to flood risk management.
- Work internally and externally to demonstrate and encourage best practice, such as the widespread use of natural flood management measures and reconnecting rivers to their flood plains.
- Seek restoration of flood plain connectivity and wet habitats via river restoration programmes.
- Develop integrated river-flood plain management plans for relevant rivers that integrate land use planning, biodiversity, and flood risk management.

Invasive non-native species

Aquatic ecosystems are particularly susceptible to invasive non-native species (INNS) due to their degree of connectivity and the practical difficulties in containing and managing outbreaks in the water environment. INNS can have a devastating impact on native biodiversity through mechanisms such as competition for resources, predation and the introduction of disease. They can also cause structural instability in riverbanks, increase flood risk by blocking channels and interfere with navigation and water supply. Examples of INNS which have significant impacts in Wales include signal crayfish, Topmouth Gudgeon, Himalayan balsam (*Impatiens glandulifera*) and New Zealand Pigmyweed (*Crassula helmsii*).

Opportunities:

- Effective application of new Invasive Alien Species Order regulatory tools.
- Support the implementation of the IAS Regulation through Wales level Contingency Plans and national Pathway Action Plans.
- Delivery of collaborative catchment-scale projects through the Area Statement process and via third sector partners such as the Rivers Trusts.

- Implementation of improved biosecurity measures via the water industry AMP7 process.
- Undertake actions to support the GB INNS Strategy, including encouraging the use of citizen science to collect data.

2. Introduction

All living things need water to survive, yet globally, freshwater ecosystems are among the most threatened (WWF, 2018). This section covers the following freshwater ecosystems: lakes, rivers, ponds, and flood plain habitats. These support rich biodiversity including some of the rarest and most iconic wildlife in Wales such as floating water-plantain, Arctic charr, salmon, otter, dipper and the genetically unique gwyniad. The health and sustainable management of freshwater ecosystems are intimately linked with the neighbouring terrestrial habitats within their catchments.

Freshwater ecosystems face multiple pressures, including climate change, rural and urban pollution, physical modifications, changes to flow, and invasive non-native species. The cumulative effects lead to low habitat quality, disrupted ecological processes, and poor water quality which reduces resilience; this is particularly evident in rivers and flood plain habitats. The majority of riverine Special Area of Conservation (SAC) features were unfavourable in the 2018 Article 17 Habitats Directive reporting round, and there were no river water bodies at high status in the Water Framework Directive 2018 interim classification. Across Wales, pressures are endangering once abundant species such as salmon, freshwater pearl mussel and water vole.

While freshwater ecosystems provide important ecosystem services including drinking water, renewable energy production, flood and drought mitigation, waste disposal, fisheries and recreation, their ability to do so is increasingly compromised. Balancing the use of these services with one another and the sustainable management of freshwater ecosystems and their surrounding terrestrial environment is a significant societal challenge.

Opportunities to reverse the situation require increase societal awareness of the environment and the impact pathways of behaviours. The climate and nature crises are forcing us to develop solutions to these new and ongoing environmental issues. For freshwater ecosystems, these include halting physical degradation of rivers, a collaborative approach to catchment management, an integrated programme of river restoration work, opportunities for reconnection of rivers and flood plains, and targeted work for declining species.

3. State and Trends (Aim 1)

Summary Assessment and Forward Look

The following tables (Table 1 to Table 5) give a brief description of the past trends and future prospects for Freshwater. These are assessed to be:

- Improving trends or developments dominate;
- Trends or developments show a mixed picture, or
- Deteriorating trends or developments dominate.

Further information is provided to put this in context.

Table 1 Key message – extent of freshwater ecosystems

Time period	Indicative Assessment	Description
Past trends (1950 - present)	Deteriorating	The extent of freshwater ecosystems, particularly river flood plains and ponds, deteriorated significantly over the 20th century. More recently, declines are thought to be more gradual, partly due to increased regulation and partly because there is now limited scope for further development in flood plains.
Future prospects (Outlook to 2030)	Mixed picture	In the absence of improvements to the current regulatory system and without large-scale restoration programmes, further gradual habitat loss is likely, especially for ponds and rivers.

Note on robustness: Accurate data on the extent of freshwater habitats is generally poor. The most vulnerable habitats such as ponds and streams tend to be relatively inaccurately mapped and can be difficult to monitor remotely (for example due to tree cover). Furthermore, the loss of river habitat through channel straightening can be overlooked as there is no process of recording in place.

Table 2 Key message – condition of freshwater ecosystems

Time period	Indicative Assessment	Description
Past trends (1990 – present)	Improving	The condition of freshwater ecosystems has shifted in response to complex interactions of pressures. In general terms, this can be summarised as: 1. General and widespread decline in the countryside, especially in lowland areas. 2. Gradual improvement in the uplands due to ongoing recovery from acidification. 3. Marked recovery in post-industrial areas, largely due to mine closures and in some instances, mine water treatment.
Future prospects (Outlook to 2030)	Deteriorating	Increasing pressures from climate change, invasive species, and emerging pressures such as microplastics and pharmaceuticals are combining to increase the range of stressors on freshwater ecosystems. In addition, the combined effects of multiple stressors constitute a significant pressure in their own right.

Note on robustness: There is an extensive evidence base covering many aspects of freshwater ecological quality. Whilst there are evidence gaps and variability in the details and patterns of different datasets and pressures, the overall picture is robust.

Table 3 Key message – connectivity of freshwater ecosystems

Time period	Indicative Assessment	Description
Past trends (1970 – present)	Deteriorating	The connectivity between rivers and their flood plains, and the longitudinal connectivity of rivers, has been significantly disrupted. Ponds and lakes are naturally more disjunct ecosystems, but reductions in pond numbers, as well as overgrazing of pond and lake margins, modifications to marginal wetlands and lake outflows, have all combined to reduce freshwater connectivity.
Future Prospects (Outlook to 2030)	Mixed picture	There is increasing awareness of the importance of connectivity for freshwaters and this is starting to translate into practical restoration projects. This is in line with SMNR principles.

Note on robustness: Although there are evidence gaps, especially with flood plains and ponds, the general understanding of issues relating to connectivity is reasonable.

Table 4 Key message – pressures and threats on freshwater ecosystems

Time period	Indicative Assessment	Description
Past trends (1970 – Present)	Deteriorating	Key pressures in the past include nutrient pollution, mine water and industrial pollution, river engineering, climate change, acidification, and infilling/drainage (ponds).
Future prospects (Outlook to 2030)	Deteriorating	Current shifts in pressures will continue. Climate change will increase the frequency of droughts, floods, and other climate-related impacts. These impacts often magnify the effects of other pressures. Invasions by invasive non-native species are likely to increase and be exacerbated by the effects of climate change. An increasing programme of river restoration should reduce and start to reverse the long-term damage to river habitat structure. Nutrient pollution is unlikely to increase dramatically but its effects will be aggravated by climate change. Mine water pollution will continue to reduce as problems at individual sites are systematically tackled. Acidification due to air pollution is likely to largely disappear as a pressure within the next two decades but will be replaced by emerging pressures such as microplastics, pharmaceuticals and industrial chemicals.

Note on robustness: Although there is uncertainty regarding individual pressures, the general pattern is fairly robust.

Table 5 Key message – status of key freshwater species

Time period	Indicative Assessment	Description
Past trends (1950 – present)	Deteriorating	A combination of pressures including direct exploitation, habitat degradation and climate change has resulted in a catastrophic decline in the numbers of many once- abundant freshwater species. Improvements to habitats are critical, but in some cases, more targeted conservation action is required.
Future prospects (Outlook to 2030)	Mixed picture	Some further decline is inevitable before habitat restoration measures start to take effect (for example growth of riverside trees, removal of barriers). Thereafter, any recovery is dependent on the scale and success of management measures.

Note on robustness: The data indicating declines of most of these species are extremely robust, although there are gaps at finer scales (for example specific locations and dates). There is good evidence to indicate measures required for many key species.

We obtain information on the status of Welsh freshwater ecosystems from many sources, and we can use this to monitor trends. Where possible, we have compared the latest available data to SoNaRR2016. In relation to the four resilience indicators, data has been presented primarily in terms of Condition and Connectivity, the most important indicators in freshwaters. For the purposes of this account, freshwater ecosystems are divided into:

Lakes (lowlands and uplands): natural water bodies at least 1ha or more in area. Artificial water bodies for example public water supply reservoirs, boating lakes, industrial lagoons are generally excluded.

Rivers and streams (lowlands and uplands)

Ponds: smaller, shallow water bodies typically less than 1ha in area. They rarely have an inflow or outflow and may dry out for part of the year. Ponds often do not support fish but are rich in other species including invertebrates and amphibians.

Flood plains: neutral and marshy grassland, swamp, wet woodland, fen and bog and their associated ecotones in land adjacent to a stream or river which stretches from the banks of its channel to the base of the enclosing valley walls, and which experiences flooding during periods of high flow.

Groundwater and its importance to the habitats listed above is also considered. Groundwater is the water stored in soil and rocks which provides base flow to springs, rivers and wetlands.

Lakes

Data on lake status and trends comes from several different sources. The most important of these is NRW's monitoring network which collects information for Water Framework Directive, Habitats Directive, and SSSI Condition Monitoring. Additional information has been provided by the Upland Waters Monitoring Network.

There are 558 lakes in Wales (NRW, 2016a). There is no evidence of significant change in extent of these.

- Upland lakes in Wales are generally in good condition and improving.
- Lowland lakes in Wales are generally in poor condition and deteriorating

The aquatic plant classification tool: LEAFPACS (UKTAG, 2014) provides a good measure of nutrient pressures on lakes. Different plant species vary in their sensitivity to the effects of nutrient enrichment. Using the composition of the aquatic plant community as a measure, it is possible to calculate an index of enrichment for the lake. This can be compared to what would be expected under natural conditions.

The tool places 90% of Upland lakes in Good or High status, indicating minimal nutrient impact (Figure 1). In contrast, Lowland lakes are significantly impacted by nutrients, with less than a third at Good or High Status (Figure 2).

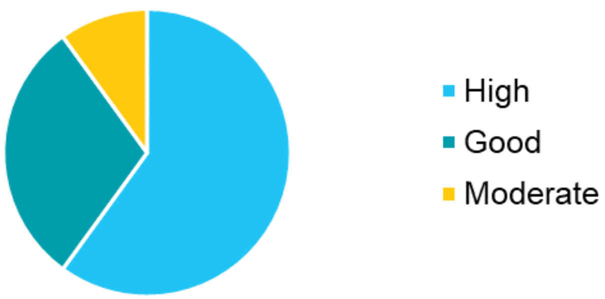


Figure 1 Current assessment of Upland Lakes at different status classes assessed using the LEAFPACS Tool (2012 to 2019).

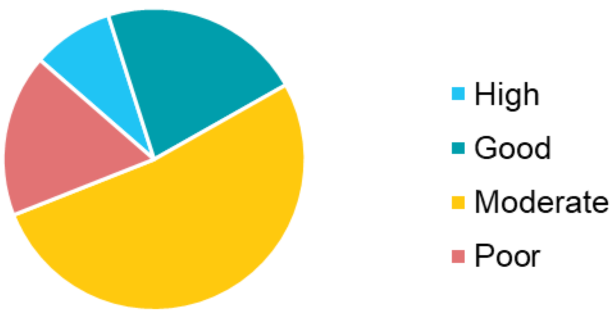


Figure 2 Current assessment of Lowland Lakes at different status classes assessed using the LEAFPACS Tool (2012 to 2019).

We can directly compare change in LEAFPACS score from 44 lakes. There is little evidence of a systematic trend in lake plant communities across the dataset: some lakes show improvements while others have declined. The largest changes are in lowland lakes, suggesting instability in these ecosystems. Instability in plant communities is common when lakes are under nutrient pressure (Sayer *et al*. 2010; Hilt *et al*. 2018) and indicates a lack of ecosystem resilience to pressures. This makes the ecosystem more sensitive to short-term factors such as weather patterns early in the growing season.

Invasive species are a significant problem in lakes (Figure 5). Based only on aquatic plant data, invasive species pressures occur disproportionately in lowland lakes (Figure 3 and Figure 4).

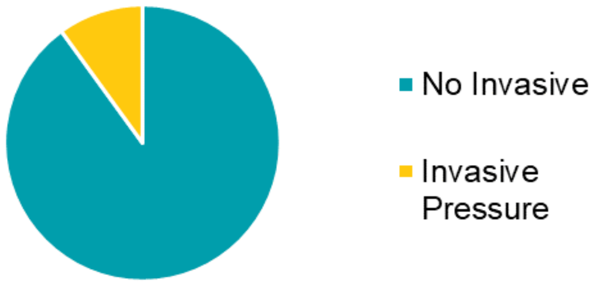


Figure 3 Proportion of Upland Lakes affected by invasive non-native species (2012 to 2019).

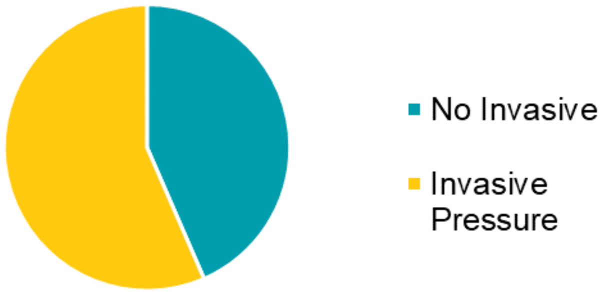


Figure 4 Proportion of Lowland Lakes affected by invasive non-native species (2012 to 2019).

Figure 5 Dense growth of invasive non-native Elodea sp. In Bosherston Lakes, Pembrokeshire outcompeting native plants

Data on lake habitats protected under the Habitats Directive show that the majority are in Unfavourable Bad condition, with some habitats in upland lakes improving (JNCC, 2019a) (Table 6).

Table 6 Article 17 conservation status assessment and trend for freshwater habitats 2007, 2013 and 2019 at either UK or Wales levels (JNCC 2019b).

Freshwater habitat	2001-7	2008-13	2014-19
Clear-water alkaline lakes and ponds with stonewort meadows.	Unfavourable Bad at UK level with downward trend	Unfavourable Bad at Wales level	Unfavourable Bad at Wales level with downward trend
Upland - clear-water, low to moderate nutrient, well-oxygenated lakes with dwarf mat-forming plants.	Unfavourable Inadequate at UK level with upward trend	Unfavourable Inadequate at UK level with upward trend	Unfavourable Inadequate at UK level with upward trend
Lowland - clear-water, low to moderate nutrient, well-oxygenated lakes with dwarf mat-forming plants.	Unfavourable Inadequate at UK level with upward trend	Unfavourable Bad at Wales level with downward trend	Unfavourable Bad at Wales level with downward trend
Naturally nutrient-rich, alkaline lakes with large submerged pondweeds.	Unfavourable Bad at UK level	Unfavourable at Wales level	Unfavourable Bad at Wales level
Peat-stained lakes and ponds	Favourable at UK level	Favourable at UK level	Unfavourable Inadequate at Wales level
Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	Unfavourable Bad at UK level with downward trend	Unfavourable Inadequate at Wales level	Unfavourable Inadequate at Wales level with downward trend
Turloughs	Unfavourable Bad at UK level with downward trend	Favourable at Wales level	Favourable at Wales level

Table 7 Article 17 conservation status assessment and trend for freshwater species 2007, 2013 and 2019 at either UK or Wales levels (JNCC, 2019a).

Freshwater species	2001-7	2008-13	2014-19
Floating water-plantain (*Luronium natans*)	Unfavourable Inadequate at UK level	Favourable at Wales level	Unfavourable Inadequate at Wales level
Otter (*Lutra lutra*)	Favourable at UK level	Favourable at Wales level	Favourable at Wales level
Great crested newt (*Triturus cristatus*)	Unfavourable Inadequate at UK level	Unknown	Unfavourable Inadequate at UK level with downward trend
Sea lamprey (*Petromyzon marinus*)	Unfavourable Inadequate at UK level with upward trend	Unknown	Unfavourable Inadequate at Wales level
Brook lamprey (*Lampetra planeri*)	Unfavourable Inadequate at UK level with upward trend	Favourable at UK level	Unfavourable Inadequate at Wales level with upward trend
River lamprey (*Lampetra fluviatilis*)	Unfavourable Inadequate at UK level with upward trend	Unfavourable Inadequate at UK level with upward trend	Unfavourable Inadequate at Wales level with upward trend
Allis shad (*Alosa alosa*)	Unfavourable Bad at UK level	Unfavourable Bad at UK level	Unfavourable Inadequate at Wales level with upward trend
Twaite shad (*Alosa fallax*)	Unfavourable Inadequate at UK level	Unfavourable Inadequate at UK level	Unfavourable Inadequate at Wales level with upward trend
Atlantic salmon (*Salmo salar*)	Unfavourable Inadequate at UK level	Unfavourable Inadequate at UK level with downward trend	Unfavourable Inadequate at Wales level with downward trend

Freshwater species	2001-7	2008-13	2014-19
Grayling (*Thymallus thymallus*)	Unknown	Unknown	Unfavourable Inadequate at Wales level
Bullhead (*Cottus gobio*)	Unknown	Unknown	Unfavourable Inadequate at Wales level
Gwyniad (whitefish) *Coregonus lavaretus*	Unfavourable Inadequate at UK level with downward trend	Favourable at UK level	Unfavourable Inadequate at Wales level
White-clawed crayfish (*Austropotamobius pallipes*)	Unfavourable Bad at UK level with downward trend	Unfavourable Bad at UK level with downward trend	Unfavourable Bad at UK level with downward trend
Freshwater pearl mussel (*Margaritifera margaritifera*)	Unfavourable Bad at UK level	Unfavourable Bad at Wales level with downward trend	Unfavourable Bad at Wales level with downward trend
Medicinal leech (*Hirudo medicinalis*)	Favourable at UK level	Unfavourable Inadequate at UK level	Favourable at UK level with upward trend
Southern damselfly (*Coenagrion mercuriale*)	Unfavourable Inadequate at UK level	Unfavourable Inadequate at UK level	Unfavourable Bad at UK level with downward trend

The status of SSSI lakes are summarised in Figure 6 and Figure 7, based on monitoring up to 2014 and 2015-19 (Burgess *et al*. 2006, 2013; Baxter & Stewart 2015; Goldsmith *et al*. 2006, 2014a,b,c, 2016, 2018; Hatton-Ellis 2014, 2016; Shilland *et al*. 2017, 2019). Due to the way sites and features overlap, some features are duplicated; these duplicates have been removed from the results reported here. Of 47 lake habitat features, ten (21%) are favourable, though this figure underrepresents the number of lakes that are in favourable condition, because upland protected sites are generally large and contain many lakes, whereas lowland protected sites generally contain only a single lake. If number of lakes were used rather than number of features, around 50% of lakes would be in favourable condition.

Figure 6 Condition of Lake Habitat Features in SSSIs 2020.

Figure 7 Condition of Lake Habitat Features in SSSIs 2014.

Although 21% is a low proportion of favourable features (Figure 6), it is a significant improvement on 2014 when only 11% were favourable (Figure 7). This is predominantly due to improvement in the quality of upland sites due to a reduction in acidification pressure.

Species features are unusual, rare, or ecologically important species that occur in lake SSSIs. They are assessed separately from the habitat. The condition of lake species features is generally better than habitats (Figure 8), with 54% in favourable condition (based on partial results as not all features were assessed). However, confidence in many species assessments is lower than for habitats.

Figure 8 Indicative Condition Assessment Results of Lake Species Features in SSSIs in 2020.

It is difficult to compare results between now and 2014 for lake species, as many features were reported as ‘Unknown’ in 2014. However, the relative proportions of lake species features in favourable and unfavourable condition appears to be broadly unchanged.

Rivers

Extent

There are 20 major river systems in Wales, with 24,000km of rivers and streams draining 20,770km² (Duigan, 2009; NRW, 2016a). Length and area of rivers has reduced significantly over the last 200 years due to straightening and channelization. The rate of this change is now greatly reduced and there has been little change since SoNaRR2016 (for example Hearn & Hatton-Ellis 2018).

Condition

Since SoNaRR2016, we have published the Water Framework Directive Interim 2018 classification (Figure 9) (NRW 2018). There is little change in the WFD overall classifications between 2015 and 2018. The 2018 data show that:

- 44% of river water bodies are at Good overall status (Figure 10).
- No river water bodies in Wales achieved High status - the best quality WFD class. However, 17 river water bodies could achieve High status if improvements were made to their hydrology, and a further 49 if improvements were made to their morphology.
- At an individual element level, high proportions of water bodies achieve Good or High status. For example, 89% of river water bodies assessed for macroinvertebrates are at Good or High status, and 81% of river water bodies assessed for either or both macrophytes or phytobenthos are at Good or High status.
- Elements that most often indicate that a water body is not achieving Good Status were fish, diatoms, phosphate, zinc, and pH. This information is used to diagnose pressures discussed in the section below.
- 7% of Wales's river water bodies do not achieve Good status due to pollution from abandoned mines.
- 12% of river water bodies are designated as Heavily Modified Water Bodies (HMWB). This designation applies to rivers which have a high degree of physical modification. Only 18% of these have mitigation measures in place.

There are also more subtle community changes not reflected in these data. For example, streams in South Wales showed a decline in specialist invertebrates (Larsen *et al*. 2018). This pattern is also seen in many terrestrial ecosystems.

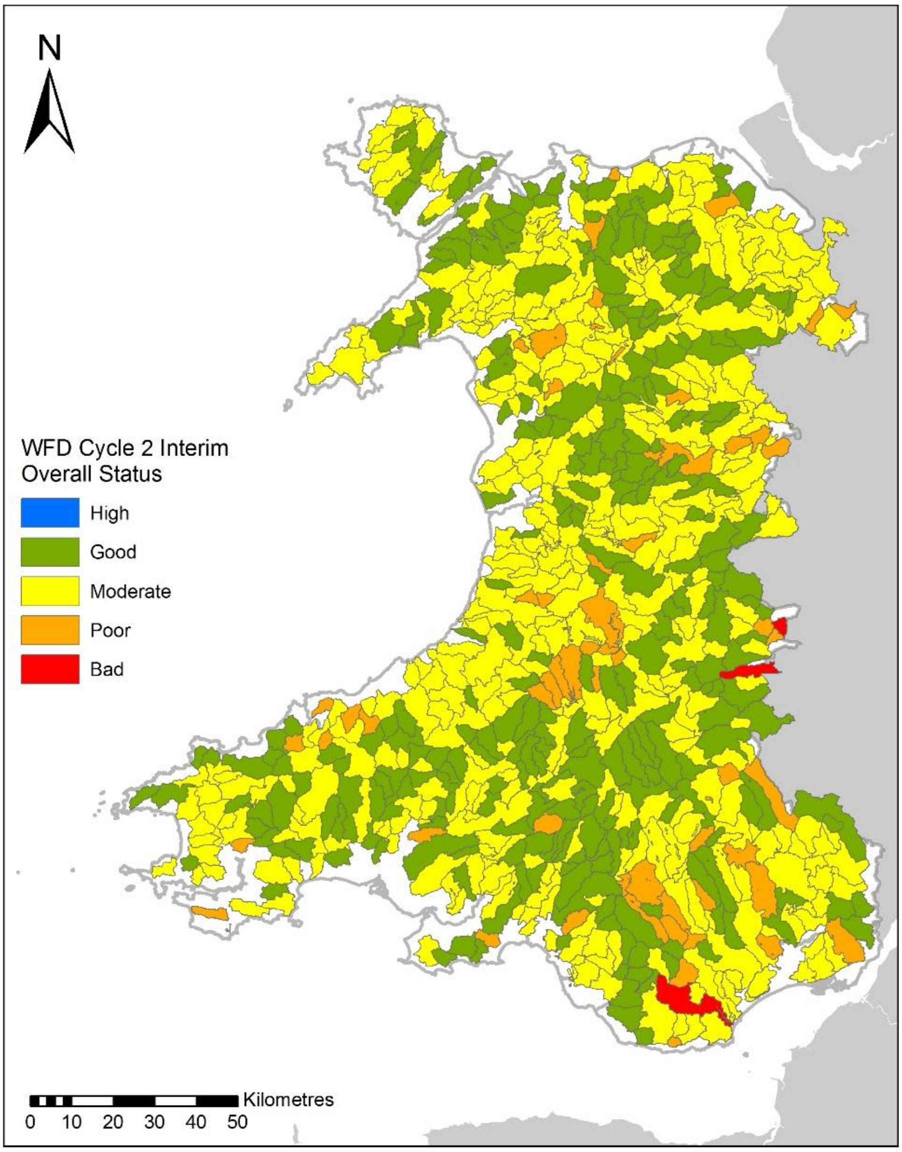


Figure 9 Map Illustrating WFD water body classification using 2018 interim data (Source: NRW 2018).

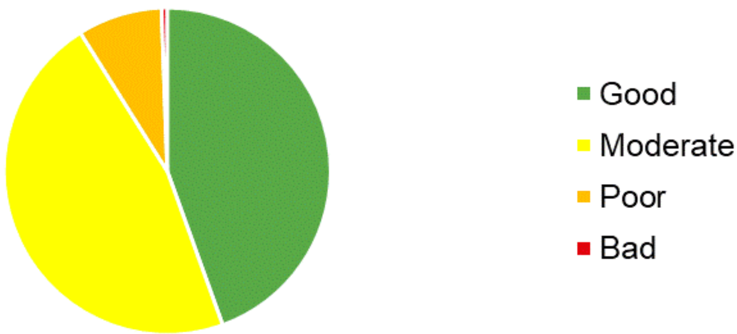


Figure 10 Chart illustrating relative proportion of river WFD classifications - 2018 interim data. (source: NRW 2018)

There are seven canal water bodies in Wales which are assessed under the Water Framework Directive. Of these, four were classified as good and three as moderate under the 2018 interim classification.

The River Habitat Survey (RHS) is another tool used to assess river health. This survey technique measures habitat quality. Our ability to assess river habitat quality is currently limited due to a lack of recent RHS data.

The condition of features of rivers which are designated as Special Areas of Conservation (SAC) under the Habitats Directive is assessed and reported every six years. Data for the fourth cycle of reporting (2013-2018) show that except for otter, all features are in Unfavourable – Inadequate or Unfavourable – Bad status (See Table 6). For the majority this has been the case since 2007. Three species – white-clawed crayfish, freshwater pearl mussel and southern damselfly – are at risk of extinction in Wales. Similarly, data from the most recent full condition assessments of SAC rivers in Wales from 2012 shows that the majority of SAC features are unfavourable.

Condition assessments for freshwater SAC features are comprised of assessments against a range of attributes including flow, water quality, habitat structure and biological assemblages. NRW regularly update aspects of these assessments such as the recent compliance against phosphorus targets which shows that phosphorus levels are exceeding the targets in more than half of the water bodies in river SACs in Wales (Hatton-Ellis TW and Jones TG, 2021).

Very limited data is available for river SSSI features that are not also SAC features. However, some notable features such as Exposed River Shingle (ERS) and its associated invertebrate assemblages are either being lost or are in very poor condition (Brewer *et al.* 2006*)*. ERS extent and condition is a good indicator of natural processes (or lack of) within a river system.

Other protected and priority species that rely on freshwater ecosystems are in decline. For example, water vole populations in Wales have declined by 89% since 1995 (Matthews et al, 2020). The causes of this decline are habitat loss and predation by invasive non-native American mink.

Salmon are a good indicator of ecosystem health due to their sensitivity to various pressures (Glick 2016). The latest salmon and sea trout stock assessments show continuing decline since SoNaRR2016, (Cefas et al. 2020; NRW 2020a). All 23 principal salmon rivers in Wales are either ‘At Risk’ or ‘Probably at Risk’ of failing to achieve their management targets until at least 2024 (Figure 11). Over two-thirds of Welsh sea trout stocks are similarly classified with no recovery predicted until at least 2024 (Figure 12).

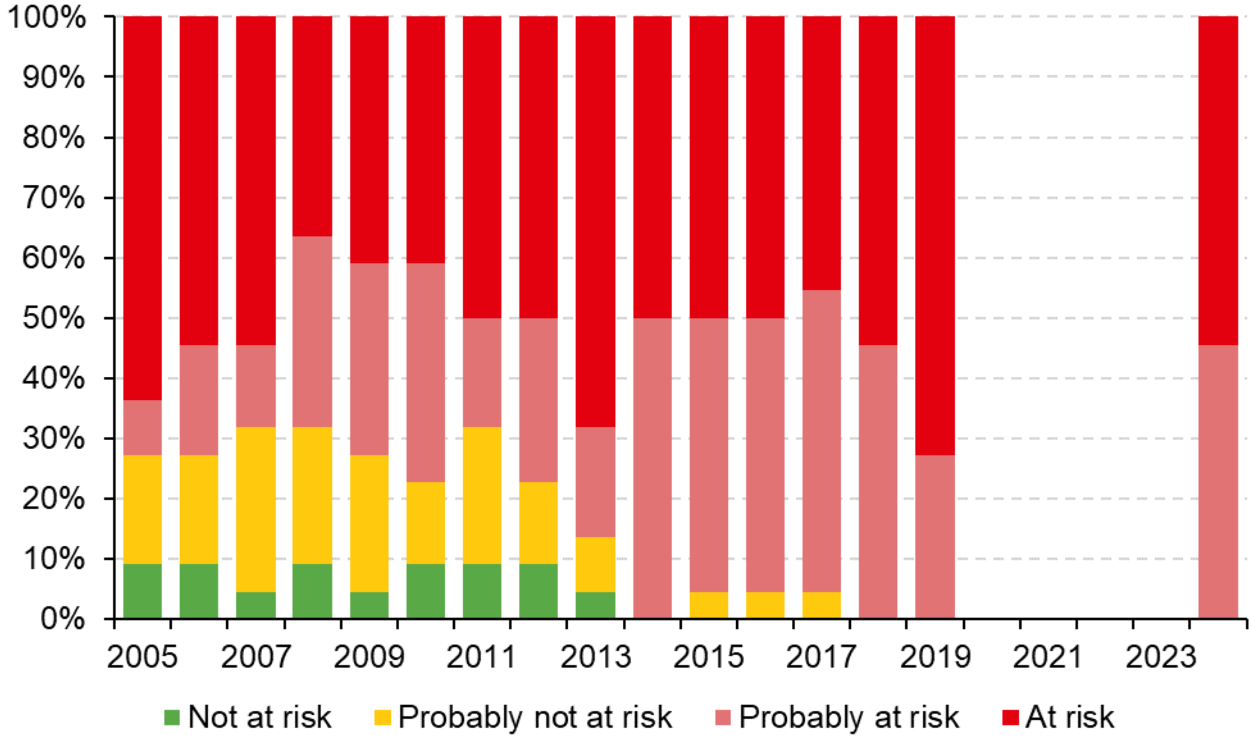


Figure 11 Percentage of principal Welsh salmon rivers in each risk category for 2005-2019 and as predicted for 2024. (Source: Cefas et al. 2020; NRW 2020a)

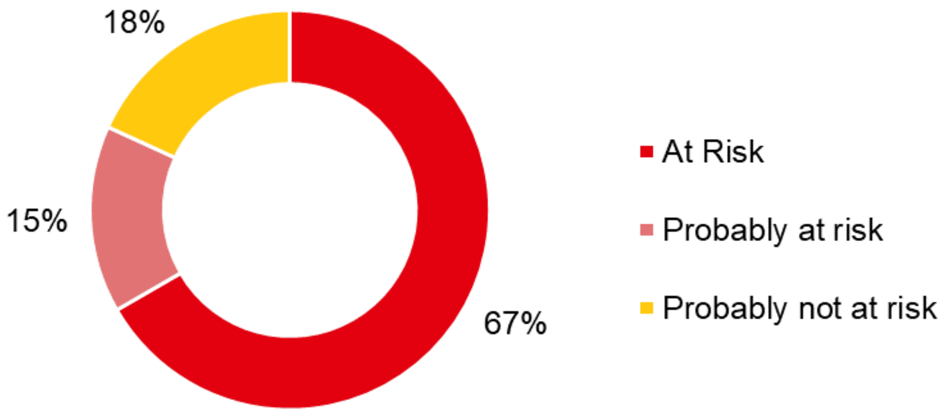


Figure 12 Percentage of principal sea trout rivers in each risk category in 2019. (Source: NRW 2020a)

Figure 13 Juvenile trout in a small stream in Snowdonia. (Source: NRW)

Connectivity

Longitudinal connectivity of rivers is significantly affected on the majority of catchments in Wales by physical factors such as long culverts, weirs, and other barriers (Williams *et al*. 2011). It is estimated that only 1% of the river network in Great Britain is free of artificial barriers (Jones *et al*. 2019). The majority of weirs on rivers in the UK are now defunct but many are retained for heritage reasons or are being re-purposed for micro hydropower (Addy *et al*. 2016). In Wales, 88 new hydro-electric power (HEP) schemes were installed between 2016 and 2018, a 32% increase (Welsh Government, 2018b). Applications for HEP schemes are assessed against NRW's guidance which is designed to minimise geomorphological and ecological impacts to the water course.

Lack of shelter provided by bankside vegetation, and extremes of flow can also hinder passage of species through river systems. Examples include fish movement hindered by low flows, and high flows causing washout of salmonid eggs (Crisp 1985, 1993). High water velocities exacerbated by in-channel engineering and artificial pinch-points such as culverts make it difficult for otters to swim upstream. This can cause otters to leave the river to bypass engineered sections of channel and subsequently be killed on roads (Liles and Colley, 2000). NRW's otter road death data base contains over 1300 records of otters killed on roads since the late 1980s. The vast majority of these road deaths occur in the autumn and winter when flows are high.

Lateral connectivity of rivers to their flood plains is very poor across the UK (see below) and this issue has far-reaching impacts on biodiversity, flood risk management and climate change. Rivers that cannot overspill into their flood plains suffer from excessive flow velocities and erosion during high flows, and flood plains that do not receive inundation from flood waters are unable to support the mosaic of biodiversity-rich wet habitats that were once commonplace but now scarce. However, a report as part of Hydroscope, a consortium project in the UK looking into connectivity in freshwater ecosystems, has concluded that the extent and type of connectivity can also allow the spread of pollutants, disease and invasive species throughout connected water bodies (Pringle *et al.* 2018).

Ponds

Ponds support a diverse range of freshwater species (plants and animals) and are important stepping-stones between freshwater habitats (Figure 14). However, these valuable habitats are disappearing from the Welsh landscape, and those that remain are subject to significant pressure (Riley *et al*. 2018). The most notable pressures on pond habitats are poor water quality as a result of run-off from surrounding land; invasion by invasive non-native species (for example *Crassula helmsii*); and disturbance (for example livestock trampling and grazing).

The extent of ponds may still be declining, but evidence on current pond extent is inadequate. The area of pond habitat has vastly reduced during recent decades, with up to 90% of lowland ponds in the UK lost in the 20th century through succession or direct infilling (Hayhow *et al.* 2019). A survey of 126 ponds across Wales found that 13 (10%) marked on current Ordnance Survey (OS) maps had been filled in for agricultural cultivation (Shaw 2017).

Figure 14 A good quality upland pond on the edge of Snowdonia. (Source: Tristan Hatton-Ellis/NRW)

There is little systematic data on pond quality in Wales, but the available information suggests that less than 10% of farmland ponds are in good condition. Biggs & Shaw (2019) surveyed 18 ponds in 2018 on National Trust properties in Mid and South Wales using the Predictive System for Multimetrics (PSYM) pond survey system. Only two ponds were in good condition, and ten were very poor or poor ecological quality. Shaw's (2017) data of 126 ponds found that only one pond was in good condition. Most ponds were affected by overgrazing with other pressures affecting small numbers of ponds. These results are consistent with other findings in England and Wales (Williams *et al*. 2010).

Connectivity of ponds has reduced as a result of significant losses in extent. The fragmentation of pond habitat is reflected by declines in common frog and toad populations. Common frog populations have been in decline since the 1970s, and recently published research indicates a 68% decline in populations of the common toad across the UK over the past 30 years (Froglife website, accessed April 2020). There are clear benefits of creating new clean water ponds for biodiversity and on restoring/re-excavating filled-in ponds (Walton et al. 2020).

Flood plains

Flood plains are not routinely monitored but have recently been reviewed in Wales (Rothero *et al*. 2018).

- There are no extensive areas of intact natural flood plain in Wales.
- Flood plains in Wales are in very poor condition. Three quarters are heavily modified and poorly connected to their river.

Flood plains occupy approximately 1,100km^2 – about $^1/_{20}$ of the area of Wales. More than 75% of flood plains are highly developed (intensive agricultural land or urbanised land), with less than 25% being natural habitats (Rothero *et al*. 2018). About half of the non-developed land on flood plains is broadleaved woodland, with the remainder being semi-natural grassland, wetlands, and other habitats (Figure 15). Most of these are very small.

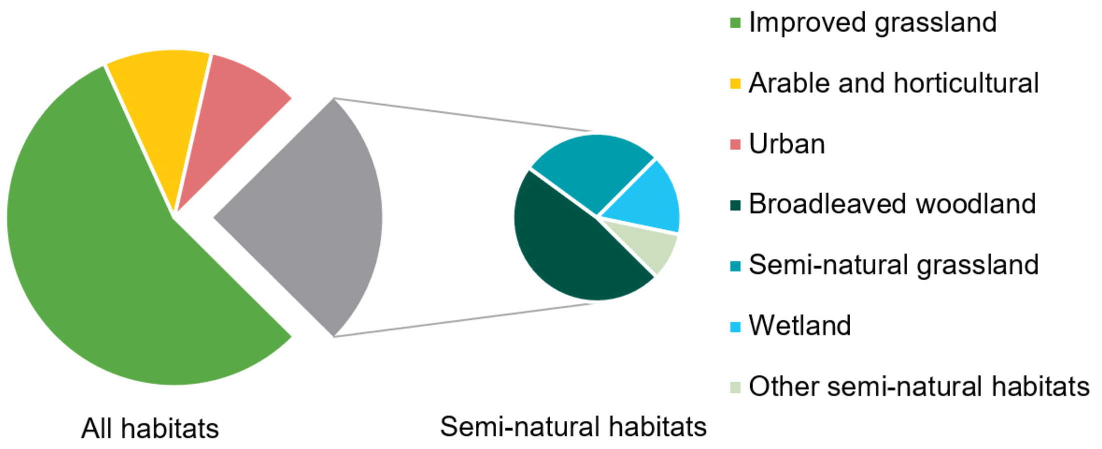


Figure 15 Terrestrial Land Use in Welsh flood plains. Based on Rothero et al. (2018). Left pie chart: Total Area; Right pie chart: Semi-natural habitats only.

Some wetland habitats occur only in flood plains and are highly threatened. An example is oxbow lakes: sections of the river which become cut off from the main channel as rivers meander. Oxbow lakes have a restricted distribution in Wales, occurring only in more active sections of larger rivers (Hatton-Ellis, unpublished) and these special habitats are threatened by silting up, poaching, overgrazing and deliberate infill. Bank reinforcement prevents the formation of new oxbows.

Connectivity of rivers to their flood plains is very poor 42% of flood plains in England and Wales are no longer connected to their river system (Maltby *et al.*, 2011). The loss of flood plain meadow habitat and its associated wet habitat features is significant in terms of biodiversity, cultural heritage, and ecosystem services.

A study on rivers and their flood plains in Scotland has demonstrated the importance of lateral dynamics and the creation of back waters on macrophyte diversity and productivity. At the riverscape scale (for example river and flood plain), the study found that 89% of aquatic plant biomass was found in backwater habitats (Keruzoré et al, 2013).

Groundwater

The WFD classification for groundwater assesses chemical and quantitative status rather than ecological status. Groundwater dependent terrestrial ecosystems and impacts on surface waters form part of the overall assessment. The WFD classification for groundwater has not been updated since SoNaRR2016, which reported 22 water bodies in good status, and 16 water bodies in poor status.

Pressures and Threats

Information on pressures and threats comes from a wide range of sources including Water Framework Directive (NRW 2019) and Habitats Directive reporting (JNCC 2019a, JNCC 2019b), and the Prioritised Action Plan Framework for Wales (NRW 2015a, 2015b). These pressures also reflect those identified as globally important in freshwaters (Reid *et al*. 2018; Tickner *et al*. 2020).

Climate change

Climate change is affecting all Welsh freshwater habitats and is a serious threat to freshwaters globally (Reid *et al*. 2018). Climate change exacerbates flood and drought risk. Climate induced changes such as rainfall patterns, storminess, maximum temperature, and the number of frost days are having a significant and complex impact on freshwater ecosystems. See Climate change chapter for more information.

Longer and more frequent low flow events along with more sudden and severe storm events cause great stress to freshwater habitats and species. Increased temperatures can kill freshwater animals and plants directly, or indirectly due to a reduction in dissolved oxygen (Crozier & Hutchings 2014). Additionally, warmer conditions combine with other pressures such as nutrient pollution to exacerbate impacts such as earlier, longer, or more acute algal blooms, deoxygenation of deeper lakes, and increased toxicity of other pollutants (Crozier & Hutchings 2014).

Climate change also intensifies other pressures. For example, storms increase soil erosion and other pollutants in surface run-off in rural and urban areas, as well as overwhelming sewage treatment facilities and remobilising legacy pollutants especially metals and POPs in river systems and from moorland peats. Finally, climate change alters patterns of human pressures, for example by changing land use and increasing demand for drinking water and hydropower.

Physical modifications

Physical modifications to freshwater habitats, such as culverts, weirs and engineered bed/banks, have various damaging effects. These include the removal or destruction of habitat features such as boulders and gravels; barriers to fish and invertebrate migration; interference with sediment transport; increase in scour during floods; increased siltation; disconnection of rivers with flood plains and increased flood risk downstream. Such modifications also result in the loss of bankside habitats and wetlands. Physical modifications are the most widespread pressure on rivers and flood plains in Wales (Figure 16). They make many habitats less resilient and hence more vulnerable to other pressures such as pollution.

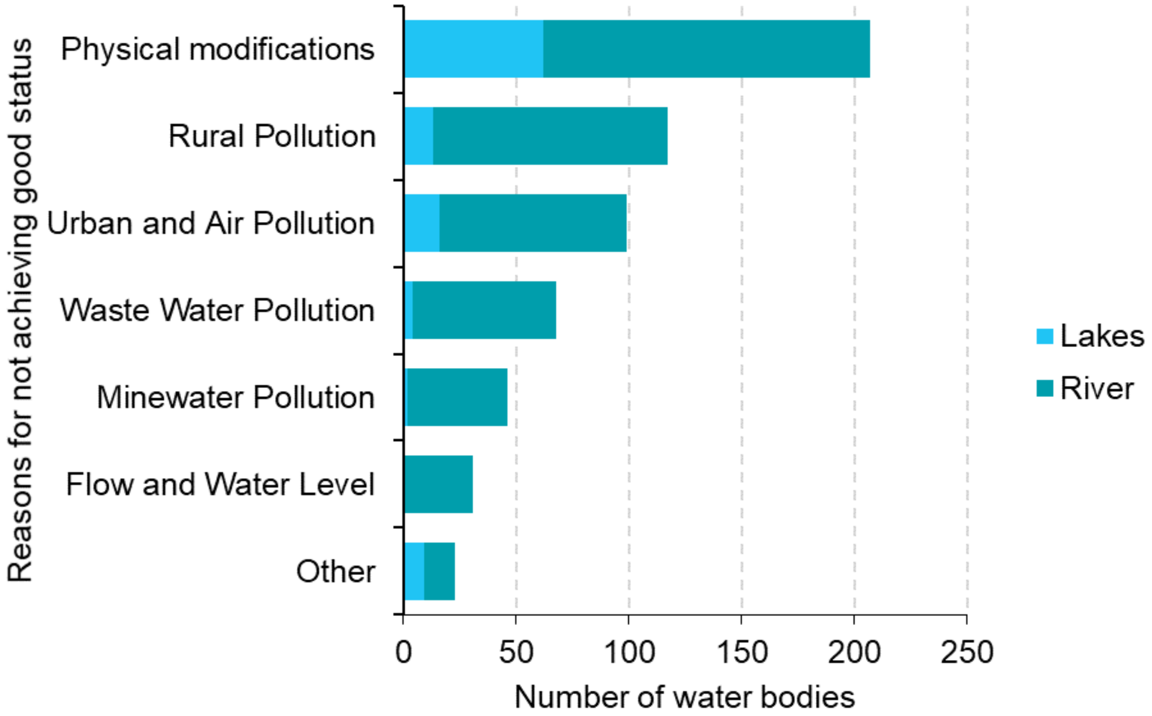


Figure 16 Summary of Reasons for Not Achieving WFD Good Status for Rivers and Lakes. (NRW 2019)

Unconsented modifications to rivers are a widespread problem across Wales. An example is gravel removal from rivers, most of which is used to create/repair farm tracks. This practice is extremely damaging to fish spawning beds and river geomorphology. Landowners are either unaware of the regulations and permit requirements pertaining to gravel removal, or they seek to avoid the permitting process and associated costs.

Between February 2016 and April 2020, NRW received 400 incident reports of river modifications (channel diversion, bank modification, culverting, damming, etc), 55 of these specified gravel removal from rivers (NRW 2020b). See Figure 17, Figure 18 and Figure 19 for examples. These figures are likely to under-represent the true total. Between 2017 and 2019 NRW officers carrying out fish habitat surveys in Carmarthenshire alone discovered 16 sites of gravel removal, with hundreds of tonnes removed at some locations.

Figure 17 Trailer in a river carrying out illegal gravel removal. This is an example of unconsented river modifications (the example shown has occurred since 2017) (Source: NRW).

Figure 18 River straightening, soil erosion and destruction of river corridor habitat (this section has since been colonised by invasive non-native plants). This is an example of unconsented river modifications (the example shown has occurred since 2017)) (Source: NRW).

Figure 19 Reprofiling, dredging and levee creation, destruction of riparian corridor and in-channel features, severely degrading fish habitat and causing extensive siltation. This is an example of unconsented river modifications (the example shown occurred in 2020) (Source: NRW).

A key barrier to the sustainable management of freshwater ecosystems is their continued physical degradation as a result of development and other consented activities. Despite legislative and policy tools (such as the Water Framework Regulations and planning policies) designed to protect freshwater habitats, development continues to cause significant, permanent harm to rivers, flood plains, and other water features.

Numerous examples of developments and infrastructure schemes involving the diversion, culverting and hard engineering of river channels have been constructed since SoNaRR2016, and are ongoing (Figure 20). Some of these schemes affect long lengths of water course and multiple rivers. New road schemes are of particular concern, with several causing significant damage to rivers in recent years (Figure 21).

This failure to implement legislation and policy undermines attempts to restore ecosystem resilience. The reasons for these failures are complex, but major barriers to effective implementation are lack of awareness and understanding amongst the relevant decision-making bodies. An additional factor is the inconsistency of approach between the consenting regimes for main rivers and ordinary water courses. Environmentally sensitive solutions can be more expensive and take longer to design and build. A shift in mindset is required, away from the quickest, cheapest options towards the most sustainable solutions.

Figure 20 Example of channel engineering as a result of a local authority flood alleviation scheme constructed in 2016 (Source: NRW).

Figure 21 Culvert installed as part of road scheme- 2017-2019 (Source: NRW).

Pollution from land management in rural areas

This is pollution resulting from run-off due to land management with the agricultural sector making a large contribution to reported pollution incidents in Wales (Figure 22).

The number of substantiated reports of pollution from agricultural sources has remained stable between 2014-2019 (Figure 23). In 2016 NRW upgraded its reporting system for pollution incidents. This caused the number of pollution incidents where the premises were not reported to decrease from around 38% to about 15%. We have taken this into account in the reported incident figures in Figure 22 by allocating the number of ‘unknown’ incidents for each year proportionally according to the identified cause of known incidents.

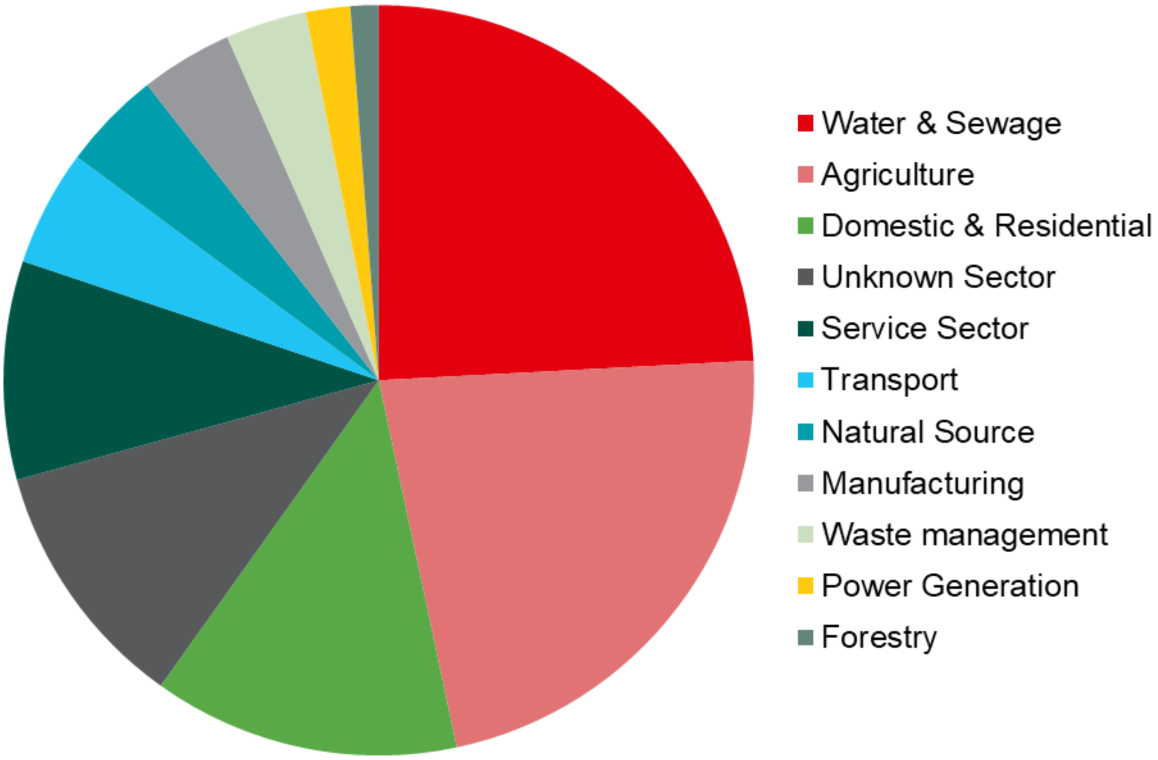


Figure 22 The proportion of pollution incidents by sector, 2014-2019, during which period NRW received 4915 substantiated reports of pollution to water. (Source: NRW 2020d)

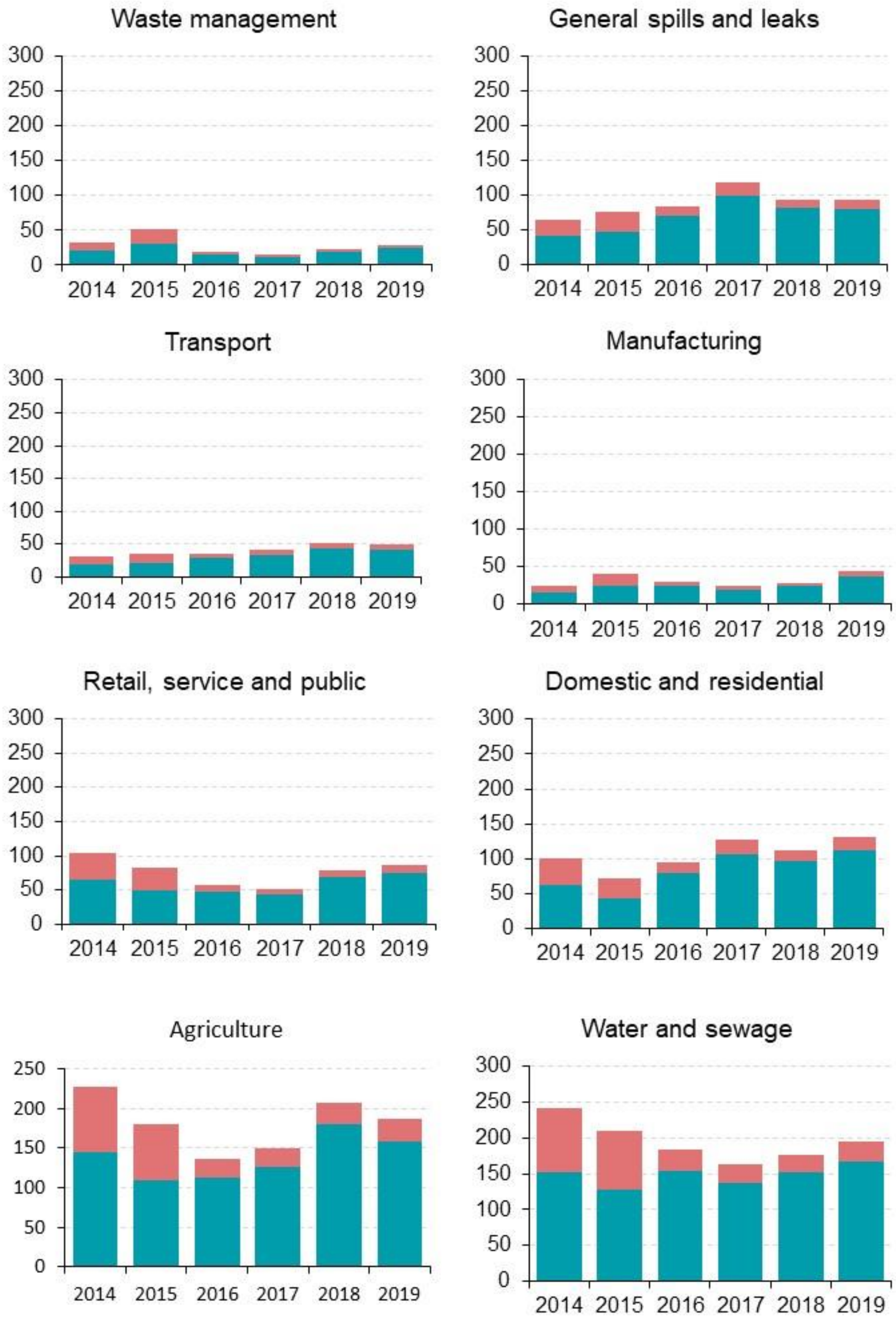


Figure 23 Trends in reported (blue) and predicted additional (red) pollution incidents by sector, 2014-2019. (Source: NRW 2020d)

Figure 24 Example of lack of winter cover crop resulting in soil erosion and run-off (Source: NRW).

Figure 25 Example of livestock trampling resulting in soil erosion and run-off (Source: NRW).

For agriculture, the dairy industry was responsible for more than 50% of all agricultural pollution (Figure 26). Beef farms were also a significant pollution source.

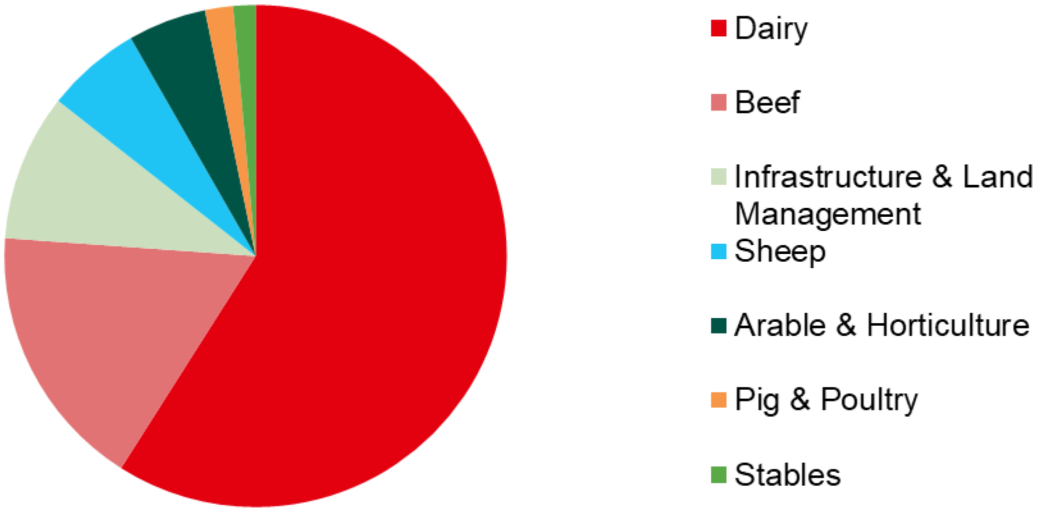


Figure 26 Breakdown of substantiated agricultural pollution incidents since 2014 by agricultural sector. (Source: NRW 2020b)

Figure 27 A river heavily polluted by slurry (Source: NRW).

Cross Compliance, which applies to Basic Payment and Rural Development Scheme claimants, has some scope when it comes to preventing pollution of freshwaters as a result of agricultural run-off. However, there is currently a lack of measures associated with good agricultural practice, and insufficient incentives for creating and maintaining in-field and riparian habitats to reduce transfer of sediments and nutrients to waters, in particular during periods of prolonged wet weather (Figure 28).

Figure 28 Run-off from a cultivated field entering a surface water land drain (Source: NRW).

Pollution from run-off, sewage, urban areas, and roads

This type of pollution consists of nutrients and inorganic pollutants such as detergents, microplastics, chemicals and oils washed into freshwater ecosystems from surface water drains, and waste water discharges. The water and sewage industry makes a large contribution to reported pollution incidents in Wales (Figure 22). For this sector, the most frequent causes of pollution were foul sewers, combined sewer overflows and sewage treatment works which together comprised about 75% of all incidents (Figure 29).The remaining incidents were related to water treatment and distribution.

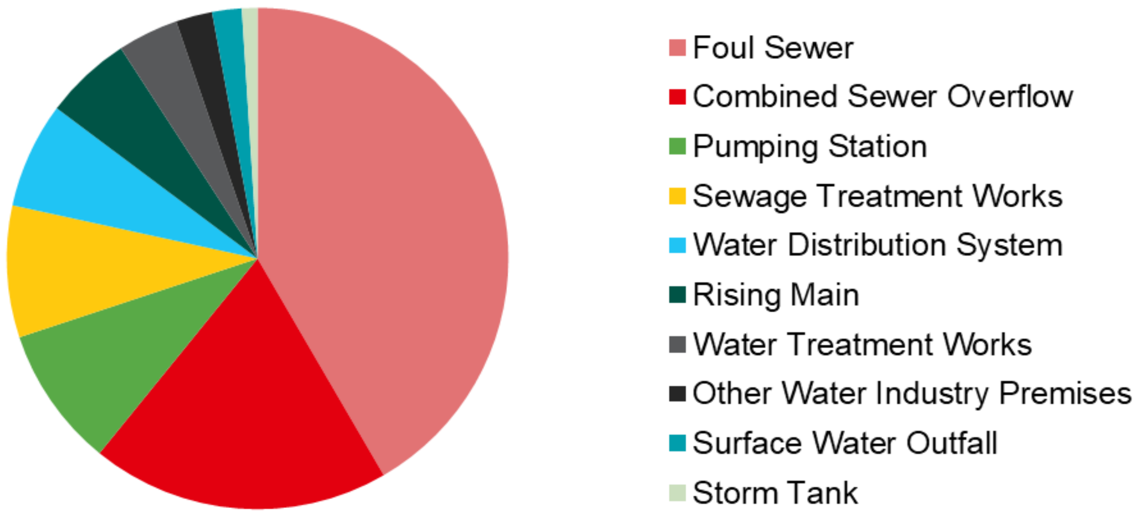


Figure 29 Breakdown of substantiated water and sewage industry pollution incidents since 2014 by activity. (Source: NRW 2020b)

While it is known that these sources of pollution impact on all freshwater habitats particularly in lowland areas, we have relatively little systematic information on the ecological impacts or scale of this pressure in Wales. Some ponds (constructed wetlands) are constructed specifically to intercept this kind of pollution to prevent damage to the wider environment.

Figure 30 A surcharging sewer causing pollution of a river (Source: NRW).

Recently published reports (O'Rourke et al. 2020a and 2020b) provide evidence on the bioaccumulation of chemicals in otter tissues in Wales, with 10 different PBDE (Polybrominated diphenyl ethers) compounds and 13 PFAS (per- and polyfluoroalkyl substances) compounds detected between 1995 and 2011. These are toxic, persistent, man-made compounds that enter the freshwater environment via pathways such as landfill sites and sewage treatment works. PBDEs are widely used as flame retardants in building materials, furnishings, and vehicles. PFAS are used in a wide variety of applications including firefighting foams, paints, cookware, and packaging.

Pollution from historical activity, including mining

This is the pollution caused by contaminated groundwater and spoil-heap run-off from disused metal and coal mines, quarries and contaminated land. There are 1,300 abandoned metal mines in Wales, impacting over 600km of rivers in Wales (Environment Agency 2008, Environment Agency Wales 2002). Impacts can be severe, for example the Afon Goch on Anglesey (Environment Agency 2008; NRW 2020b). Contaminated water may contain toxic dissolved metals such as arsenic, lead, copper, zinc, and cadmium which can bioaccumulate in the food chain and reach dangerous concentrations. In a study of otter corpses collected in Wales between 2006 and 2017, 100% tested positive for zinc, cadmium and copper, 97% positive for mercury, 89% positive for silver, 84% positive for arsenic and 38% positive for lead (O'Rourke et al. 2020c).

Persistent organic pollutants (POPs) originate from a wide range of current and historic sources and although now banned, remain widespread in freshwater food chains, especially in former industrial catchments of South Wales (Lambert & Wagner 2018; Windsor *et al*. 2019).

Changes to natural flows as a result of abstraction and discharges

Abstraction is the removal of water for human use; discharge is the release of water or treated waste water. Both abstractions (with their associated impoundment structures) and discharges are widespread in the Welsh river network. Groundwaters are also affected by abstraction and discharges which can impact natural flows in adjacent rivers and lakes.

Although most of these activities are managed by a system of licences and permits, they represent a disruption to natural flow regimes. This in turn affects flow volume, velocity, variability and the characteristic hydromorphology of the water course. These impacts can affect species with specific flow and humidity requirements. Most of Wales's internationally important oceanic woodlands have their humidity regime governed by river flows (Bosanquet 2015). Lakes are also used as sources of abstraction, or to discharge water down a river for abstraction downstream. See Water efficiency chapter for more information.

Acidification from atmospheric deposition

Acidification is the impact of deposition of acid gases, especially sulphur dioxide, released by burning fossil fuels. These cause low pH episodes in waters with naturally low levels of dissolved minerals. In some of these areas, plantation forestry has aggravated the effects of acidification as trees trap pollutants from the air.

Acidification affects rivers, streams, lakes, and ponds in upland areas. Large areas of Wales are potentially acid-sensitive (Hankin *et al*. 2014). However, there has been a general recovery from acidification over the last two decades (Ormerod & Durance 2009; Shilland *et al*. 2018; NRW unpublished data) due to measures to reduce sulphur dioxide emissions.

Impact of invasive non-native species

Invasive non-native species (INNS) are animals and plants that have been accidentally or intentionally introduced by human activity to a part of the world where they do not naturally occur, and which have subsequently caused serious ecological or socioeconomic damage (NRW 2021). Impacts from INNS include competition, predation, introduction of disease, damage to infrastructure, and disruption to navigation and water supply. For further information on INNS and their impacts, please refer to the INNS chapter.

The growing prevalence of online trading in aquatic species is considered an increased risk factor for the spread of invasive species (Reid *et al*. 2018).

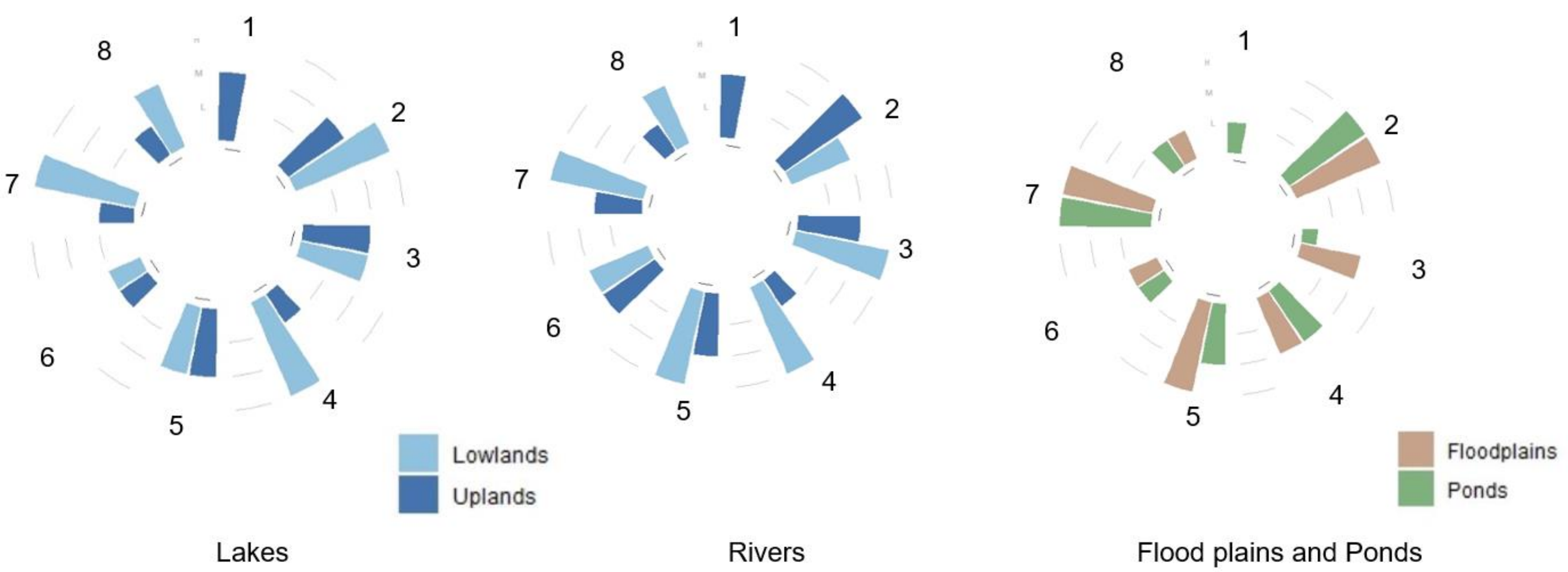
Emerging pressures and threats

Reid *et al*. (2018) identified twelve emerging or increasing global threats to freshwater biodiversity. Some have been discussed above. Additional threats likely to be relevant to Wales are infectious diseases; expanding hydropower; emerging contaminants; engineered nanomaterials; microplastic pollution; light and noise, and cumulative stressors.

Plastic pollution has received significant media attention recently. Studies of microplastic contamination demonstrate that they appear to be virtually ubiquitous in freshwater systems (Lambert & Wagner 2018), including in Wales with about half of sampled invertebrates having ingested plastics (Windsor *et al*. 2019). Studies have shown that many freshwater species take up plastics (Scherer *et al*. 2018a). A study of regurgitates and faecal samples from Eurasian dippers (*Cinclus cinclus*) in South Wales suggests that around 200 plastic particles are ingested daily by dippers via their prey, are passed to offspring via regurgitates, and that concentrations of plastic in samples increase with urban land cover (D'Souza et al. 2020).

Along with other synthetic chemicals released by sewage treatment works, many plastics are also endocrine disruptors, causing sex change in fish. This is a risk predicted to grow in England and Wales in the future (Keller *et al*. 2015). However, the ecological impact of both microplastics and persistent organic pollutants (POPs) is not well understood and is significantly underestimated (Scherer *et al*. 2018b, Windsor *et al.* 2019a, 2019b).

The above information does not include all pressures or cover all freshwater habitats. We have therefore also included a general overview of the severity of pressures on freshwaters in Wales based on a combination of available data and expert opinion, including pressures that are not or cannot be covered by WFD. These are summarised in Figure 31 below.



Key to pressures:
1: Acidification;
2: Climate Change;
3: Hydrology and Flow;
4: Invasive Species;
5: Physical Modifications;
6: Pollution: Historical Mining and Persistent Chemicals;
7: Pollution: Rural Land Management;
8: Pollution: Urban, roads and sewage.

Figure 31 Overall summary of pressures and threats in different Freshwater habitats. The longer the bar, the higher the relative impact of the pressure or threat.

Example of progress towards the sustainable management of natural resources (SMNR)

Freshwater ecosystem restoration for multiple benefits

River restoration aims to reinstate natural river habitat and biodiversity. It can be defined as the re-establishment of natural physical processes (for example variation of flow and sediment movement), features (for example sediment size and river shape) and physical habitats of a river system (including submerged, bank and flood plain areas. (Addy *et al.* 2016). A variety of river restoration work is ongoing across Wales taking an SMNR collaborative approach involving community engagement. There are also projects relating to other freshwater habitats such as the network of Flood plain Ambassadors established by the Flood plain Meadows Partnership to inform management of sites and provide advice to others on their appropriate management.

Mechanisms for implementing restoration include NRW's Area Statements, the WFD programme of measures, management of protected sites, flood risk management, NRW's metal mine restoration strategy, the Plan of Actions for Salmon and Sea trout and NRW's Freshwater Pearl Mussel strategy.

Projects range from local projects such as Taclo'r Tywi on the Afon Tywi in South Wales to large catchment scale cross-border projects such as the LIFE Dee River, a European-funded project encompassing a range of interventions to benefit the habitats and species of the river Dee SAC. NRW are currently setting up an Integrated River Restoration Programme to co-ordinate and plan river work in Wales.

Positive work with sectors

A collaborative approach to working with sectors is important in achieving SMNR. There are several fora which demonstrates the value of this approach:

- The Wales Land Management Forum (WLMF) Sub-Group on Agricultural Pollution. The group has representatives from the farming sector, water industry, environment groups and Welsh Government which work together to deliver the joint goal of reducing agricultural pollution whilst maintaining a thriving agricultural sector in Wales.
- The Wales Water Management Forum provides an opportunity for membership organisations to share evidence and to work together towards the sustainable management of water in Wales.
- The Wales Fisheries Forum represents a range of stakeholders with an interest in the protection and development of the freshwater and diadromous fisheries resources of Wales.

The water industry is another key sector working to deliver improvements for freshwater ecosystems. Dwr Cymru / Welsh Water (DCWW)'s Asset Management Plan 6 (AMP6*,* 2015-20) delivered 12 water quality schemes at sewage treatment works to meet WFD "no deterioration" requirements, and five schemes to contribute to achieving WFD Good Ecological Status. During AMP7 (2020-25) and AMP8 (2025-30) DCWW plan to deliver 26 water quality schemes to meet WFD "no deterioration" requirements, 22 schemes to contribute to meeting targets for SAC rivers and 14 schemes to contribute to achieving WFD Good Ecological Status. A further 27 schemes will also be appraised to identify which require further investment from DCWW and Hafren Dyfrdwy.

Another way of improving the management of freshwater ecosystems is via the planning and development process. In Wales as of January 2019, Schedule 3 of the Flood and Water Management Act (2010) was implemented, which requires all new developments of more than one dwelling house, or where the area is greater than 100 square metres, to incorporate sustainable drainage for surface water that complies with national standards (Welsh Government 2019). This requirement will result in both water quality and biodiversity benefits. Please see Urban chapter for more information.

4. Assessment of Resilience (Aim 2)

The resilience of freshwater ecosystems is their capacity to withstand external pressures. The mechanisms of resilience are generally quite well understood in freshwaters, although our understanding of the resilience of freshwaters in Wales is hampered by a lack of national level datasets to measure it.

The assessments below (Table 8) reflect the way ecosystem resilience of freshwaters has been significantly compromised by human impacts on habitat structure such as invasive species, the extent of shade, weirs and dams, abstractions, and river-flood plain connectivity. Lake resilience can also be affected by historical pollutants which are retained in sediments and slowly released. This long-term damage to the structure and function of river ecosystems (Hearn & Hatton-Ellis 2018), makes them more vulnerable to pressures such as nutrient pollution and climate change.

The main challenge in delivering SMNR for freshwater habitats and species in Wales is preventing further damage and identifying opportunities to restore natural ecosystem function in order to build resilience.

Table 8 SoNaRR2020 Ecosystem Resilience Assessment by attribute of resilience for Freshwater ecosystem.

Practical habitat unit	Diversity	Extent	Condition	Connectivity
Rivers upland	Low The physical and biological diversity of rivers has been severely reduced in Wales over the 20th Century.	Medium The extent of rivers has declined over the 20th Century although less in upper reaches due to accessibility.	Medium Under WFD 44% of all rivers in Wales are at good ecological status. There are no Welsh rivers in High Ecological Status.	Medium Connectivity of upper reaches (longitudinal and lateral) has been less degraded than lower due to accessibility.
Rivers lowland	Low The physical and biological diversity of rivers has severely reduced in Wales over the 20th Century.	Low The extent of rivers has declined dramatically over the 20th Century particularly in the lower reaches.	Low Article 17 reporting in 2018 assesses rivers (water courses of plain to montane levels) with *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation as Unfavourable – Inadequate and declining.	Low 42% of flood plains in England and Wales are no longer connected to the river system (Maltby *et al.*, 2011).

Practical habitat unit	Diversity	Extent	Condition	Connectivity
Lakes – low nutrient and upland	High The majority of this lake type in Wales has a good habitat structure and biodiversity that reflects the expected range of species.	High There has been no significant loss of extent of this habitat type in Wales.	Medium The main pressures affecting this lake type in Wales are acidification, invasive species, and nutrient enrichment (Hatton-Ellis 2012, 2018a, b).	High No significant loss of connectivity.
Lakes – lowland / higher nutrient	Low	Low	Low	High No significant loss of connectivity.
Marl Lakes	Medium	Low	Low	High No significant loss of connectivity.

Practical habitat unit	Diversity	Extent	Condition	Connectivity
Ponds	Medium	Low The number of ponds in Wales has decreased by about 65%, from about 134,000 in the late 19th Century to around 47,000 in 2007 (Williams et al. 2010).	Low	Medium Reduction in the number of ponds will have resulted in a significant loss of connectivity. However, many pond animal and plants are good colonisers (Ormerod et al. 2012), so the effect of this is considered moderate.
Flood plains	Low The diversity of flood plain habitats (neutral and marshy grassland, swamp, wet woodland, fen and bog and their associated ecotones) is extremely degraded.	Low Extent of functioning flood plains are severely reduced as are associated flood plain habitats.	Low In Wales, 84% of flood plains are comprised of modified habitats, with only 10,200ha referable to semi-natural habitats (Jones *et al*., 2009).	Low 42% of flood plains in England and Wales are no longer connected to the river system (Maltby *et al.*, 2011).

5. Healthy places for people (Aim 3)

The regulating and cultural ecosystem services for well-being provided by freshwater habitats are outlined in Table 9 and Table 10 below are developed from the set of services and definitions of the UK NEA Conceptual Framework (UK NEA, 2011) and the UK NEA Synthesis Report The Wales assessment is our current interpretation based on expert opinion.

Table 9 Relative importance of regulating ecosystem services delivered by Freshwaters (open water, wetland, flood plain)

Regulating services	Level of importance
Climate	Medium to low
Hazard	High
Disease and Pests	Medium to high
Noise	Medium to low
Water Quality	High
Soil Quality	Medium to high
Air Quality	Low

Table 10 Relative importance of cultural ecosystem services delivered by Freshwaters (open water, wetland, flood plain)

Cultural services	Level of importance
Environment settings: local places	High
Environment settings: landscape	High

Rivers, lakes, flood plains, and ponds, as well as connected groundwaters, are fundamentally important for human survival. They provide drinking water and contribute to well-being through the opportunities they provide for recreation and the appreciation of landscape. Participating in water-related recreation such as kayaking, wild water swimming and angling can make a significant contribution to the physical and mental health of the population in Wales. In order for us to benefit from the services provided by freshwater ecosystems, we need to balance the needs of the environment, society and the economy.

A key source of data is the Welsh Outdoor Recreation Survey (NRW, 2016b), which provides a comprehensive account of participation in various outdoor activities, from walking to birdwatching. Overall, 93% of adults in Wales took part in outdoor recreation at least once a year with 10% participating in water sports, 11% fishing and 34% wildlife watching. Economic prosperity and employment opportunities for communities and local enterprises are often derived from recreational opportunities and are particularly important for areas that are economically reliant on tourism activity.

Wales's fisheries provide jobs and income in commercial and recreational fishing, fisheries management, and tourism. Angling is one of Wales's most popular outdoor participatory sports, providing a relatively cheap form of recreation, accessible across all sectors of society. A recent study showed that angling in Welsh rivers supports 700 full-time equivalent jobs and produces an annual household income of about £20 million (Mawle 2018). The community value placed upon local fisheries is reflected in the fact that the majority of the fishing rights on rivers are still in the ownership of the local community. There are over 150 local angling clubs across Wales most of which are run on a voluntary basis for the good of all members.

Information about participation and associated economic values for inland fisheries is far more detailed and comprehensive than for most other water sports such as canoeing, kayaking, gorge walking and wild water swimming. Access to suitable waters for non-angling activities, particularly in rivers, is limited and this can sometimes lead to conflict between the different user groups. A key consideration for policy makers is how to increase access to freshwater to all members of society in a way which is sustainable. This may require legislative changes and voluntary agreements between competing user groups.

Salmon, sea trout and eel commercial fisheries have a heritage value with some fishing methods such as the coracle fisheries on the rivers Tywi, Teifi and Taf dating back hundreds of years and remaining in the same local families for many generations. New restrictions on these fisheries have been introduced in recent years which restrict the allowable catch whilst allowing the fisheries to continue to operate. Similar restrictions have been placed on the rod fisheries to protect vulnerable fish stocks whilst ensuring that the socio-economic benefits of the fisheries continue.

Freshwater ecosystems are a valuable educational resource. Projects with schools, such as "Salmon homecoming" and "Eels in Schools", enable young people to engage with and understand their local environment, and therefore promote a sense of environmental responsibility. Reserves managed by organisations such as the Wildlife Trusts and Royal Society for the Protection of Birds (RSPB) Wales provide opportunities for thousands of people to undertake educational activities such as pond dipping and to get more closely involved in practical conservation work through volunteering.

Flooding impacts massively on the lives and health of people in Wales and is increasing in frequency and severity as a result of climate change. Building hard flood defences is expensive and may not always be the best option long-term. Using nature-based remedies, implementing catchment-wide sustainable drainage measures and restoring rivers and flood plains to their natural state will help alleviate the severity of flood events. Improving catchment connectivity by, for example, removing barriers such as weirs will also improve resilience to climate-related changes to flows. Most of the major man-made barriers to the movement of fish in rivers have now been addressed, however, there remain many hundreds of partial barriers in Welsh rivers.

Pollution also detracts from people’s enjoyment of freshwater ecosystems and while water quality has been improving generally across Wales, most notably in the post-industrial rivers of South Wales, there remain areas of concern that must be addressed in the coming years if well-being goals are to be realised. These include diffuse pollution from agriculture, particularly in areas of high intensity dairy farming, dealing with the legacy of pollution from metal mines and addressing microplastics.

Many rivers in Wales continue to be blighted by the presence of litter including plastic from agricultural sources and sewage debris from stormwater overflows. As well as causing an aesthetic impact, this litter will remain in the environment for many years and is difficult to remove.

Finally, there is a requirement to carefully regulate Wales’s water resources. We must ensure that the amount of water being taken from rivers or groundwater can be sustained without damage to the environment. In cases where water cannot be abstracted sustainably, existing licences may need to be amended under the Restoring Sustainable Abstraction (RSA) programme.

6. Regenerative Economy (Aim 4)

The provisioning ecosystem services for well-being provided by freshwater habitats are outlined in Table 11 below. They are developed from the set of services and definitions of the UK NEA Conceptual Framework (UK NEA, 2011) and the UK NEA Synthesis Report. The Wales assessment is our current interpretation based on expert opinion.

Table 11 Provisioning ecosystem services provided by Freshwaters (open water, wetland, flood plain)

Provisioning services	Level of importance
Crops	Low
Livestock & Aquaculture	Low
Fish	Medium to high
Trees, Standing Veg, Peat	Medium to high
Water Supply	High
Wild Species Diversity	High

Freshwaters provide crucial ecosystem services across Wales and beyond including water supply for homes, industry and agriculture, energy generation, flood and drought regulation and recreation. An increasing global population with large scale consumerism has led to the realisation that the usual linear model of take-make-waste is not sustainable; a regenerative economy approach provides an alternative to this, looking to move to a model of avoid-reduce-reuse.

Water supply

In water management, the current model can be described in terms of abstract-use-discharge. To manage water resources more sustainably, we need to reduce usage and optimise water efficiency. Welsh Government's Water Strategy for Wales, 2015, outlines a range of key objectives and supporting actions for the short, medium, and long term (WG, 2015). These include reviews of existing and introduction of new legislation; collaboration to deliver more sustainable and efficient use of water; new standards on sustainable drainage (SuDS) and leakage targets. See Water efficiency chapter for further information.

Climate, flood and drought risk

There is recognition that flood risk management and sustainable drainage needs to take a catchment management approach to reduce flood risk both now and in the future. Early consideration of multiple benefits and the impacts of climate change on long term resilience is now widely encouraged through the new Flood and Coastal Erosion Risk Management (FCERM) policy. In line with WG's Natural Resources Policy, the current FCERM strategy (Welsh Government, 2020) includes objectives to support the delivery of flood risk management measures that utilise nature-based solutions, either as stand-alone or hybrid schemes. There is also increasing focus on the need for sustainable drainage whereby surface run-off passes through a number of SuDS (Sustainable Drainage Systems) before reaching the water course or other water body. See SuDS Wales website for more information.

WG are also looking at ways to measure the environmental benefits delivered by such approaches to help improve understanding and inform future funding strategies. Projects such as the Tweed Forum's Eddleston Water project exemplify a nature-based approach, using a range of measures including "leaky" ponds, flow restrictors, re-meandering, and tree planting schemes (Tweed Forum, 2020). The Working with Natural Processes project provides a comprehensive evidence base for such measures (Maslen *et al.* 2018). Planning Policy Wales and Technical Advice Note 15 also supports the delivery of catchment-wide, nature-based measures to deliver long term sustainable development that is resilient to flood risk.

Hydropower

Renewable energy sources are key to delivering a circular economy approach to energy production, and hydropower makes a significant contribution. There is an estimated 182 megawatts (MW) of installed hydropower capacity in Wales (Welsh Government, 2018b). Approximately 128 MW is delivered by just four schemes in Mid and North Wales with the remainder dominated by small scale run-of-river schemes, numbers of which proliferated between 2010 and 2019 during the period of support from the Feed-in Tariff. Despite this increase, and with 88 new operational schemes between 2016 and 2018, the contribution of these small schemes towards national annual electricity generation totals is limited: median scheme size is less than 100 kilowatts.

Local energy generation is important in raising public awareness of the impacts of energy use and the importance of increasing efficiency. Community Energy Wales is a network of over 50 local energy generation schemes in Wales including Ynni Anafon and Ynni Ogwen community hydropower schemes. These schemes offer the opportunity for local communities to get involved in the entire process as well as benefitting from sessions on energy efficiency.

Opportunities to harness energy from existing water management infrastructure are currently being investigated. In Wales, a number of turbines have been retrospectively fitted to outfalls for public water supply reservoirs. In addition, research is looking at how to improve the long-term sustainability of water supply, treatment and end-use, such as micro-hydropower installations in water and waste water networks to recover energy (Dwr Uisce, 2020). See Energy chapter for more information.

Crops, livestock, water quality and soil quality

At present, the dominant approach to land management in Wales is linear, with waste products from crop and livestock production contributing to freshwater ecosystem degradation. Soil erosion from agricultural land is a significant problem. Current management practices are a legacy of the historical drive towards increased food production at the expense of the environment.

Whilst we are currently far from moving towards a circular economy in this sector, there is a high level of awareness of this issue. Organic farming and low intensity farming have an important contribution to make towards a regenerative economy (See Enclosed farmland chapter and Land Use and Soils chapter for more information).

Taking a holistic view, moving towards a regenerative economy involves:

- Avoidance of food waste within the supply chain and domestically.
- Less intensive, monoculture farming and more extensive varied farming.
- Better on-farm land, water efficiency and waste management practices including development of new technologies to reduce and reuse waste.

The Prosiectslyri Project is an example of innovative technology developed at Gelli Aur agricultural college. A de-watering and purification system is used to filter slurry, producing a good quality fertilizer and clean water suitable for recycling or discharge to a water course. The process reduces the overall volume of slurry by up to 80%, producing a valuable bi-product and it is anticipated that this process will result in a significant reduction in nutrients entering groundwater and water courses.

Waste water

In order to reduce the impact of waste water on the environment, the traditional approach is to remove or reduce the pollutants prior to its discharge. For example, phosphate stripping and Ultra-Violet (UV) treatment of waste water are carried out at some treatment plants. However, such technologies are costly, and therefore a shift is required to address/remove pollutants at their source.

Management of microplastics at source is considered a priority in terms of a circular economy. In a review of the regulation and management of microplastics, Brennholt *et al*. (2018) considered that regulation is urgently required to take into account product cycles and pathways into the freshwater environment. Similarly, Eriksen *et al*. (2018) recommended a focus on tackling the problem at source as it is not possible to remove microplastics once they have entered freshwater systems.

A circular economy approach will also have significant benefits for other ecosystem services including **fisheries, wild species diversity** and **recreation**. More sustainable management of the major provisioning ecosystem services, such as water supply, will improve the resilience of Welsh freshwater ecosystems and ensure continued provision of a full range of services in the future.

7. Synergies and Trade-offs

The management of freshwater ecosystems to enable the delivery of ecosystem services can result in conflicts with achieving the sustainable management of resources. Information is provided below on some of these conflicts, and the choices society needs to make in balancing ecosystem services with ecosystem resilience.

Water supply

Synergy

Improvements to water quality driven by the water industry are beneficial for water supply, biodiversity and ecosystem resilience. For example, Dwr Cymru's Pestsmart scheme has been successful in engaging with landowners to reduce the run-off of pesticides into freshwaters.

Many of Wales's reservoirs are popular tourist attractions and recreational sites.

Trade Off

As described in the discussion on pressures above, abstraction of water from freshwater ecosystems, along with the associated impoundment infrastructure, has negative impacts on freshwater biodiversity, ecosystem function and resilience to climate change. These can be direct impacts to rivers and groundwaters, and also indirect impacts to associated wetlands whose hydrology may be affected by water draw down. Abstraction pressure is likely to rise with population increases and climate change pressures.

Infrastructure associated with water supply such as reservoirs, dams and weirs cause permanent detriment to the functioning of river catchments, affecting the hydrological regime, water temperature, sediment supply and migration of species, and therefore severely reduce the resilience of those catchments. In a comparison of structurally similar sections of the regulated river Elan below the Elan valley reservoirs and the adjacent river Wye, the Elan is typified by lower species richness of benthic invertebrates and lower salmon spawning (Dobson *et al*, 2009).

Water transfers from one catchment to another to redistribute the supply of water across the country have complex detrimental impacts to natural riparian processes, and also introduce a pathway for INNS invasion (UIKWIR 2016); new applications need to be assessed rigorously.

Flood risk and Climate Regulation

Synergy

Nature-based solutions for flood mitigation such as natural flood management have significant benefits for freshwater biodiversity and ecosystem function and can help increase resilience to climate change. Making space for water through the reconnection of rivers with flood plains has significant benefits to biodiversity and river function and can help to slow the flow of water downstream with potential flood risk benefit (Environment Agency 2018)

Measures to reduce water demand and increase water use efficiency in response to predicted drought scenarios will benefit freshwater ecosystems and help increase resilience to climate change.

Trade Off

Traditional hard-engineered approaches to flood control has negative impacts on freshwater ecosystem biodiversity and function, landscape character and reduce resilience to climate change. Hard engineering designed to prevent or reduce flooding increases in-channel flow velocities and shear stress, increases erosion and destabilises substrates. The disconnection of rivers with their flood plains reduces the quantity and quality of wetland habitats which in turn results in reduced biodiversity within flood plains, see evidence presented in section

3. State and Trends (Aim 1).

Waste Disposal/Pest and Disease Regulation

Synergy

Waste water discharges can support river flows during drought. However any such benefit would only be provided by discharges of good water quality.

Trade Off

The river network and groundwaters are a means of disposal of waste water such as sewage, trade effluent and urban run-off. Most of these discharges are regulated by means of a permit. Use of rivers and groundwater in this way is a convenient means of disposal and dilution of waste that may otherwise present an increased risk of disease. However, it is undeniably to the detriment of freshwater ecosystems and their resilience. Pollutants that enter groundwater tend to be retained for a long time due to very slow flow rates.

Hydropower

Synergy

Energy generation from hydropower helps reduce the need for energy from non-renewable power generation sources which produce polluting discharges and place a significant demand on water resources.

Trade Off

Hydropower schemes have a detrimental impact (to a lesser or greater degree depending on the scale of the scheme) on natural catchment processes, principally the movement of sediment through a catchment, natural flow variability and altered humidity and splash-zone regimes (which can have complex impacts on lower plant species).

Reduced flows in the depleted reach can result in hydromorphological and ecological harm, and poorly designed infrastructure associated with hydropower schemes can constitute barriers to species migration. The presence of several hydropower schemes in one catchment can have a cumulative detrimental impact on the ecology and hydromorphology of that catchment.

Land Use- Agriculture and Development

Synergy

Sustainable Drainage Systems (SuDS) help to remediate water quality in urban environments and can provide valuable additional freshwater habitat and connectivity in urban landscapes. See Urban chapter for further information.

Rural Sustainable Drainage Systems (RSuDS) can be implemented on rural sites to slow run-off rates, reduce flood risk, capture silt and remediate pollutants. These micro-wetland features can also create valuable habitats for wildlife (Environment Agency 2012).

Development and regeneration can be a mechanism to restore damaged freshwater ecosystems. There are several examples in the UK where the reclamation of former collieries for development has resulted in the restoration of water courses, such as the restoration of the river Morlais at the former Ffos Las opencast site in Carmarthenshire.

Agri-environment schemes have historically provided limited scope for freshwater habitat restoration/creation. Future schemes may be able to deliver more benefits for freshwater ecosystems.

Trade Off

Flood plain land is fertile, productive and valued agricultural land. Approximately two thirds of Wales's flood plain land is intensively farmed (Rothero *et al*. 2018), resulting in inputs of fertilizers and sediment, and severely compromised or absent natural riparian vegetation. Intensive agriculture has replaced species-rich flood plain meadows and associated wet habitat features with monocultures.

Population increases will increase demand for food and intensive agricultural practices, and this will in turn place additional pressure on catchments that are already compromised.

River corridors and flood plain are often highly valued, desirable areas of land for development. Urban development is historically linked to rivers, and water-side land remains highly desirable for residential, recreational, and industrial developments. Increasing population and housing demand is placing ever increasing pressure to develop on flood plains (Committee on Climate Change 2012).

Implementing suitable measures through the development planning process to adequately protect river corridors and lake-side habitats is challenging and often unsuccessful. In general, short term human needs continue to take precedence over long term resilience and the sustainable management of natural resources.

Flood defences frequently accompany development and agriculture on flood plains, to the detriment of river and flood plain functioning and resilience – see above.

Lighting, noise, infrastructure, drainage, and human presence have detrimental impacts on freshwater habitats and species.

Development and agriculture provide pathways for the spread of INNS, for example the dispersal of Japanese Knotweed and Himalayan Balsam by machinery and livestock.

Fisheries

Synergy

Measures for the protection and enhancement of commercially valuable fish stocks (salmon and trout), such as those set out in NRW's Plan of Action for Salmon and

Sea trout in Wales (NRW 2020c), are likely to benefit wider species and freshwater ecosystems as a whole.

Income derived from angling can assist in funding river and lake restoration measures.

Trade Off

The angling industry adds pressure to fish stocks, and to the general riparian environment (for example disturbance to banks, provision of bankside infrastructure).

Schemes to conserve salmonid and eel stocks, such as catch and release, may have a negative impact on angling-based tourism and the economy.

Wild species diversity

Synergy

Diverse, healthy ecosystems have increased resilience to climate change and other pressures such as invasive non-native species.

Healthy, attractive ecosystems benefit the economy via eco-tourism, recreation, and educational opportunities.

Trade Off

Management or restoration of freshwater ecosystems for the benefit of biodiversity may result in localised consequences and compromises for society. For example, schemes to remove historic weirs and dams for the benefit of freshwater biodiversity can result in short to medium term disruption for landowners in terms of temporary changes to river erosion dynamics. The restoration of flood plain habitat may result in a reduction of land available for intensive agriculture.

Tourism and recreation

Synergy

The value we place on the importance of freshwater habitats as part of Welsh landscape and heritage and their contribution to tourism, recreation and well-being through activities such as walking, kayaking, canoeing, fishing, bird watching is linked to the effort dedicated to their protection.

Trade Off

Tourism and recreation results in disturbance which is generally detrimental to species and habitats. For example, footpaths along lake and river banks can exacerbate soil compaction and erosion, and a high level of human presence can discourage or even preclude species such as otter from using areas of habitat they may otherwise use.

Recreational activities such as angling, boating, and kayaking increase the risk of spreading invasive non-native species between sites.

8. Opportunities for action for achieving the sustainable management of natural resources

The sustainable management of freshwater ecosystems requires an evidence-based approach working in collaboration across catchments. Opportunities are based on three fundamental concepts: **reducing pressures**, **building resilience** and **specific additional measures** to tackle the nature and climate emergencies. Often these three areas overlap. They also complement wider environmental approaches, such as reducing carbon emissions and managing water resources, reflecting global priorities for reversing freshwater biodiversity loss (Tickner *et al*. 2020).

Catchment management approaches are required over the long-term at a landscape-scale, embodying SMNR principles. Collaboration is key, with NRW, stakeholders and community groups working together to achieve sustainable management of natural resources.

These catchment-scale measures need to be in tandem with:

- Effective implementation, and strengthening where necessary, of regulatory tools and guidance to prevent ecological and geomorphological damage.
- Awareness raising and education in the sustainable management of freshwaters, particularly for land managers and development planners.
- The ability to review existing permits.

The following sections explore opportunities for sustainable management in more detail; climate change is not addressed separately as all of the measures described below will improve the functioning of freshwater ecosystems and build resilience to climate change.

Restoration of rivers at a catchment scale

Physical damage to rivers is increasingly being understood as a problem in its own right (see Ormerod *et al*. 2011; Addy *et al*. 2016; Maslen *et al*. 2018). Restoring physical damage and improving habitat diversity helps mitigate some of the harmful impacts of climate change in rivers (Broadmeadow *et al*. 2011).

Opportunities include:

- Delivering NRW's Integrated River Restoration Programme to bring river restoration work across Wales together.
- Implementing river restoration projects that deliver measures such as weir and culvert removal, reconnection of rivers to flood plains, introduction of woody debris, re-meandering to improve habitat diversity, creation of flood plain wetlands and restoration of oxbow lakes and ponds.

- Engagement with communities and stakeholders to raise awareness of freshwater ecosystems and encourage ownership of freshwater health at a local level.
- Improving access to funding for river restoration at a local and catchment scale.

Management of land to protect water quality

In order to effectively prevent or remediate pollution of freshwater ecosystems, it is critical to work with the relevant sectors to deliver long-term, sustainable solutions. A good example of this is the Metal Mine Strategy for Wales (Environment Agency 2002) which, in collaboration with industry partners, has been systematically tackling mines causing pollution.

In contrast, progress to address nutrient pollution across the wider countryside has been slow: sources are varied and not always easy to identify. Different sources require different solutions, with farmyards, slurry pits and septic tanks tackled through one-off interventions and diffuse run-off requiring long term changes to land management.

Addressing the problem of diffuse pollution is complex and requires a high degree of voluntary participation. Opportunities include:

- Catchment-wide, collaborative approaches that integrate land management, flood risk management and river restoration and connect with strategic programmes such as River Basin Management Plans and Area Statements.
- Ensure the forthcoming Sustainable Farming Scheme includes measures to protect water quality and freshwater ecosystem resilience.
- Ensure that the Water Resources (Control of Agricultural Pollution) (Wales) regulations are implemented to deliver improvements in key areas.
- Introduce policy instruments or legislation that improve the design of rural landscapes so that pollution is less likely to enter rivers and lakes.
- Continue to deliver existing initiatives such as River Basin Management Plan measures and the Metal Mine Strategy for Wales.
- Expand the use of Sustainable Drainage Schemes in both the Urban and Rural Environments, in order to prevent pollutants from reaching watercourses and better manage surface water run-off.
- Work with key sectors such as agriculture and industry to identify and develop technologies, techniques and practices that reduce the risk of agricultural pollution while reducing the burden on farmers.
- Improve education and awareness of the agricultural community on sustainable land management for example via agricultural colleges.

Restoration of flood plains

The sustainable management of freshwater ecosystems requires the reconnection and restoration of flood plains (Maslen *et al*. 2018). Flood plains support a range of ecosystem services such as biodiversity, flood management, water quality, fisheries, recreation, and agriculture, as well as increasing resilience of rivers by providing shade through alluvial woodland, and filtration of pollutants. Flood plain reconnection encourages more regular flood plain inundation and flood water storage thereby reducing flood peaks downstream. Past approaches to flood management largely relied on hard engineering and infrastructure, such as walls and embankments, as a means of preventing flooding in specific areas. However, high cost, increasing levels of development and climate change have made this approach untenable.

Welsh Government's draft National Strategy for Flood and Coastal Erosion Risk Management has a key priority to deliver more natural interventions and catchment approaches to help improve environmental, social, and economic resilience (WG, 2020). In addition, revisions to planning policy via TAN15 require a comprehensive flood consequences assessment at the catchment scale to identify flood storage areas which can be included in Flood Risk Management Plans. These policies recognise the need for a new approach to flood management accepting that we cannot prevent all floods, but we can choose where floodwaters are stored.

Opportunities for the delivery of flood plain restoration:

- Support the Welsh Government National Strategy objectives (WG, 2020) and Wales's Planning Policy (TAN15) to take a catchment approach to flood risk management.
- Work with stakeholders to demonstrate and encourage best practice, such as the widespread use of natural flood management measures, sustainable drainage systems and reconnecting rivers to their flood plains.
- Seek restoration of flood plain connectivity and wetlands via the River Restoration Programme.
- Develop integrated river-flood plain management plans for relevant rivers that integrate land use planning, biodiversity, and flood management.

Targeted plans for freshwater biodiversity recovery

Some freshwater habitats and species are in urgent need of special measures to prevent their extinction in Wales. We need to:

- Continue to deliver action plans and strategies for salmonids, pearl mussel and eel.
- Continue to deliver NRW's Freshwater Pearl Mussel Strategy.
- Identify measures to reverse the decline of other seriously endangered freshwater species via collaborative projects such as Back from the Brink Cymru.
- Identify a mechanism to significantly increase the number and quality of lowland ponds.

Measures to Reduce the Impact of Invasive Non-Native Species

INNS can have a devastating impact on native biodiversity, cause structural damage and interfere with flood risk, navigation, and water supply. They also reduce the resilience of freshwaters to other pressures. See also INNS chapter.

Key opportunities in the control of INNS lie in the engagement of the general public and land managers. Citizen science plays a vital role in the monitoring, reporting and control of INNS.

Opportunities to control INNS:

- Effective application of new Invasive Alien Species Order regulatory tools.
- Support the implementation of the IAS Regulation through Wales level Contingency Plans and national Pathway Action Plans.
- Implementation of improved biosecurity measures for transfers of water between rivers/catchments via the water industry AMP7 process.
- Delivery of collaborative catchment-scale projects through the Area Statement process and via third sector partners such as the Rivers Trusts.
- Undertake actions to support the GB INNS Strategy, including encouraging the use of citizen science to collect data.
- Engagement with communities to raise awareness and encourage ownership of INNS control at a local level.

9. Evidence needs summary

Effective management of freshwater ecosystems relies on good quality evidence on existing and emerging pressures and their interactions, as well as biodiversity responses to these pressures. Long term, high quality datasets and expert analysis are vital in order to understand the processes that are taking place. Robust evidence is essential to inform prioritisation of actions.

Evidence requirements for freshwater are broad due to the diverse nature of this ecosystem, with the main themes relating to assessment of condition and understanding the impacts of climate change, physical modification and pollution.

For example, we need to understand and quantify expected changes in river flows, water temperatures and sea level. This in turn will help identify which freshwater habitats and species are most vulnerable to climate changes impacts (low flows, extreme flood events, raised temperatures) and the location of these habitats and species within Wales.

Better understanding is required of pollution source apportionment, the impacts of silt pollution in rivers and of new and emerging chemical pollutants and their interactions. The extent of the physical modification of rivers and floodplains across Wales is not quantified as there is currently no system in place to effectively monitor river habitat structure and geomorphology. A lack of information on the extent and condition of river gravels is a particular concern. In addition, the lack of reliable tools to measure the impact of physical modifications is a significant evidence gap.

Several specific evidence gaps were encountered during the writing of this freshwater assessment. These include:

- robust information on the extent, condition and connectivity of ponds in Wales
- outdated SAC and SSSI feature assessment data
- the causes of the decline in salmon populations
- the impact of river barriers on migratory fish species
- the value of citizen science and community action in the control of invasive non-native species
- accessible information to assess the contribution of freshwater ecosystems to a regenerative economy

Finally, there is a need for reliable tools to identify opportunities and appropriate measures for the restoration of freshwater habitats. Restoration using nature-based solutions is key to addressing the climate and nature emergencies. Whilst there is a growing body of information on how to carry out freshwater restoration, there is less evidence on the benefits these measures have for biodiversity at a local and landscape scale. Such evidence will enable informed policy decisions for regulators and land managers.

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