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Drivers of and pressures arising from selected key water management challenges
A European overview

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European Environment Agency

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Contents

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Key messages

The European Green Deal, adopted towards the end of 2019, and the Water Framework Directive are linked to a number of key EU strategies with targets relevant to water, such as the policy initiatives of the Farm to Fork strategy, the new biodiversity strategy for 2030, the new EU strategy on adaptation to climate change and the zero pollution action plan.

The 2018 EEA assessment of the status of and pressures on European waters concluded that European waters remained under significant pressures linked to altered habitats and pressures from pollution and water abstraction.

As well as providing background information on the European Green Deal and related strategies, this report aims to give a European overview of the main drivers and pressures that are at the core of key water management challenges and which put European water bodies most at risk of not achieving key environmental objectives. The following key European water management challenges have been selected for presentation in this report:

- pollution pressures, including point source pollution, diffuse source pollution, including scattered dwellings, and pollution pressures from mining;
- hydromorphological pressures, including issues related to barriers, loss of lateral connectivity, pressures from hydropower and pressures from inland navigation;
- abstractions and water scarcity;
- aquaculture;
- invasive alien species.

A broad range of technical and management measures are already available to tackle the selected key European water management challenges. The measures required can be mobilised through better implementation of the existing legislative framework on water and the introduction of supplementary measures that further reduce key pressures.

Some cross-cutting issues of EU-wide relevance to the implementation of measures for addressing the selected key European water management challenges are highlighted.

- First, to meet EU targets and goals on water resources, greater coherence is needed in the specific objectives and management responses of the relevant EU directives and policies, in particular nature conservation plans, programmes of measures under the Water Framework Directive and the Floods Directive, and management interventions based on other policies such as the Sustainable Use of Pesticides Directive.
- Second, the use of multi-benefit measures, such as water retention measures, nature-based solutions and land use change measures, is an effective solution for coordinating management responses. Enhancing the use of multi-benefit measures can help to shift the focus from single-issue solutions to an integrated management approach.
- Third, water-using sectors, such as agriculture, energy, mining, aquaculture and navigation, should adopt management practices that can keep water ecosystems healthy and resilient.
- Fourth, financial support for the implementation of measures needs to be mobilised from all available funding sources at local, regional, national and European levels. The success of implementation also depends on using financial instruments beyond water policies including sectoral ones, for example from agricultural, fisheries and biodiversity policies.

Executive summary

This report aims to give a European overview of the main drivers and pressures that are at the core of key water management challenges and which put European water bodies most at risk of not achieving key environmental objectives. Identifying the pressures from and drivers of key water management challenges at the European level can help in prioritising the main issues that should be tackled with measures.

Key management challenges for European waters, in particular those related to the degradation of freshwater ecosystems, pollution from chemicals and nutrients, and water abstraction and scarcity, are addressed by different EU strategies and policies, which are further operationalised in management responses to the water and environmental EU directives. Harmonising the objectives and management responses of different policies to tackle these key water management challenges is one of the ambitions of the European Green Deal and its associated strategies. Examples are the new biodiversity strategy for 2030, the Farm to Fork strategy, the chemicals strategy for sustainability, the new EU strategy on adaptation to climate change and the zero pollution action plan. The ambitious targets of these strategies address the main pressures on European waters, such as combatting disrupted river continuity by aiming to restore 25 000 km of free-flowing rivers by 2030 or counteracting high discharges of nutrients and chemicals from agriculture by aiming to reduce the loss of nutrients and the use and risks of using pesticides by 50 %.

A key source of information for defining key management challenges for European freshwaters is the river basin management plans (RBMPs) of the Water Framework Directive (WFD). The latest (second) RBMPs showed that a large share of European waters still fail to achieve the objective of good status, as a result of significant pressures on their hydromorphology and pressures arising from pollution from diffuse and point sources and from water abstraction.

Based on the analysis of significant pressures and drivers affecting water bodies in the latest RBMPs, 10 key European water management challenges were selected to be presented. In addition to describing the main sources and sectoral activities behind key pressures and the main associated impacts, the key measures that are available to tackle these challenges in European countries are summarised. Most of the selected pressures and drivers regarding pollution, hydromorphology and abstractions affect a large share of European water bodies and are reported to be experienced by a large number of countries. Some other pressures, such as mining, navigation, aquaculture and invasive alien species, seem to affect only a small share of European water bodies, but they can be of considerable importance and intensity in specific regions of Europe, thus significantly contributing to the failure to achieve good water status at a regional level. Table ES.1 summarises the drivers of and pressures arising from the key European water management challenges presented in the report. More details on their key impacts on water ecosystems and key measures and management challenges of EU-wide relevance are available in Chapter 3.

A broad range of technical and management measures are already available to tackle the selected key European water management challenges. The measures required can be mobilised through better implementation of the existing legislative framework on water and the introduction of supplementary measures that further reduce key pressures.

Some cross-cutting issues of EU-wide relevance for the implementation of measures for addressing the selected key European water management challenges are highlighted. These cross-cutting issues are discussed with emphasis on their role in improving and accelerating the implementation of measures to achieve the WFD objective of good status for European waters.

First, to meet EU targets and goals on water resources, greater coherence is needed in the specific objectives and management responses of the relevant EU directives and policies. This applies in particular to nature conservation plans, programmes of measures under the WFD and Floods Directive, and management interventions based on other policies such as the Sustainable Use of Pesticides Directive.

Second, the use of multi-benefit measures, such as water retention measures, nature-based solutions and land use change measures, is an effective solution for coordinating management responses. Enhancing the use of multi-benefit measures can help to shift the focus from single-issue solutions to an integrated management approach, such as ecosystem-based management for the improvement of ecosystem services and using catchment-based approaches.

Third, water-using sectors, such as agriculture, energy, mining, aquaculture and navigation, should adopt management practices that can keep water ecosystems healthy and resilient. The report describes several existing sustainable sectoral initiatives at regional and national levels, such as sustainable farming programmes, sustainable hydropower and navigation strategies, and codes of good practice for aquaculture. Such initiatives intend to reduce the pressures and impacts of sectoral activities on water resources and need further upscaling. Water sustainability elements brought into sectoral strategies need to be consistently enforced and implemented on the ground.

Fourth, financial support for the implementation of measures needs to be mobilised from all available funding sources at local, regional, national and European levels. The success of implementation also depends on using financial instruments beyond water policies, including sectoral ones, e.g. from agricultural, fisheries and biodiversity policies. Furthermore, the report presents innovative financing mechanisms, including the participation of industry, and some of the mechanisms that have already been set up in European countries.

Table ES.1 Overview of pressures, sectors and activities for selected key European water management challenges

Pressure/sector/activity	Importance for European water bodies in second RBMPs
Pollution: point sources	15 % of surface water bodies (urban wastewater, industrial wastewater) and 14 % of the groundwater area (mainly contaminated sites, industrial sites, waste disposal, mining and urban wastewater) are affected by point source pollution as a significant pressure
Pollution: diffuse sources	22 % of surface water bodies and 28 % of the groundwater area are affected by diffuse pollution from agriculture as a significant pressure. Mercury from atmospheric deposition is the main reason for failing good chemical status in more than 30 % of surface water bodies
Pollution: non-connected dwellings	10 % of surface water bodies and 7.5 % of the groundwater area are affected by diffuse source pollution from non-connected dwellings as a significant pressure (i.e. discharge from households not connected to the sewerage network and urban waste water treatment plants or other collection systems)
Pollution: mining	7.5 % of the groundwater area and ca. 1 100 (less than 1 %) of surface water bodies in 17 countries are affected by mining as a significant point and/or diffuse source pressure
Hydromorphological pressures: barriers	20 % of surface water bodies are affected by barriers as a significant pressure. Many barriers reported in the RBMPs are used for hydropower production, flood protection and irrigation, but for 40 % of affected water bodies the purpose of the barriers is unclear
Hydromorphological pressures: loss of lateral connectivity	10 % of surface water bodies are affected by physical alterations to the channel, bed or riparian area due to flood protection and/or agriculture. Furthermore, flood protection and/or drainage for agriculture are the reasons that almost 7 500 water bodies are designated as heavily modified in 26 countries
Hydromorphological pressures: hydropower	6 % of surface water bodies are affected by significant pressures due to hydropower barriers, hydrological alterations and abstractions
Hydromorphological pressures: navigation	< 1 % of surface water bodies (ca. 700 water bodies in 13 WFD countries) are affected by pressures from inland navigation, in particular barriers and physical and hydrological alterations. However, navigation issues are of high importance in the largest European river basins
Abstractions and water scarcity	6 % of surface water bodies and 17 % of the groundwater area are affected by abstractions as a significant pressure. These are mainly linked to agriculture, public water supply and industry
Aquaculture	ca. 1 400 water bodies in 20 countries are affected by significant pressures from aquaculture, mainly related to water abstractions but also from point and diffuse source pollution and hydrological alterations
Invasive alien species (aquaculture, pet/aquarium species, shipping fisheries/ angling)	2 % of surface water bodies (ca. 2 700 water bodies) in 15 countries are affected by invasive alien species as a significant pressure

Note: More details on the above pressures, sectors or activities are available in Table 3.1.

1 Introduction

Water is an essential resource for human health, food production, energy production, transport and nature. Securing sustainable management of water and of aquatic and water-dependent ecosystems and ensuring that enough high-quality water is available for all purposes remains one of the key challenges of our time in Europe and is the main aim of EU water policy and the European Green Deal.

The European Green Deal, adopted towards the end of 2019 (EC, 2019d), set a new milestone in European environmental policy and it creates a framework for transitioning to a modern, resource-efficient and competitive economy. Several goals and targets of the European Green Deal are relevant to water resources, for instance restoring ecosystems, reducing pollution from different sources and using resources more efficiently. At the same time, many actions are ongoing and further efforts are needed across Europe to achieve the objective of the Water Framework Directive (WFD) for all surface water bodies and groundwater to achieve good status by 2027 at the latest. In this context of existing and new policies, European countries are called on to address several key water management challenges, in particular those related to the degradation of freshwater ecosystems, pollution from chemicals and nutrients, and water abstraction and scarcity.

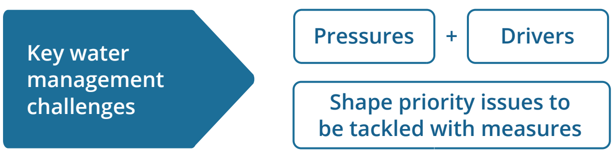
1.1 Aims of this report

This report builds on the 2018 EEA assessment of the status of and pressures on European waters (EEA, 2018b). In that assessment, the EEA concluded that European waters remained under significant pressures linked to changes in their hydromorphology and pressures from pollution arising from diffuse and point sources and from water abstraction. The report noted limited progress in improving water status between the first and the second planning cycle of the WFD. The pressures on European waters often act at the same time and affect the efficient functioning of ecosystems, contribute to biodiversity loss and threaten the valuable benefits that water brings to society and the economy. However, the 2018 report did not include a detailed assessment of the main drivers and pressures causing less than good status in EU water bodies. This report takes the 2018 assessment of water status and pressures one step further and aims to give a European overview of the main drivers and pressures that are at the core of key water management challenges at the European level.

The key water management challenges identified in this report are a structured presentation of EU-level evidence on the main drivers and pressures that put European water bodies most at risk of not achieving the WFD's environmental objectives. The presentation of these key water management challenges aims to improve our understanding of the main sources and sectoral activities behind key pressures and the main associated impacts. In addition, the key measures that are available to tackle these challenges across most European countries and management issues of EU-wide relevance are summarised.

Identifying the pressures and drivers of key water management challenges at the European level can help in prioritising the main issues that should be tackled with measures, especially those set out in the river basin management plans (RBMPs) under the WFD (Figure 1.1). The identification of key European water management challenges can also support the assessment of the upcoming third RBMPs, especially in terms of whether efforts and resources in the third cycle are being directed to addressing the most challenging issues.

Figure 1.1 Key European water management challenges



Based on the analysis of significant pressures and drivers affecting water bodies in the latest (second) RBMPs, the following key European water management challenges have been selected for presentation in this report:

- **pollution pressures**, including point source pollution, diffuse source pollution; including scattered dwellings, and pollution pressures from mining;
- **hydromorphological pressures**, including issues related to barriers, loss of lateral connectivity, pressures from hydropower and pressures from inland navigation;
- **abstractions and water scarcity**;
- **aquaculture**;
- **invasive alien species**.

Key European water management challenges were selected that affect a sufficiently large share of European water bodies and that have been important for long enough to develop a solid knowledge and information base, from which to describe the scope of the issue at the European level (see Chapter 3 for more information).

The report also discusses cross-cutting issues of EU-wide relevance in implementing measures for addressing the main drivers of and pressures arising from key European water management challenges. These cross-cutting issues are discussed with emphasis on their role in improving and accelerating the implementation of measures to achieve the WFD objective of good status in European waters.

1.2 Policy context

The key aspects and aims of the European Green Deal are shown in Figure 1.2. The European Green Deal includes a number of key EU strategies with targets relevant to water, such as the policy initiatives of the Farm to Fork strategy (EC, 2020c), the new biodiversity strategy for 2030 (EC, 2020b), the new EU strategy on adaptation to climate change (EC, 2021a) and the zero pollution action plan (EC, 2021b). The targets of these strategies are expected to have far-reaching impacts on several of the key European water management challenges presented in this report. Further EU strategies with high-level targets for water include the proposal for the Eighth Environmental Action Programme (EC, 2020f) and the implementation of the Sustainable Development Goals (EC, 2016a) (see Table 1.1). In addition, in 2019 the European Commission published the evaluation of water legislation, the Fitness Check, and this provides the main directions for revisions and future water policies (EC, 2019b).

Figure 1.2 Key aspects and aims of the European Green Deal

Source: Communication from the European Commission on the European Green Deal (EC, 2019d).

Table 1.1 Overview of EU policies and strategies and key targets related to water

EU strategy	Key targets related to water
European Green Deal (EC, 2019d)	Roadmap with actions up to 2050 to boost the efficient use of resources by moving to a more circular economy and stop climate change, reverse biodiversity loss and cut pollution
Farm to Fork strategy (EC, 2020e)	• 50 % reduction in use of and risk from pesticides • 50 % reduction in nutrient losses • 20 % reduction in the use of fertilisers • 50 % reduction in the use of antimicrobials • 25 % increase in the amount of organic farming
Biodiversity strategy for 2030 (EC, 2020b)	• 30 % of EU land and sea protected, one third of which is under 'strict protection' • No deterioration in any protected habitats and species by 2030; trend to be positive for at least 30 % of them • > 10 % increase in biodiverse landscape features • Increased efforts to restore freshwater ecosystems and the natural functions of rivers • Restore at least 25 000 km of free-flowing rivers by removing primarily obsolete barriers and restoring floodplains and wetlands • Member States to review water abstraction and impoundment permits to restore and preserve ecological flows • Focus on implementation and enforcement of EU environmental legislation including the objectives of the WFD, which are to be met by 2027 • Reduce the use of and risk from pesticides by 50 % • Reduce pollution from fertilisers by 50 % and their use by 20 % • Enable actions to achieve transformative change such as promotion of nature-based solutions
Chemicals strategy for sustainability towards a toxic-free environment (EC, 2020a)	• Ban the most harmful chemicals • Account for the cocktail effect of chemicals • Phase out per- and polyfluoroalkyl substances (PFAS) • Boost the production and use of chemicals that are safe and sustainable by design throughout their life cycle • Promote the EU's resilience of supply and the sustainability of critical chemicals
Zero pollution action plan (EC, 2021b)	Pollution is reduced to levels no longer considered harmful to health and natural ecosystems with the following targets related to water: • Reduce by 50 % nutrient losses, the use and risk of chemical pesticides, the use of the more hazardous ones, and the sale of antimicrobials for farmed animals and in aquaculture; • Reduce by 50 % plastic litter at sea and by 30 % microplastics released into the environment.
A new circular economy action plan (EC, 2020g)	• Focus on the sectors that use most resources, such as plastics, water and nutrients • Implement the new Water Reuse Regulation • Facilitate water reuse and efficiency, including in industrial processes
EU strategy on adaptation to climate change (EC, 2021)	• Ensure climate-resilient, sustainable use and management of water by improving coordination of thematic plans and other mechanisms, such as water resource allocation and water permits • Reduce water use by introducing water-saving requirements for products, encourage water efficiency and savings, and promote wider use of drought management plans and sustainable soil management and land use • Guarantee a stable and secure supply of drinking water by incorporating the risks of climate change in risk analyses of water management • Highlight the role of nature-based solutions for land use management and infrastructure planning to reduce costs, provide climate-resilient services and improve compliance with the WFD and Floods Directive
Eighth Environment Action Programme (EC, 2020f)	• Pursue a zero-pollution ambition, including for air, water and soil • Protect, preserve and restore biodiversity and enhance natural capital, notably air, water and soil as well as forest, freshwater, wetland and marine ecosystems • Integrate assessments on the Floods Directive, Urban Waste Water Treatment Directive and Nitrates Directive, and integrate a freshwater and marine ecosystem-based approach as part of the economic transition • Make full use of nature-based solutions

Table 1.1 Overview of EU policies and strategies and key targets related to water (cont.)

Sustainable Development Goals	Goal 6 is to ensure the availability and sustainable management of water and sanitation for all by: • improving water quality by reducing pollution • substantially increasing water use efficiency across all sectors and ensuring sustainable withdrawals and a supply of freshwater • implementing integrated water resources management at all levels, including through transboundary cooperation as appropriate • protecting and restoring water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

The targets and actions in the EU strategies listed in Table 1.1 are in general implemented through specific environmental directives and policies such as the WFD, the Floods Directive, the Habitats Directive and the Birds Directive. They are also implemented through directives related to specific issues, such as the Urban Waste Water Treatment Directive (UWWTD), the Nitrates Directive and the Sustainable Use of Pesticides Directive. The water-related contributions of these directives to EU strategies are briefly described in this section.

The WFD (EU, 2000) aims to achieve good status of all surface waters and groundwater in Europe. With its programme of measures, the WFD addresses most of the previously mentioned targets and goals and is therefore key for water management. In 2009, EU Member States published the first RBMPs and in 2015 the second RBMPs on how to achieve the environmental objectives of the WFD. At present, EU Member States are finalising the third RBMPs, to be published in 2021, which will frame the management of water resources in the third WFD planning cycle, covering the period up to the end of 2027. More information on the implementation of the WFD and assessments of the latest second RBMPs are available in the European Commission's fifth WFD implementation report, published in 2019 (EC, 2019a). The Commission also evaluates the programmes of measures expected to be implemented during the second RBMP period (2016-2021) at both the European and national levels. EU Member States reported the progress in implementing measures in December 2018 and the Commission's evaluation of the progress will be published in 2021.

The goal of the Floods Directive (EU, 2007b) is the sustainable management of flood risks to reduce the negative consequences of flooding on, for example, human health and the environment. Member States are requested to develop a programme of measures, which includes win-win measures in coordination with the implementation of WFD measures.

Targets for the restoration of aquatic ecosystems are also considered by the Habitats Directive (EU, 1992), which aims at the conservation of rare habitat types and threatened or endemic animal and plant species, and the Birds Directive (EU 2009b), which focuses on the protection of 500 wild bird species, including their habitats in the form of protected areas. These areas are part of the Natura 2000 network set up under the Habitats Directive.

The UWWTD (EU 1991a) specifically addresses the reduction of nutrient and chemical pollution to waters. Other directives and pieces of legislation related to chemicals in waters are the REACH Regulation (EU, 2006c) on the registration, evaluation, authorisation and restriction of chemicals and the Industrial Emissions Directive (IED) on industrial emissions for integrated pollution prevention and control. Furthermore, the Nitrates Directive (EU, 1991b) and the Sustainable Use of Pesticides Directive (EU, 2009a) aim to avoid nutrient and chemical pollution from agriculture into soil and waters, and they are specifically linked to the Farm to Fork strategy. For both directives, Member States are obliged to establish national action plans, including mitigation measures, to fulfil the directives' requirements.

Furthermore, the regulation on the prevention and management of the introduction and spread of invasive alien species (IAS Regulation) (EU, 2014) and the Eel Regulation (EU, 2007a) support targets of the EU biodiversity strategy. The Bathing Water Directive (EU, 2006a) and the Drinking Water Directive (EU, 2020) set quality standards for waters, relevant for human health. To ensure that water is safe to use, sources of pollution on a catchment scale need to be considered. However, a link to directives addressing chemical or nutrient pollution (as previously mentioned) is crucial.

All of these policies constitute an elaborate set of European environmental policies and standards that provide the framework for planning and implementing measures to address the key European water management challenges presented in this report.

1.3 Structure of this report

Chapter 2 recaps the key findings of the 2018 EEA assessment of the status of and pressures on European waters. The results of the 2018 assessment have been updated to include reporting information from more countries (EU-27 plus Norway and the United Kingdom) compared with those assessed in 2018. Chapter 2 thus presents an updated summary of the information published by the EEA in 2018 (which was based on 25 Member States).

Chapter 3 presents the drivers of and pressures arising from selected key European water management challenges and gives an overview of each issue in Europe, the main impacts on water ecosystems and key measures available to tackle the issue. Chapter 3 also briefly explains how the key water management challenges have been selected and the information used to describe them (based on the WFD reporting and other sources of information on sectors, activities and impacts).

In Chapter 4, the report discusses certain cross-cutting issues of EU-wide relevance in implementing measures for addressing key European water management challenges. These cross-cutting challenges address:

1. the coherence of EU policies and their management responses to reduce pressures in the water environment;
2. the coherence of sectoral strategies with water policy objectives;
3. the funding of measures;
4. the role of multi-benefit measures.

2
Status of and pressures on Europe's waters in the second RBMPs

In 2019, the European Commission published its report on the assessment of the second river basin management plans (RBMPs) and the first flood risk management plans (FRMPs) (EC, 2019a), including a detailed analysis of Member States' programmes of measures and country-specific and EU-wide recommendations to tackle water management challenges. To accompany and inform the assessment, the EEA produced a report on the state of Europe's waters (EEA, 2018b). In addition, the Water Information System for Europe (WISE) Water Framework Directive (WFD) visualisation tool presents more and more detailed results ([1]).

This chapter is an updated version of part of the executive summary ([2]) of the EEA 2018 report on the state of Europe's waters (EEA, 2018b). Although the 2018 EEA report was based on data from 25 EU Member States, this updated chapter is based on additional data from Greece, Ireland, Lithuania and Norway. Therefore, the results presented in this chapter on the water status and pressures cover the 27 EU Member States, Norway and the United Kingdom ([3]). Throughout this report, the term 'WFD countries' is used to cover the countries that implement the WFD: the 27 EU Member States, Norway and the United Kingdom.

2.1 Improvements in monitoring and assessment

In comparison with the first RBMPs, the quantity and quality of the evidence available on the water status and pressures has grown significantly in the second RBMPs. Many Member States and river basin districts have invested in new or better ecological and chemical monitoring programmes, with a greater number of monitoring sites and the inclusion of more chemicals and quality elements. Surface waters and groundwater have been monitored at around 190 000 monitoring sites. In the second RBMPs, this has resulted in both a marked reduction in the proportion of water bodies with unknown status and clearly increased confidence in status assessments.

2.2 Surface waters: status and pressures

2.2.1 Ecological status

Ecological status or potential is an assessment of the quality of the structure and functioning of surface water ecosystems. It shows the influence of all pressures, such as pollution, habitat degradation and hydrological changes, in rivers, lakes, transitional waters and coastal waters. Ecological status is based on biological quality elements and supporting physico-chemical and hydromorphological quality elements.

On a European scale, around 44 % of the surface water bodies are of good or high ecological status or potential, with lakes and coastal waters having better status than rivers and transitional waters ([4]). There has been limited change in ecological status since the first RBMPs were reported, although this comparison is difficult to make, as the data underpinning the first RBMPs were of lower quality than the data for the second RBMPs. The status of many individual quality elements that make up ecological status is generally better than the ecological status as a whole. The analysis shows that the ecological status of some biological quality elements improved from the first to the second RBMPs.

([1]) WISE Freshwater WFD visualisation tool (https://www.eea.europa.eu/themes/water/european-waters/water-quality-and-water-assessment/water-assessments).

([2]) More detailed information is available in the 2018 EEA report (EEA, 2018b) and the WISE Freshwater WFD visualisation tool.

([3]) This summary presents data from the second RBMPs (up to 2016), when the United Kingdom was still an EU Member State, and therefore data on the UK status and pressures are included.

([4]) Compared with the results in EEA (2018b), there is an increase in the proportion of surface water bodies with high or good ecological status (from 40 % to 44 %) because of better-than-average ecological status in the extra countries included (Greece, Ireland, Lithuania and Norway). See also Surface water bodies: Ecological status or potential.

2.2.2 Chemical status

For surface waters, good chemical status is defined by limits (environmental quality standards, EQS) on the concentration of certain pollutants found across the EU, known as priority substances. The second RBMPs found that 31 % of surface water bodies are of good chemical status, while 35 % have not achieved good chemical status; the status of 34 % of surface water bodies is unknown ([5]).

In many Member States, relatively few substances are responsible for failure to achieve good chemical status. Mercury causes failure in many water bodies. If the widespread pollution by ubiquitous priority substances, including mercury, is omitted, the proportion of water bodies with good chemical status increases to 64 %, with a remaining 3 % that have not achieved good status and 34 % for which the status is unknown ([6]). The main reasons for failure to achieve good status are atmospheric deposition and insufficiently treated discharges from waste water treatment plants.

Since the publication of the first RBMPs, Member States have made progress in tackling priority substances, leading to a reduction in the number of water bodies failing to meet standards for substances such as priority metals (including cadmium, lead and nickel) and pesticides.

2.2.3 Pressures on surface waters

The main significant pressures on surface water bodies are hydromorphological pressures (affecting 34 % of water bodies), diffuse pollution sources (33 %), particularly from agriculture, and atmospheric deposition (31 %), particularly of mercury, followed by point sources (15 %) and water abstraction (6 %) ([7]). The main impacts on surface water bodies are nutrient enrichment, chemical pollution and altered habitats as a result of morphological changes.

2.3 Groundwater: status and pressures

The WFD requires that Member States designate separate groundwater bodies and ensure that each one achieves 'good chemical and quantitative status' ([8]). To meet the aim of good chemical status, hazardous substances should be prevented from entering groundwater, and the entry of all other pollutants (e.g. nitrates) should be limited.

Good quantitative status can be achieved by ensuring that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction. In addition, impacts on surface water linked with groundwater or groundwater-dependent terrestrial ecosystems should be avoided, as should saline or other intrusions.

In the EU, 75 % and 90 % of the area of groundwater bodies are of good chemical and quantitative status, respectively ([9]). This is a small improvement in status from the first RBMPs.

Nitrate is the main pollutant, affecting over 17 % of the area of groundwater bodies. In total, 170 pollutants resulted in failure to achieve good groundwater chemical status. Most of these were reported in only a few Member States, and only 29 pollutants were reported by five or more Member States.

In the EU, agriculture is the main cause of groundwater's failure to achieve good chemical status, as it leads to diffuse pollution from nitrates and pesticides. Other significant sources are discharges that are not connected to a sewerage system and contaminated sites or abandoned industrial sites.

Water abstraction for public water supply, agriculture and industry is the main significant cause of failure to achieve good quantitative status.

([5]) Compared with the results in EEA (2018b), there is a marked increase in the proportion of surface water bodies with unknown chemical status (from 16 % to 34 %), because nearly all surface water bodies in Norway and Ireland have unknown chemical status. The high proportion of unknown statuses reduces the percentage with good or failing to achieve good chemical status. See also Surface water bodies: Chemical status.

([6]) The high proportion of surface water bodies with unknown status also reduces the proportion with good chemical status (from 81 % to 64 %).

([7]) Compared with the results in EEA (2018b), there is a decrease in the proportion of surface water bodies affected by the pressures listed (of between 3 and 7 percentage points), because of better status and less pressures in the extra countries included (Greece, Ireland, Lithuania and Norway). See also Surface water bodies: Significant pressures.

([8]) See the specific criteria on chemical and quantitative status in Annex V of the WFD (EU, 2000).

([9]) Compared with the results in EEA (2018b) there are minor increases of 1 percentage point in good quantitative and good chemical status. See also Groundwater bodies: Quantitative status and Groundwater: Chemical status.

2.4 Overall progress since the first RBMPs

Overall, the second RBMPs show limited change in all four measures of status ([10]), as most of the water bodies had the same status in both cycles. However, having fewer water bodies with unknown status increased both the proportion with good status and the proportion with less than good status. The analysis of the second RBMPs shows that there has been progress in the status of single quality elements and single pollutants.

There are several possible explanations for the limited improvement in groundwater and surface water status ([11]) from the first to the second RBMPs:

- First, additional biological and chemical monitoring was implemented after 2009 and the classification methods were improved.

- Second, for some water bodies, some quality elements have improved in status, but there has been no improvement in their overall ecological status.

- Third, the second RBMPs generally show status classification up to 2012/2013, and at that time many measures were only in the process of being implemented; therefore, there may be a time lag before pressures are reduced and status improves.

- Finally, some pressures may have been unknown in 2009, and so the measures implemented may not have been sufficient or as effective as expected in reducing these.

In the next chapter, the key pressures on European water bodies and their drivers are illustrated in more detail for a number of selected key European water management challenges. These include summaries of key measures available to tackle these and reference to key management challenges of EU-wide relevance (ongoing challenges and new challenges ahead).

([10]) Surface water ecological and chemical status and groundwater chemical and quantitative status.
([11]) 'Groundwater status' is the general expression of the status of a body of groundwater, determined by the poorer of its quantitative and chemical status. 'Surface water status' is the general expression of the status of a body of surface water, determined by the poorer of its ecological and chemical status.

3 Selected key European water management challenges

As explained in Chapter 1, the selected key European water management challenges presented in this report summarise EU-level evidence on the main drivers and pressures that put European water bodies most at risk of not achieving the Water Framework Directive (WFD) environmental objectives and which affect water bodies in the second river basin management plans (RBMPs).

Ten key European water management challenges are presented that are related to pollution issues, hydromorphological pressures, abstractions and water scarcity, and problems related to aquaculture and invasive alien species are also presented. These key water management challenges arise not only from ongoing human activities (such as agriculture and energy production) but also partly from historical human activities (e.g. obsolete barriers on rivers or abandoned mines) and new developments (e.g. new hydropower plants).

The 10 key water management challenges have been selected based on the analysis of significant pressures affecting water bodies in the second RBMPs (see the 2018 EEA assessment of the status of and pressures on European waters (EEA, 2018b). Pressures that affect a sufficiently large share of European water bodies and which are reported by many WFD countries were selected. In addition, key European water management challenges have been selected that have been important for long enough to develop a solid knowledge and information base from which to describe the scope of the issue at the European level.

Although some of the selected water management challenges, such as mining, navigation, aquaculture and invasive alien species, seem to affect only a small share of European water bodies, they do pose a risk to aquatic ecosystems in many WFD countries. In addition, they can be of considerable importance and intensity in specific regions of Europe and contribute significantly to the failure to achieve good water status at a regional level.

Additional key European water management challenges may be identified in the future as European data collection and research on activities and pressures that put water bodies at risk of reaching the WFD objectives improve.

Table 3.1 summarises the key European water management challenges presented in the report.

The following sections give a brief overview of the selected key European water management challenges, including:

- a description of the issue (pressure types and drivers) and information on the share of WFD water bodies affected in the second RBMPs;
- an outline of the key impacts of the pressure types or drivers on water ecosystems;
- a summary of key measures that are available to tackle the issue and management challenges of EU-wide relevance (ongoing challenges and new challenges ahead).

The summary includes the main measures taken under the first and second RBMPs of the WFD as well as measures to meet the requirements of other relevant directives, regulations or national action plans that were used as a basis for deriving information on key measures and management challenges.

The presentation of each key water management challenge is concise and limited to two pages, focusing on the main issues of European relevance. For more detailed information, the literature cited in each section should be consulted. The forthcoming third RBMPs will provide further details on the main drivers and pressures that are important at the river basin district level and will also provide details of specific measures required in the new WFD planning cycle.

Table 3.1 Overview of drivers, pressures, impacts and measures linked to the selected key European water management challenges

Pressure/sector/ activity	European water bodies affected in second RBMPs	Impacts (summary)	Measures and other management issues (summary)
Pollution: **point source** (urban waste water, industry)	15 % of surface water bodies 14 % of groundwater area	Oxygen deficit from organic pollution with impacts on biota Impacts from nutrients, hazardous substances and emerging pollutants	Installation and enhancement of sewers and treatment to reduce pollution from urban waste water (UWWTD) and industry (IED) Reduction at source Storage and treatment of storm waters to reduce overflows Enhanced treatment for emerging pollutants
Pollution: **diffuse source** with nutrients and chemicals (agriculture, atmospheric deposition)	22 % of surface water bodies 28 % of groundwater area	Eutrophication and algal blooms affecting biota Groundwater nitrates affecting drinking water quality Pesticide threats to biota and human health Sediment run-off with impacts on habitats Impacts on biota from atmospheric deposition of mercury	Nutrient pollution reduction measures for agriculture (including the Nitrates Directive) New integrated nutrients management strategy Implementation of the revised CAP, financing instruments Measures against air pollution (including the Industrial Emissions Directive)
Pollution: **non-connected dwellings**	10 % of surface water bodies 7.5 % of groundwater area	Many disease-causing organisms affecting human health Local oxygen depletion Nutrient input leading to eutrophication and oxygen depletion	Connection to sewerage network or local treatment Homeowner responsibility and enforcement
Pollution: **mining**	7.5 % of groundwater area Less than 1 % of surface water bodies Reported in 17 WFD countries	Changes in surface and groundwater hydrology Metal pollution Sediment load Acid run-off	Site-adapted measures to reduce mining pressures on hydrology and quality Rehabilitation of abandoned mining sites More synergies between the WFD and the Extractive Waste Directive to tackle issue
Hydromorphological pressures: barriers (hydropower, flood protection and irrigation)	20 % of surface water bodies	Habitat loss Flow regulation River fragmentation Changed sediment transport and erosion Water quality Cumulative effects	Strategies for restoring continuity/ prioritisation Removal of barriers or making barriers passable for fish Setting of ecological flows and measures for sediment
Hydromorphological pressures: loss of lateral connectivity (flood protection and drainage on floodplains)	10 % of surface water bodies	Loss of key habitats and species decline in rivers and floodplains Changed hydromorphology dynamics and sediment supply Impacts on nutrient cycling	Restoration of bank structures, reconnection of floodplains, wetland restoration More systematic inclusion of floodplain restoration in RBMPs/ FRMPs Targeted financing of floodplain restoration

Table 3.1 **Overview of drivers, pressures, impacts and measures linked to the selected key European water management challenges**

Pressure/sector/ activity	European water bodies affected in second RBMPs	Impacts (summary)	Measures and other management issues (summary)
Hydromorphological pressures: hydropower	6 % of surface water bodies	Interruption of river continuity and impacts on migrating fish Altered sediment transport Changed flow regime with morphological and ecological effects Altered physico-chemical conditions Cumulative effects	Measures for fish migration, habitat restoration, sediment management, ecological flows Strategies for sustainable hydropower Permit/licensing system Construction of new hydropower plants is an ongoing challenge
Hydromorphological pressures: navigation	< 1 % of surface water bodies but very important in the largest European river basins	Hydromorphological changes in river beds and banks Changed water levels and flows Loss of connectivity with floodplain Interruption of river continuity Impacts on key habitats of biota Pollution (waste, accidents) Spread of invasive alien species	River restoration, measures to reduce pollution from navigation Strategies, programmes and guidelines for sustainable inland navigation Mitigation of impacts from prolonged periods of low water levels
Abstractions and water scarcity (agriculture, cooling, water supply)	6 % of surface water bodies 17 % of groundwater area	Low flow and dry rivers with impacts on biota Decreased ability to dilute contaminants Lowered groundwater levels Salinisation of aquifers	Measures to manage water demand, e.g. water pricing, increased efficiency of water use, public education Permit/licensing systems, metering Innovative measures to supply water, e.g. desalination, water reuse, rainwater harvesting Drought management plans, coordination with RBMPs
Aquaculture	< 1 % of surface water bodies, but significant pressures from aquaculture reported in 20 WFD countries	Release of oxygen-consuming substances, nutrients and chemicals (pharmaceuticals) Escape of cultured organisms Disruption of continuity (barriers), hydrological changes and sediment transport disruption	Management and technical measures (e.g. waste water treatment, limits on production, improved siting, codes of best management practices)
Invasive alien species (IAS) (aquaculture, pet/aquarium species, shipping, fisheries/ angling)	2 % of surface water bodies, but reported as significant pressures in 15 WFD countries	Altered biota communities Impacts on food webs Constraint on recovery of native biodiversity	National strategies for IAS Prevention, early detection and rapid eradication, management measures Need for cross-linking management efforts under IAS Regulation, WFD and MSFD

Note: CAP, common agricultural policy; FRMP, flood risk management plan; MSFD, Marine Strategy Framework Directive; UWWTD, Urban Waste Water Treatment Directive.

3.1 Pollution

To reach good ecological status of surface waters and good chemical status of surface waters and groundwater, a reduction in water pollution is crucial and is one of the main topics in water management, according to the WFD.

A range of pollutants still reach European surface waters and groundwater via different pathways and have high impacts on water quality. Those pollutants are caused by diffuse sources of pollution and point sources of pollution. Whereas point sources have a specific discharge location, diffuse sources contain many smaller sources spread over a large area. This is also problematic for the identification of polluters. Point sources from urban waste water or industry can be more easily addressed and managed, in contrast to diffuse pollution, for which the measures may be difficult to implement.

Point source pollution is mainly caused by discharges from waste water treatment plants. Over the past few decades, clear progress has been made in reducing emissions from point sources. The implementation of the Urban Waste Water Treatment Directive (UWWTD) and the Industrial Emissions Directive (IED), together with national legislation, has led to improvements in waste water treatment across many European countries.

Diffuse source pollution occurs mainly from agriculture and run-off from urban areas, and also from atmospheric deposition and non-connected dwellings. EU action on curbing diffuse nutrient pollution has a long history. Member States currently use many measures, including farm-level nutrient planning, fertiliser standards, appropriate tillage, nitrogen fixing and catch crops, buffer strips and crop rotation.

Although recent decades have seen considerable success in reducing the number of pollutants discharged into Europe's waters, challenges remain in terms of urban and industrial waste water and diffuse pollution from agricultural sources. Once released into waters, pollutants can be transported through the aquifers (groundwater) or downstream and are in the end discharged into coastal waters.

The impacts of water pollution are diverse. Nutrients, such as phosphorus or nitrogen, lead to eutrophication with algal blooms and oxygen depletion, affecting fish and other aquatic communities. Pesticides, heavy metals and brominated diphenyl ether (BDE; used as a flame-retardant in, for example, textiles) harm the environment and human health.

According to the second RBMPs of the WFD, 33 % of all surface water bodies in Europe are affected by diffuse source pollution and nearly the same amount of groundwater area (34 %). Point source pollution affects 15 % of all surface water bodies and 14 % of the groundwater area.

Key pressures from point source pollution and diffuse sources are described in the following sections. The main pressures from point sources are waste water releases from households and industry. For diffuse sources, the focus is on pressures from agriculture, nutrients and pesticides in particular. Other sectoral pressures with major impacts on aquatic ecosystems are non-connected dwellings (see Box 3.1 in Section 3.1.2) and mining. This pressure is addressed in a separate section.

3.1.1 Point source pollution (urban waste water, industry)

Overview

Point source pollution of surface waters relates mostly to discharges from urban waste water, including storm overflows, industrial sites and, to a much lesser extent, aquaculture. Groundwater is mainly affected by the leaching of hazardous substances from landfills and contaminated sites (EEA, 2018b).

In Europe, point source pollution discharges have markedly decreased over recent decades as a result of improved purification of urban waste water and reduced industrial discharges. Nevertheless, point source pollution still results in water pollution by oxygen-consuming substances, nutrients and hazardous substances with high impacts on aquatic ecosystems and human health.

According to the second RBMPs, 15 % of all surface water bodies are affected by point source pollution, of which 67 % are assigned to urban waste water from treatment plants and some 20 % to industrial waste water. For groundwater, significant point source pressures are present in 14 % of the area, mainly from contaminated sites, industrial sites, waste disposal sites, mining areas and urban waste water (EEA, 2018b).

More than 30 000 industrial and urban waste water facilities in Europe discharge more than 40 000 million m³ waste water every year (EC, 2018c; Van den Roovaart et al., 2017). Three quarters of them treat water from urban sewerage systems that have an agglomeration of more than 2 000 population equivalents (EC, 2019b). Of the population in EU Member States, 90 % is connected to sewerage systems. The highest connection rates of above 80 % are found in central and northern Europe, where the highest level of treatment (e.g. nutrient removal) is also implemented in the majority of waste water treatment plants (EEA, 2020d).

Waste water from industry has decreased over decades. This is caused by increased regulation (e.g. Industrial Emissions Directive, IED; the European Pollutant Release and Transfer Register, E-PRTR), improvements in treatment and the implementation of best available techniques reference documents ([12]). Furthermore, the relocation of various heavily polluting and energy-intensive manufacturing industries to outside Europe has also led to water quality improvements (EEA, 2020a). The connection of industrial waste water to urban waste water treatment plants to avoid industrial emissions to water has marginally increased (EEA, 2019d). Industries that still have high direct releases to water include pulp and paper, steel, energy supply and chemicals; by contrast, manufacturing or food production tend to be more connected to urban waste water treatment plants (EEA, 2019d). This is also due to the recommendation made in the best available technique reference document for industrial installations (Canova et al., 2018).

Furthermore, storm water causes problems for the sewerage system. In the event of heavy rain, overflows from combined sewerage systems are discharged into surface waters with a mixture of rainwater and untreated waste water. This can lead to a temporarily high pollution pressure.

Impacts

Impacts from point source pollution to waters are caused by oxygen-consuming substances, indicated by the measurement of the biochemical oxygen demand (BOD) and ammonium, nutrients such as phosphorus and nitrogen, hazardous substances, emerging pollutants, pathogens (such as bacteria, viruses and parasites) and microplastic particles.

The BOD shows how much dissolved oxygen is needed for microorganisms to decompose the organic matter. The resulting oxygen deficit in highly organic polluted waters has an impact on aquatic communities, e.g. the loss of several macroinvertebrates and the acute toxic impact on fish.

Overall, concentrations of oxygen-consuming substances (BOD, ammonium) and nutrients (nitrate and phosphate) have decreased since 1992 (Figure 3.1). The presence of nitrate as well as phosphorus in rivers is not solely attributable to point sources of pollution. Those substances can also be released from diffuse sources.

Hazardous substances are defined as toxic, persistent and liable to bioaccumulate (Article 2 of the WFD). Some of the priority substances listed in Annex X of the WFD are defined as hazardous, for which all discharges, emissions and losses must be ceased within 20 years after the adoption of cessation proposals by the European Parliament and the Council (Article 16(6) of the WFD). Those substances are, for example, 4-nonylphenol, used as a surfactant, and polybrominated diphenyl ethers (PBDEs), used as flame-retardants. In addition to the risk of hazardous substances, emerging pollutants are present in low concentrations and include pharmaceuticals and personal care products, chemical degradation products and endocrine-disrupting compounds. The long-term effects of these pollutants and the cocktail effect in water is rather unknown (EEA, 2018a).

The contamination of water by faecal bacteria poses a risk to human health, in particular at bathing water sites or in waters used for drinking water abstraction. The major sources of pollution are sewage and water draining from farms and farmland. Such pollution increases during heavy rains and floods as a result of sewage overflow and polluted drainage water being washed into surface waters. Whereas impacts of, for example, coliforms are well known, research on the risks of antimicrobial-resistance (AMR) in the aquatic environment is at an early stage.

Measures and management challenges

Because of the successful implementation of the UWWTD, point source pollution pressure from urban waste water has significantly decreased. This is the result of not only an increase in the share of the population connected to sewerage systems but also the implementation of second- (biodegradation) and third-level (nutrient removal) treatment all over Europe (EEA, 2020d).

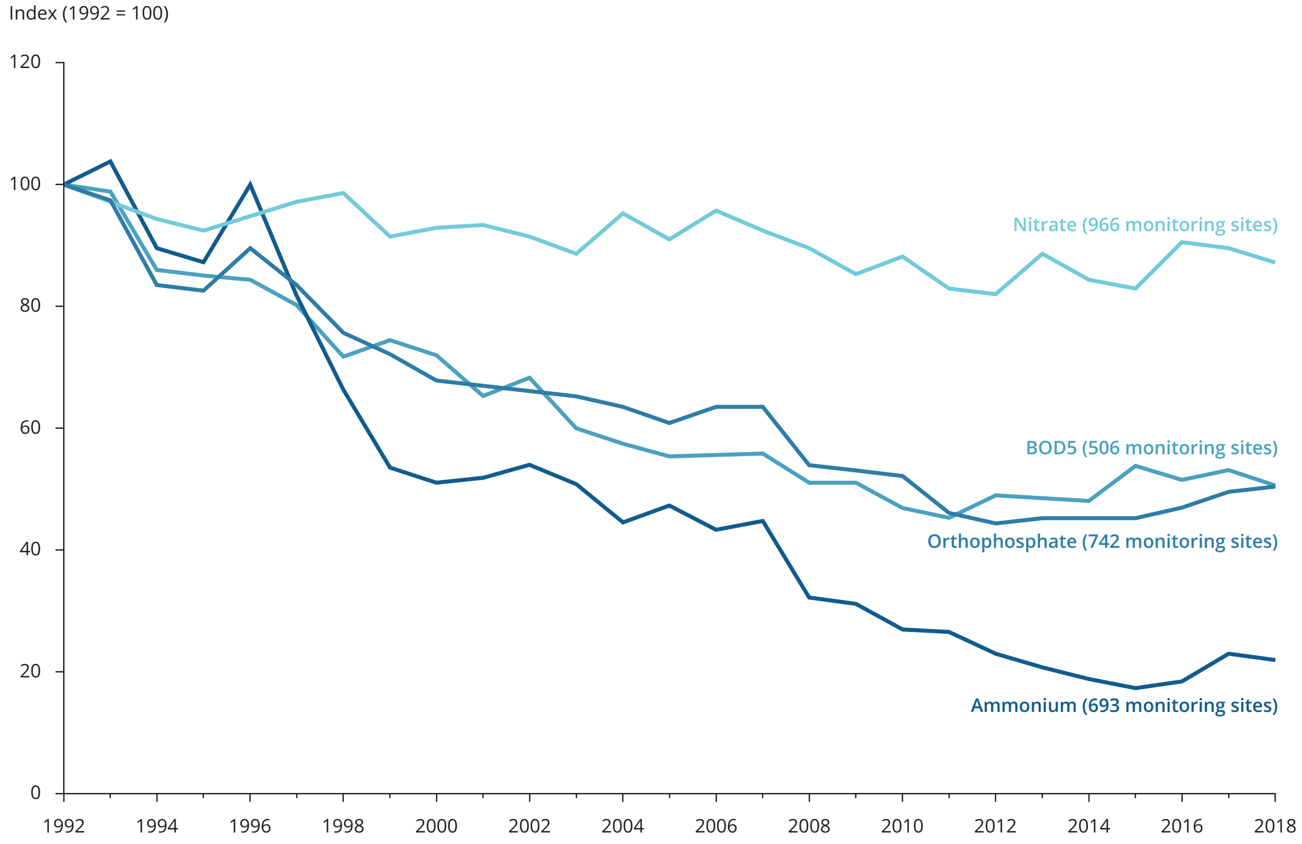
Measures to further reduce point source pollution from urban waste water and industry include construction and adaptation, expansion, optimisation of existing treatment plants, connection of households to sewerage systems and the consolidation and closure of ineffective treatment plants.

Improved efforts to retain chemicals in waste water treatment plants should go hand in hand with clear efforts to reduce them at the source. Such measures can range from raising consumer awareness and encouraging industries to adjust the composition of their products to, over the longer term, fundamentally reviewing our use of chemicals and product design.

One example of source-based measures is the ban on phosphates in consumer detergents to avoid eutrophication in surface waters. The remaining permitted use of phosphates was legally fixed in Regulation 648/2004/EC on detergents (EU, 2004). The European Parliament proposed a ban of the use of phosphates in consumer laundry detergents as of 30 June 2013, with similar restrictions on consumer automatic dishwasher detergents coming into force on 1 January 2017 (EC, 2011a).

([12]) List of best available technique reference documents as part of the IED (https://eippcb.jrc.ec.europa.eu/reference).

Figure 3.1 **Trends in biochemical oxygen demand (BOD), ammonium, orthophosphate and nitrates in European rivers**



Sources: EEA (2020b, 2020c).

Furthermore, measures can be assigned to achieve stricter requirements, such as lower targets for concentrations of specific pollutants in the waste water discharged by the responsible authority. This has been applied at Lake Constance to protect its drinking water resources. All treatment plants on the tributaries flowing into the lake markedly reduced the phosphorous concentrations in their waste water discharges. Lake Constance has been at good ecological status with high drinking water quality since the introduction of the requirements (IGKB, 2021).

Although considerable success has been achieved in reducing the discharge of pollutants from point sources, more emphasis is needed to protect water quality and human health. Despite varying conditions such as the density of population in and economic background of European countries, treatment must be further improved in the eastern parts of Europe in particular. Nature-based solutions can be used to help reduce discharges from storm overflows. To improve treatment, the implementation of a fourth treatment level is in progress. This consists of innovative treatment techniques (e.g. oxidation with ozone, activated carbon filtration, membrane filtration) (UBA, 2014, EEA, 2019f). For example, by 2040, 100 of the 700 waste water treatment plants in Switzerland will be equipped with a fourth level of treatment. The investment requirement of CHF 1.2 billion (EUR 1.1 billion) will be financed through a nationwide waste water tax, which is a maximum of CHF 9 (EUR 8.3) per inhabitant per year (VDI, 2017).

Furthermore, increasing energy costs, the reuse of high-quality waste water, the recycling of raw materials to the circular economy and the consideration of climate change will be challenging tasks for the future (EEA, 2019f).

3.1.2 *Diffuse source pollution*

Overview

In Europe, agriculture is the main diffuse source for water pollution, with high emissions of nutrients, such as nitrogen and phosphorus, and chemicals, such as pesticides (EEA, 2018b). A driver for nutrient surpluses in soil and water pollution is the excess use of fertiliser for crop production coming from mineral fertilisers and manure from livestock farming. Nutrients (as well as pesticides) enter the water cycle through erosion, surface run-off, leaching or inflow from polluted drainage and groundwater to surface waters, which has an impact on water quality, aquatic communities and human health. In the second RBMPs, Member States identified that diffuse pollution from agriculture affects 22 % of surface water bodies and 28 % of the groundwater area, leading to failure of good ecological and chemical status.

Nutrients are key for plant growth. In the EU, the nitrogen surplus from agriculture is estimated to total approximately 27 million tonnes per year (Misselbrook et al., 2019). Nitrogen surpluses decreased by 10 % between 2004 and 2015 (ESTAT, 2021). Today, the highest total nitrogen surpluses occur generally, although not exclusively, in western Europe.

Based on reported long-term data for nitrates in European waters, nitrate concentration in rivers showed a decreasing trend (Figure 3.1). The decline reflects the effects of improvements in waste water treatment and reductions in agricultural inputs. In contrast to rivers, nitrate concentration in groundwater has not shown any trend during recent decades (EEA, 2020b).

Pesticides are used to prevent or control any pest causing harm to agricultural products (FAO, 2002). Pesticide sales data in Europe show that, in the period 2011-2016, pesticide sales amounted to 400 000 tonnes per year (EEA, 2018d). Despite tonnes of pesticides used, 0.4 % of all surface water bodies and 6.5 % of the groundwater area fail to achieve good chemical status based on exceedances of environmental quality standards according to the status assessments in the second RBMPs. Reporting data for European surface water monitoring sites, based on Waterbase Water Quality, suggest that in the period 2007-2017, 5-15 % showed exceedances for herbicides and 3-8 % for insecticides. For groundwater, the percentages were about 7 % for herbicides and below 1 % for insecticides. Exceedances of fungicides seemed to be less prevalent for both surface waters and groundwater (Mohaupt et al., 2020).

Atmospheric deposition plays a role as a diffuse source of water pollution with chemicals, such as mercury and polycyclic aromatic hydrocarbons (PAHs). PAH emissions occur during all combustion processes involving organic materials, such as wood, coal and oil. Mercury is released into the atmosphere, mainly by coal combustion, spreading over great distances and washing out in rain to soil and waters (BMU/UBA, 2016). It can accumulate in biota, especially fish, which is a risk for fish-eating animals and is also a potential risk for human health (Zupo et al., 2019). In Europe, mercury from atmospheric deposition is the main reason for failing to achieve good chemical status in more than 30 % of all surface water bodies (EEA, 2018b).

Impacts

Nutrients and pesticides release from agriculture as well as sediment run-off have a high impact on surface waters and groundwater. The presence of too many nutrients leads to eutrophication with high levels of algae and aquatic plant growth. In lakes, high nutrient concentrations can induce potentially toxic blue-green algae proliferation, which can be detrimental to human health (Image 3.1). Coastal water bodies show similar reactions to excessive nutrient inputs (Ibisch et al., 2016).

Elevated groundwater nitrate concentrations affect water for drinking water abstraction and thus create a risk to human health. Groundwater that contains nitrates can also affect surface water bodies that are fed by groundwater (BMU/ UBA, 2016).

Pesticide inputs can have impacts on aquatic communities if they are directly exposed to pesticide inflows from farmland through erosion or indirectly through the trophic chain (Hasenbein et al., 2016; Maksymiv, 2015). Furthermore, aquatic communities are exposed to mixtures of different pesticide substances. Knowledge of the combined effects of these mixtures on the aquatic environment is scarce (Mohaupt et al., 2020).

Sediment run-off from agricultural fields can result in the accumulation of fine sediments (see Box 3.2 in Section 3.2), which overlay the natural riverbed, resulting in the loss of habitats (e.g. spawning ground for trout and salmon).

Image 3.1 Toxic blue-green algal bloom in a reservoir

Source: © J. Völker.

Measures and management challenges

Member States are implementing different kinds of measures to reduce nutrient pollution from agriculture. Those measures include imposing restrictions on organic fertiliser application (e.g. up to 170 kg N/ha at the farm level, in compliance with the Nitrates Directive), restrictions on the application conditions for mineral and organic fertiliser and restrictions on the amount applied of certain types of fertiliser during specific periods (e.g. no spreading of manure during winter). Some Member States have limited the total nitrogen applications for all crops, to inform farmers about their obligations and to facilitate progress in implementing the Nitrates Directive (EC, 2019a). To further improve efficient nutrient use, the EU Farm to Fork strategy includes integrated nutrient management action plans to tackle nutrient pollution at the source and to reduce pollution from fertilisers by 50 % and reduce their use by 20 % (EC, 2020c).

Further strategies to reduce diffuse nutrient pollution are expanding the scope of organic farming, the use of precision farming with new digital technologies and innovative monitoring concepts (e.g. remote sensing), and the reduction of livestock density. Technical measures include catch cropping, the use of ground cover crops and tillage methods, the establishment of buffer strips with strict restriction on use and increasing manure storage capacity at the farm level. Manure storage can improve the timing of application of manure to minimise the risk of excessive leaching into the water environment. Advisory services can lead to better informed farmers, as a result of having practical and relevant information, and an increase in their acceptance of measures.

To reduce pesticide pollution, relevant measures include minimising the risk of off-site pollution caused by spray drift, drain-flow and run-off, and reducing or eliminating applications close to surface water or groundwater. Other measures include using pesticides that are not classified as dangerous for the aquatic environment, establishing untreated buffer zones and implementing a ban or restriction on the use of pesticides. Some European countries (Denmark, France, Sweden and the United Kingdom) use reduction targets and timelines within national pesticide action plans to achieve a stepwise reduction in pesticide use (EC and Directorate-General for Health and Food Safety, 2017).

Although water quality has improved over recent decades, pollution from diffuse sources, in particular agriculture, remains a severe water management problem in Europe and is a major cause of failing good ecological and chemical status of surface waters and groundwater. To protect water ecosystems, there will be a need to strengthen the implementation of agricultural measures (both basic and supplementary) (EC, 2019a). This also includes a wider uptake of sustainable management practices, such as organic farming, and nature-based solutions with multiple benefits (see Section 4.5), the implementation and integration of EU policies with incentives and the prioritisation of funding within the reform of the common agricultural policy (CAP) (EEA, 2021).

Specific implementation challenges also remain in addressing water quality issues in 'hotspots' with high nutrient loads as a result of farming, through better coordination of national/regional sectoral administrations (e.g. agriculture, water) and balanced fertiliser application (EC, 2017b). Still, basic measures need to be more strictly implemented to fully comply with the Nitrates Directive (EEA 2018b, 2019c).

Box 3.1 Non-connected dwellings

Non-connected dwellings are a diffuse source pollution pressure caused by discharge from households not connected to sewerage systems and urban waste water treatment plants or other collection systems.

In 2017, 11 % of the European population (approximately 50 million people) were not connected to waste water collection systems, with the highest shares located in the eastern part of Europe (Eurostat, 2021). Based on the second river basin management plans, 21 Water Framework Directive (WFD) countries reported significant diffuse source pollution pressures caused by discharges not connected to sewerage systems in 10 % of all surface water bodies. Furthermore, about 7.5 % of all groundwater area is affected by this pressure.

If the waste water is not properly treated, discharges of untreated waste water to waters can lead to nutrient inputs or the presence of lots of disease-causing organisms with potential risks for human health in, for example, bathing waters (EEA, 2019f).

Measures to reduce water pollution are mainly technical and include waste water package plants, sand filters, drain fields, seepage pits and constructed wetlands with varying purification efficiencies (Vorne et al., 2019). Furthermore, national regulatory frameworks have been developed to require the installation of appropriate treatment systems; for example, in Bulgaria it is required that the water is collected and treated within watertight cesspools (Grebot et al., 2019). However, the installation of treatment systems, monitoring and maintenance are mainly the responsibility of homeowners, and technical or financial support from local, regional or national authorities is rather rare. This makes it difficult to enforce those treatment techniques in single houses or small agglomerations.

There is still a huge knowledge gap on the impacts of discharges from non-connected dwellings, because neither the Urban Waste Water Treatment Directive (UWWTD) nor the WFD directly regulate mitigation measures, and reporting obligations solely address connected dwellings of more than 2 000 population equivalents. This hinders the gathering of information and the drawing of conclusions on the implementation, use and effectiveness of individual technical treatment systems. There is a need to further improve our knowledge of this issue, to adapt and harmonise WFD and UWWTD measures and reporting, and to control implemented techniques and to provide more financial support for homeowners (EC 2019b; Grebot, et al., 2019).

3.1.3 Mining

Overview

Mining has been undertaken in Europe for many hundreds of years. Many mines are now closed, but both working and abandoned mines still affect the quantitative, chemical and ecological quality of water. The main pressures and impacts include acid run-off caused by lowering the pH, which may result in the discharge of heavy metals, other chemical pollution, saltwater intrusion, an alteration in flow or the lowering of the water table, caused by excessive dewatering during mine operations or after mining activities have stopped. The recovery of affected aquatic ecosystems — including groundwater — may take decades.

In the second RBMPs, 17 WFD countries reported mining as significant point and/or diffuse source pollution pressures, affecting approximately 1 100 surface water bodies (less than 1 % out of all surface water bodies) and 7.5 % of the whole groundwater area. Countries with high shares of reported pressures from mining include Bulgaria, Germany, Hungary, Italy, Norway and the United Kingdom.

Other analyses of mining pressures and their potential risks to water show a slightly different picture on account of the use of other sources of data from existing and abandoned mine activities; those show that Czechia, France, Germany, Poland, Romania, Spain, Sweden and the United Kingdom have the highest potential risk of mining pressures (Briere and Turrell, 2012).

Mining activities include the extraction of coal and lignite, minerals (mainly potassium, rock salt and magnesium-containing minerals), clay, peat, metals (such as copper and gold), shale oil and gas as well as the extraction of stones, gravel and sand (aggregates). It is estimated that in the EU more than 32 000 mining sites exist, of which more than 25 000 are used for the extraction of aggregates, with the highest number of sites in Poland and Germany. There are some 1 400 peat extraction sites in the EU, of which 75 % are located in Finland (Garbarino et al., 2018).

Europe-wide data on the number of abandoned mines are rare (EC, 2017a) and the number of abandoned mines is likely to be much higher than that of active ones based on available data for certain countries, such as Slovakia and Hungary. Slovakia has registered more than 17 000 abandoned mines and Hungary has reported some 6 000 abandoned mining sites (UNCCD, 2000). The bulk of mine water problems in Europe are associated with abandoned mining sites, and in numerous catchments the single greatest cause of freshwater pollution is pollution from abandoned mines (ERMITE-Consortium et al., 2004).

Impacts

Different types of mining, such as surface and underground mining, placer mining and hydraulic fracturing, have great effects on aquatic ecosystems, including changes in groundwater and surface water hydrology, reduction of water quality, alteration in stream morphology and habitats, and changes in sediment dynamics (Figure 3.2).

Groundwater **hydrology**, which in turn can affect surface waters that are in hydraulic continuity with the affected groundwater systems, is affected by surface and underground mining in particular (ERMITE-Consortium et al., 2004). This is mainly due to dewatering, resulting in a depression of the water table around the dewatered zone.

The **water quality** of mining activities is mainly affected by acid mine drainage or salinisation. The acid run-off further dissolves heavy metals such as copper, lead and mercury into groundwater or surface water. Problems that can be associated with mine drainage include iron hydroxide precipitation during the oxygenation of mining water, contaminated drinking water (e.g. with metals or sulphate), impacts on aquatic plants and animals and the corroding effects of the acid on parts of infrastructure (Hutson, 2004). Salinisation is caused by the extraction of salts, e.g. potassium, and by the discharge of highly mineralised groundwater from coal mines. Aquatic communities altered by high salt content and salt intrusion into the groundwater can endanger the quality of drinking water.

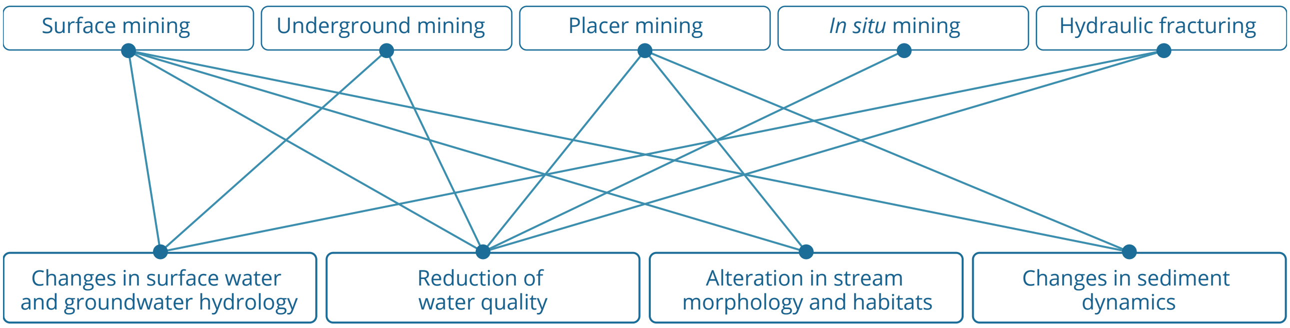
Hydraulic fracturing to extract shale oil or shale gas also poses a risk for water quality. It potentially threatens drinking water resources (mainly groundwater) as a result of contamination with chemicals used in the hydraulic fracturing process. Surface water contamination can occur if the waste water, containing the chemical additives as well as saline water and naturally occurring heavy metals and radioactive materials from the shale formations, is not properly managed and treated (UBA, 2012). In the example of an Estonian oil shale basin, impacts on the hydrological regime and the high sulphate concentration affect groundwater and surface waters. Furthermore, some wells used for drinking water supply dried up as a result of oil shale water abstraction or the water was not suitable as drinking water due to low water quality (OECD/ECLAC, 2017).

Placer mining leads to **changes in sediment dynamics** and it also decreases water clarity. Furthermore, stream morphology and habitats are affected by the replacement of coarse substrates, such as gravels and boulders, resulting in an impact on, for example, invertebrate species.

Impacts of the removal of peat are increased sedimentation, increasing dissolved organic carbon and phosphoros concentrations and decreasing pH values in the receiving waters (Lundin et al., 2017; Ramchunder et al., 2012). The leaching of phosphorus and nitrogen causes eutrophication problems in the watercourses or downstream lakes and the load of solid peat particles causes silting of downstream water bodies.

Mining accidents can have tremendous impacts on the aquatic environment; an example is the spill of cyanide-rich waste water in Baia Mare, Romania, in 2000. After a dam broke in the retreatment plant of a gold-mining company, a large number of fish were killed in the Somes, Tisza and Danube rivers. Furthermore, drinking water resources were contaminated.

Figure 3.2 Impacts of mining activity types on water



Notes: **Surface mining**: removal of plants, soil and bedrock from the surface to be able to access shallow deposits. **Underground mining**: digging down into the Earth's surface and creating tunnels and shafts to reach deeper deposits of resources. **Placer mining**: generally done in riverbeds, sands or other sedimentary environments to extract stones, gravel or sand. ***In situ* mining**: pumping chemicals underground to dissolve resource-containing ore and pumping back the enriched liquid to the surface for further processing. **Hydraulic fracturing**: cracks in and below the Earth's surface are opened and widened by injecting water, chemicals and sand at high pressure to extract shale oil or gas from deep Earth layers.

Sources: Smith (2019); National Geographic (2021).

Measures and management challenges

Measures to reduce pressures from mining activities on surface waters include reusing or recycling excess water, diverting run-off systems and using reagents or chemicals with a low environmental impact, as well as using drainage systems, removing suspended solids or liquid particles and removing dissolved substances by, for example, adsorption or nanofiltration. For groundwater, physical barriers, drainage systems or covering techniques are listed as effective measures to protect aquatic ecosystems (Garbarino et al., 2018). For example, to reduce diffuse discharge from saline waters into groundwater, the K+S company in Germany covers the salt tailing piles and uses chemical transformation processes to treat the waste water. It is estimated that this will reduce the proportion of saline waste water by 20 % (K+S, 2021). These measures are part of the best available techniques for the management of waste from extractive industries, which need to be implemented in EU Member States targeted by the Extractive Waste Directive (EWD; 2006/21/EC). According to Article 5 of the EWD, operators must submit an extractive waste management plan (EWMP) as part of their permit applications.

After the closure of mines, restoration is envisaged to mitigate the impacts of former activities on soil and water. Many countries have national plans, such as the environmental monitoring programme and rehabilitation plan for the Avoca river in Ireland (Department of Communications, Energy and Natural Resources, 2014) and the Landscape evaluation tool for open-pit mine design in Greece (Mavrommatis and Menegaki, 2017). In Germany, numerous post-mining lakes were created as part of the refurbishment of former brown coal mines. Most of these lakes are already being used for tourism purposes (Deshaies, 2020).

Current mining activities are strongly regulated by Member States under national laws. In most countries, water acts and water laws include the protection of waters from mining activities. Additional legislation and regulations are implemented for the protection of groundwater, e.g. the decree on activities that affect the quality of groundwater in Hungary and the Groundwater Exploration Act in Sweden (Endl and Berger, 2016). The legislative instruments on international and national levels regulating the current mining sector should ensure that the objectives of the WFD (2000/60/EC) and the Groundwater Directive (2006/118/EC) are achieved (Briere and Turrell, 2012).

Measures under the WFD also aim to reduce water abstraction related to mining, which is commonly used to control quantitative impacts from quarrying activities but could also be of use for underground mining.

Data on measures implemented under the WFD and the EWD are scarce. In the context of the WFD, information on mining is part of different reporting obligations, e.g. WFD emissions inventory, pressure characterisation of water bodies and the exceedance of environmental quality standards for, for example, heavy metals as a result of mining activities. If mining activities cause significant pressures, putting at risk the achievement of the WFD objectives for surface water or groundwater, measures need to be included in the RBMPs. In the context of the EWD, mining operators must draw up an EWMP as part of permit applications. Among other issues, EWMPs should cover the monitoring of surface water and groundwater quantity and quality and the management of excavated material as well as mining waste (EC, 2019f). Because of the relevance of both directives (WFD and EWD) to the assessment and management of water risks due to mining, a more synergistic way of gathering information and developing management strategies and measures for mining activities would be beneficial.

3.2 Hydromorphological pressures

For decades, humans have altered the shape of water bodies and the flow of river courses to farm the land, facilitate navigation, generate energy and protect settlements and agricultural land against flooding. For these purposes, rivers have been straightened, channelised and disconnected from their floodplains; land has been reclaimed, dams and weirs have been built, embankments have been reinforced and groundwater levels have changed. These activities have resulted in altered habitats, changed flows, interruptions in river continuity, loss of floodplain connectivity and severe impacts on the status of the aquatic environment. These changes have caused damage to the morphology and hydrology of the water bodies, i.e. to their hydromorphology (EEA, 2018b, 2019a).

Hydromorphology plays a key role in aquatic ecosystems. For example, water flow and substrate provide physical habitats for plants and animals, such as fish and benthic invertebrates. Good hydromorphological functioning is an essential element of ecosystem health and underpins the delivery of many ecosystem services and benefits for society (EPA Catchment Unit 2016; Houlden, 2018).

In the second RBMPs, hydromorphological pressures are the most commonly occurring pressure on surface waters, affecting 34 % of all such water bodies (see Chapter 2 of this report). The most frequently reported hydromorphological pressures are physical alterations related to flood protection, urbanisation, agricultural development and navigation, and barriers, including dams and weirs, built for different purposes (hydropower, flood protection, irrigation or navigation). In addition, several thousands of water bodies are affected by hydrological alterations driven by water abstractions (for public water supply, agriculture or industry) and reservoirs used mainly for hydropower and irrigation. However, in the second RBMPs of most Member States, the hydromorphological pressures identified are not clearly apportioned to specific drivers (EC, 2019a). Furthermore, 16 % of European water bodies have been designated as heavily modified (13 %) or artificial (3 %) water bodies.

Key hydromorphological pressures are described in the following sections of this report, which elaborate on the role of hydropower, navigation, flood protection and agricultural drainage as major drivers of impacts on hydromorphology in Europe. Separate sections address the role of barriers to illustrate their very dense distribution and far-reaching impacts on the European river network and key issues related to the loss of lateral connectivity to floodplains.

Certain aspects of hydromorphological pressures and impacts are less well known in terms of their extent and implications on the European scale. One of these aspects is the issue of changed sediment dynamics due to hydromorphological pressures; this is gaining more and more attention and will require targeted management interventions soon (see Box 3.2). In the meantime, the sediment issue should remain in focus of further data collection and research to identify the main underlying processes, impacts on water bodies and appropriate management approaches.

Box 3.2 Sediment quantity and hydromorphology

Sediments and sediment transport are essential and integral natural elements of the hydromorphology of rivers, lakes, estuarine and coastal systems. Sediments are also vital to the ecology of these systems, providing and supporting habitats and nutrients for aquatic plants, invertebrates, fish and other organisms. Although the Water Framework Directive (WFD) does not explicitly take account of sediments, ecological status is clearly dependent on habitat (including sediment quantity), and a clearer understanding is needed of the role of sediments in the WFD and related legislation, such as the Floods Directive and the Marine Strategy Framework Directive.

The management of most European rivers by humans has resulted in substantial modifications to natural sediment transport processes, sometimes with dramatic consequences for the stability of rivers and coastlines (SedNet, 2014). Dams act as barriers in the hydrological system, as they interrupt the continuity of sediment transport through river systems. Sediments trapped in reservoirs cause a deficit of sediments downstream of reservoirs, leading to erosion and morphological and ecological consequences in the downstream rivers (Kondolf et al., 2014). Furthermore, the dredging of sediment, which is necessary to maintain and develop ports or navigable waterways, can increase tidal floods and damage ecology by directly affecting physical habitats, disrupting riverine processes and reducing connectivity with the floodplain (England and Burgess-Gamble, 2013).

The relevance of sediments for achieving fundamental management goals in river basins is obvious. However, the perceived complexity often hinders the full integration of sediment issues into river basin management (SedNet, 2017). The WFD takes a river basin scale approach to water management, which is well aligned with the need to manage sediments at this scale, through the development of sediment management plans, rather than locally, as has been the case traditionally. However, to date, most European countries do not have sediment management plans in place (Dworak and Kampa, 2019).

Some major European river basin commissions have taken up the challenge of working towards transboundary sediment management plans as part of river basin management planning, such as the Rhine and Danube commissions (Brils, 2008). In addition, in the Elbe, a comprehensive sediment management concept has been developed in support of management planning in a large international river basin, serving as an inspiring example on how to integrate sediments in river basin management (SedNet, 2017). A transboundary dimension in sediment management plans, beyond national borders, is important so that national plans are coordinated and have similar levels of ambition within transboundary catchments.

The WFD explicitly requires Member States to manage the effects on the ecological status of water that result from changes to physical characteristics of water bodies. It requires action in those cases in which hydromorphological modifications are having an impact on the ecological status, interfering with the ability to achieve the WFD's objectives and to avoid deterioration due to new modifications. The restoration of hydromorphological conditions can take place using a wide range of measures, such as removing river obstacles to restore river continuity, setting ecological flow requirements, improving physical habitats in rivers and on their floodplains, and implementing natural water retention measures. The EU biodiversity strategy (EC, 2020b), one of many initiatives under the European Green Deal, which was adopted in 2020, encourages EU Member States to restore freshwater ecosystems, floodplains and free-flowing rivers.

At the same time, WFD measures to address hydromorphological pressures should not be taken in isolation; it is beneficial, in terms of the effects to be achieved and the funding opportunities that are available, to coordinate the planning of WFD measures with the planning process for other sectors (e.g. planning for the energy, transport and agricultural sectors) (EC 2019a).

3.2.1 Barriers

Overview

Humans have fragmented European water bodies with artificial barriers such as dams and weirs for centuries, as a means of ensuring water supplies, generating energy, facilitating navigation and controlling flooding. Such human-made barriers (1) reduce the ecological connectivity of a water body, impeding the flows of water, nutrients and sediment; (2) obstruct species movement (particularly migratory species); (3) often alter the quantity, quality and timing of river flows, both upstream and downstream; and (4) can affect surrounding riparian zones and floodplains (Freshwater Information System, 2019).

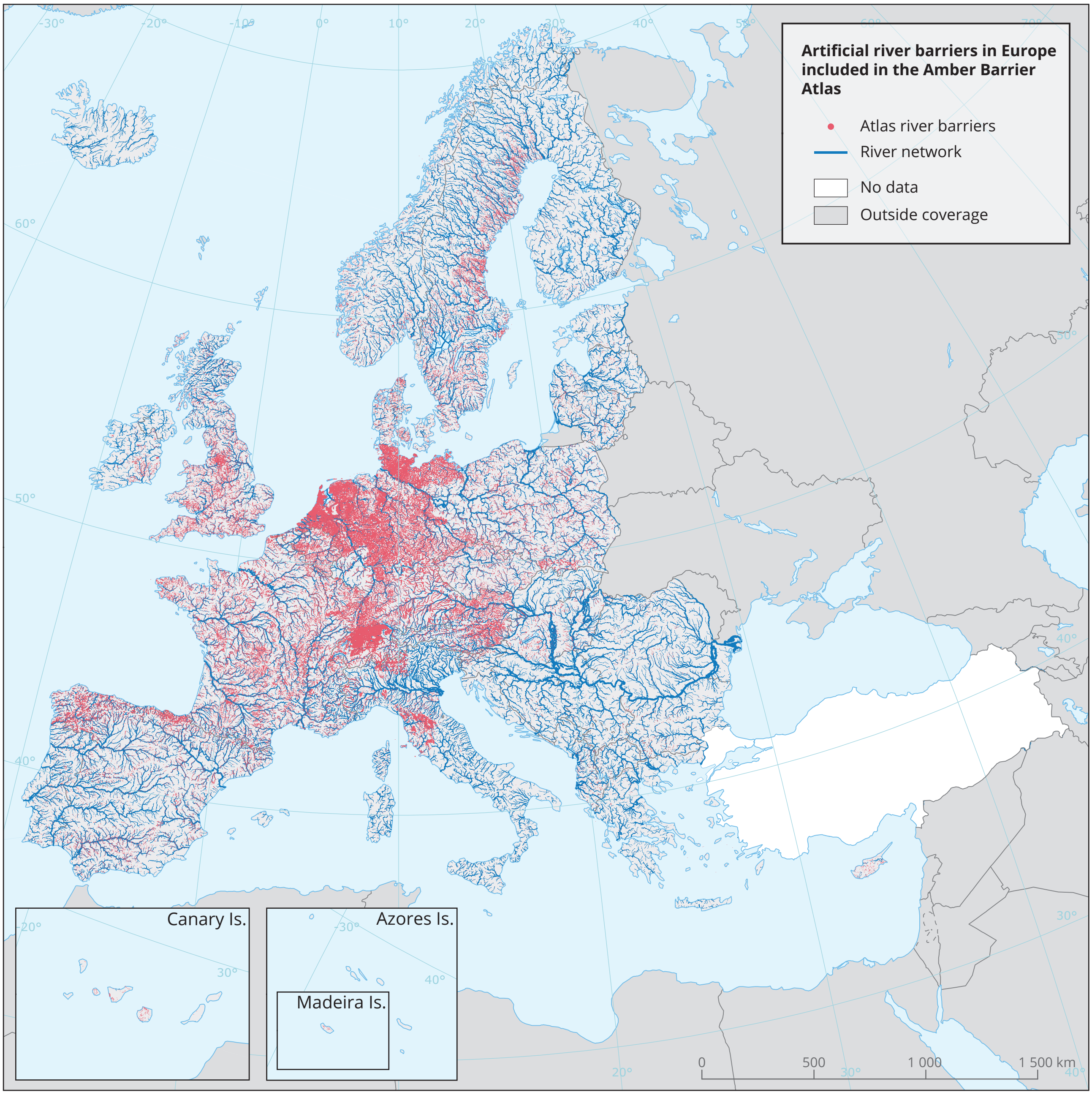
There are different types of barriers, including dams, sluices, weirs, culverts, fords and ramp-bed sills, and the extent to which these are recorded in the different national river assessment systems across Europe differs.

In the second RBMPs, barriers are a significant pressure for almost 30 000 surface water bodies (20 % of total number) in WFD countries, with the highest numbers being reported in Sweden, Germany, Austria, France, Denmark and Spain. Furthermore, barriers are the reason, or one of the reasons, for designating approximately 10 000 water bodies as heavily modified, which amounts to more than half of all heavily modified water bodies in Europe.

Many barriers are reported in the RBMPs to be used for hydropower (dams for hydropower production), flood protection and irrigation (water storage reservoirs). However, for a large share of water bodies affected by barriers (ca. 40 %), the purposes of the barriers are unclear, as they are either unknown or not explicitly reported or obsolete. Indeed, many barriers on European rivers originated between the 10th and 19th centuries to operate mills, and a high proportion of these are now redundant. It is estimated that in just France, Poland, Spain and the United Kingdom, there are up to 30 000, mainly small, dams that are now obsolete (Gough et al., 2018). In addition, there are many weirs without a practical use.

The most comprehensive overview of river fragmentation in Europe is provided by the Pan-European Atlas of In-stream Barriers (Amber Barrier Atlas; see Map 3.1), which was published in 2020 (AMBER Consortium, 2020). The atlas contains information on 630 000 barriers, including not only large dams, but also hundreds of thousands of smaller weirs, ramps, fords and culverts. However, researchers have recently shown that the actual number of barriers is much higher, amounting to at least 1.2 million instream barriers in 36 European countries, with a mean density of 0.74 barriers per kilometre (Belletti et al., 2020). This scale of river fragmentation is alarming and makes Europe the most fragmented river landscape in the world, with hardly any unfragmented, free-flowing rivers left (WWF, 2020).

Map 3.1 Artificial river barriers in Europe included in the Amber Barrier Atlas



Reference data: ©ESRI

Note: This is a compilation of 630 000 unique barrier records from existing data sets, and the full barrier picture includes at least 400 000 additional barrier points whose locations are being modelled.

Source: Map based on data from AMBER Consortium (2020).

Impacts

Artificial barriers such as dams, weirs and other impounding structures typically have the following negative effects on the environment of rivers:

- *Habitat loss*. Natural dynamics and river habitats are lost upstream of dams, as they are 'drowned' or suffer depleted flows downstream due to the alteration of water flow conditions. As a result, aquatic flora and fauna are dramatically altered (Gough et al., 2018).

- *Flow regulation*. This is one of the main adverse ecological consequences of dams and reservoirs for rivers. This is evident in downstream river ecosystems and is a result of dam operations reducing natural flows, eliminating peak flows, changing seasonal flow patterns, regulating low flows or other regulatory practices. Flow regulation may have significant negative effects on fish fauna and benthic invertebrate communities.

- *Fragmentation*. Rivers are transformed into a series of ponded sections; dams block migration routes for fish in both upstream and downstream directions, and habitats are isolated through fragmentation. This transforms natural fish fauna and leads to the local extinction of fish species (Gough et al., 2018).
- *Sediment*. Dams block the transport of sediments in rivers, leading to accumulations and poor water quality in the reservoir, deprivation of sand and gravels downstream of dams, a higher risk of erosion downstream of dams and in river deltas and a decrease in habitat quality upstream and downstream of the dam (Gough et al., 2018).
- *Water quality*. Storage of organic material and nutrients in reservoirs, and also in backwater from smaller dams, often leads to a decrease in water quality, changes in temperature and the capacity to dissolve oxygen, and sometimes to seasonal stratification (Gough et al., 2018). Ponded sections have a longer water residence time, thus enhancing eutrophication effects such as phytoplankton blooms.

The impacts of barriers vary according to their height and location. A major impact on a river could be caused by a single, very damaging, structure or by accumulated effects throughout the length of the river of a series of small structures, which may have only a small impact individually (EEA 2018b). The location of barriers in a catchment determines, to a large extent, the impacts on sediment fluxes and fluvial habitats, such as floodplains and deltas, and on the abundance and diversity of freshwater biota. For example, barriers in lowlands can prevent or delay fish migration, while headwater barriers can alter downstream flows and sediment transport (Jones et al., 2019).

The height of barriers also plays a major role in determining the impacts on freshwater biota and the surrounding ecosystem. High-head structures (large structures), typically taller than 8 m or 15 m, often create large impoundments, which can cause shifts in the composition of biota communities within the reservoir as well as downstream. Low-head structures (small structures) can also affect key ecological processes just as strongly. Because of their large number, small structures are likely to cause greater cumulative impacts and a more significant loss of river connectivity than high-head structures (Jones et al., 2019).

Measures and management challenges

In the first RBMPs, several European countries had already planned measures to improve the ecological condition of rivers affected by barriers. The planning of measures in the second RBMPs indicated substantial further effort to improve longitudinal continuity in river basin districts. The most common measures planned in this respect include the building of fish ladders and bypass channels, the removal of artificial structures such as barriers and the setting of ecological flows and measures for sediment management.

The implementation of such measures is linked to the environmental objective of the WFD to restore continuity for migrating species in regulated rivers. Several other EU policies also support the restoration of river continuity and the rehabilitation of surface waters that are affected by barriers, including the Birds Directive, the Habitats Directive (EU, 1992), the new EU biodiversity strategy for 2030 (EC, 2020b) and the Eel Regulation (EU, 2007a). The new EU biodiversity strategy for 2030 has a specific commitment to restore at least 25 000 km of free-flowing rivers by 2030 through the removal of primarily obsolete barriers and the restoration of floodplains and wetlands (EC, 2020b).

Overall, on account of the very large number of barriers present on rivers in Europe, there is a need for prioritising measures to restore continuity. Some national and regional strategies for restoring continuity are in place to ensure a phased approach in dealing with the issue of barriers. Examples are the Benelux treaty on free fish migration (adopted in 1996), continuity restoration initiatives in the international river basins of the Rhine (WFF and ERN, 2016) and the Danube (Shepherd, 2012) and national programmes and priority networks for river continuity restoration in specific countries such as Austria, Finland, France and Germany (Kampa et al., 2017; Ollikainen and Vilhunen, 2019).

The implementation of measures is affected by significant gaps in our knowledge concerning barriers, their abundance, distribution in the European river network (especially of small barriers) and their ecological effects. The recent European project AMBER (see above) has summarised much of the needed basic information. Furthermore, knowledge still needs to be consolidated on the effects of some of the key measures. For instance, barrier removal is increasingly viewed as a necessary management measure to reinstate natural connectivity. However, we so far have insufficient knowledge to make predictions about the geomorphological and biological trajectory of a river system once a barrier has been removed (Birnie-Gauvin et al., 2017).

An additional implementation challenge arises from the large number of barriers with an unknown or obsolete use. Funding measures to make obsolete barriers passable is a challenge, because of the lack of a specific water use sector assigned to these modifications in the rivers.

In parallel to planning measures for dealing with the impacts of existing barriers, new barriers and dams are being built elsewhere in Europe, driven by policies for energy production, transport, flood protection and securing water supply (e.g. new hydropower plants in the Western Balkans (WWF et al., 2019).

In this respect, a much closer coordination of river basin management planning under the WFD and the planning of new river infrastructure to serve sectoral development is essential to safeguard river continuity.

3.2.2 Loss of lateral connectivity (flood protection and drainage on floodplains)

Overview

Wetlands and floodplains play a particularly important role in the ecological integrity of aquatic ecosystems. By providing habitats for the life stages of aquatic organisms, they are significant in ensuring or achieving the good ecological status of adjacent water bodies. Wetlands and floodplains also play a significant role in flood retention (EEA, 2018b).

Studies have shown, however, that 70-90 % of European floodplains have been environmentally degraded because of structural flood protection, river straightening, disconnection of floodplain wetlands from the river, agricultural land use and urbanisation over the past two centuries. The largest pressures on floodplains are hydromorphological pressures and those arising from land use and pollution (EEA, 2019a).

Flood protection structures play a key role in this context. Flood events in degraded floodplains with little buffering capacity and space for flood retention are one of the most common and most dangerous natural hazards affecting European society (EEA, 2016a). For decades, European countries have taken flood protection measures that mostly involve conventional engineering flood protection infrastructure to mitigate the catastrophic consequences of floods. At the same time, flood protection infrastructure and measures (such as levees, retention basins, channel straightening and removal of vegetation and sediment) are among the main causes of hydromorphological alteration and ecological impairment of rivers, in particular by disconnecting river channels from the floodplains and modifying riparian zones.

Further pressure on the river-floodplain system is exerted by activities that drain excess water from the soil to increase the area of land suitable for crop production. Land areas may also be drained to serve for forestry or coastal and urban development. Drainage for agriculture has led to major losses of wetlands throughout Europe and is related to several hydromorphological pressures such as channelisation of rivers and channel deepening (Vartia et al., 2018). In Europe, 35 % of wetland loss between 2000 and 2006 was due to conversion to agriculture (EEA, 2012a); in south-western Sweden alone, almost 70 % of wetlands have been lost as a result of drainage over the last 50 years (Franzén et al., 2016). In many European countries, mainly in northern and central Europe, between 40 % and 100 % of farmland is being drained (based on data from ICID, 2011).

In the second RBMPs under the WFD, almost 15 000 surface water bodies (about 10 % of total) are affected by physical alterations to their channel, bed or riparian area as a result of flood protection and/or agriculture in 21 of the WFD countries. In addition, flood protection and/or drainage for agriculture are the reasons for designating almost 7 500 water bodies as heavily modified in 26 WFD countries.

Impacts

Both flood protection infrastructure and drainage affect floodplains and the connectivity of rivers and streams to floodplains, as they cause changes in the land area surrounding water bodies (Image 3.2). This can have major implications for the integrity of both riparian and aquatic ecosystems (Amoros and Roux, 1988; Junk et al., 1989; Junk and Wantzen, 2004). In a natural system, lateral connectivity between rivers and their floodplains allows the exchange of water, sediments, biota and nutrients. The loss of lateral connectivity leads to the loss of key habitats and, as a result, to the decline of species and biodiversity, both on the floodplain itself and in the aquatic environment. Furthermore, physical processes related to the natural water retention capacity of floodplains and sediment dynamics are disturbed.

Artificial bank protections that provide flood protection (embankments, levees or dykes) affect the morphology and dynamics of the river channel by restricting the channel width and the sediment supply from the river banks. Bank reinforcement and levee construction can also lead to bed incision because of the resulting high-speed flows; in turn, bed incision reduces the connectivity between the river and its floodplain (lateral connectivity). The reduction of this lateral connectivity damages the functioning of the riparian zone and reduces productivity, nutrient exchange and dispersal of biota more widely across the floodplain (Reform, 2015).

As far as land drainage is concerned, natural channels have been straightened and deepened for surface drainage ditches with significant effects on channel morphology, instream habitats for aquatic organisms, floodplain and riparian connectivity, sediment dynamics and nutrient cycling (Blann et al., 2009) Furthermore, the regular maintenance of drainage ditches and rivers (through dredging and weed cutting) leads to physical disturbances and morphological changes in water bodies (Vartia et al., 2018).

Image 3.2 Embankments for flood protection (left) and agricultural drainage (right)

Sources: © Peter Kristensen, EEA.

Measures and management challenges

The restoration of bank structures, the reconnection of floodplains or backwaters (such as oxbow lakes and side channels) and the restoration of wetlands are key measures applied in river basin management planning to restore lateral connectivity between rivers, their riparian area and the wider floodplain (EEA, 2018b). For example, in the international Rhine basin, about 125 km² of floodplains had been restored by 2012, with a target of restoring more than 150 km² by 2020. In addition, measures were taken to increase the structural diversity of approximately 100 km of river banks by 2012 with a target of 800 km by 2020 (ICPR, 2015). With increasing awareness of the importance of floodplains, the number of examples of restoration measures or work aiming to improve river floodplain systems' functioning is rising (EEA, 2019a).

The improvement of lateral connectivity between rivers and their floodplains is a key element for the achievement of the environmental objectives of the WFD. Multi-benefit measures that support the achievement of environmental requirements of various environmental policy instruments beyond the WFD, such as the Floods Directive, Birds and Habitats Directives and the Nitrates Directive, are particularly relevant to the restoration of disconnected wetlands and floodplains. For example, buffer strips can be beneficial for reducing pollution (included in the Nitrates Directive and the good agricultural and environmental conditions of CAP cross-compliance), improving riparian habitats, reducing hydromorphological pressures, increasing water retention and mitigating the impacts of floods.

River restoration measures aiming to give more room to rivers are also important for floodplain restoration as well as for the prevention of flood events. A targeted 'Room for the River' programme was established in the Netherlands, consisting of over 30 projects that were completed at the end of 2018. The key to the room for the river approach is to restore the river's natural floodplain in places where it is least harmful to protect those areas that need to be defended from floods (Dutch Water Sector, 2019).

It is difficult to predict exactly how pressures on European floodplains and lateral connectivity of rivers may develop in the future. However, climate change is bound to lead to increased precipitation and flood events, in particular in northern Europe. In turn, this may require further mitigation measures linked to flood defences as well as increased drainage, leading to increased pressures on floodplains and lateral connectivity (EEA, 2021). At the same time, European targets in the new biodiversity strategy need to be met, and the restoration of floodplains and wetlands is a means of restoring at least 25 000 km of free-flowing rivers by 2030 (EC, 2020b).

Despite the obvious importance of floodplain restoration, it has not yet been systematically included in river basin or flood risk management plans. To devise more strategic approaches to floodplain restoration in the future, it will be important to develop a more coherent knowledge base on floodplains and a more targeted approach towards financing this type of restoration (EEA, 2019a).

3.2.3 Hydropower

Overview

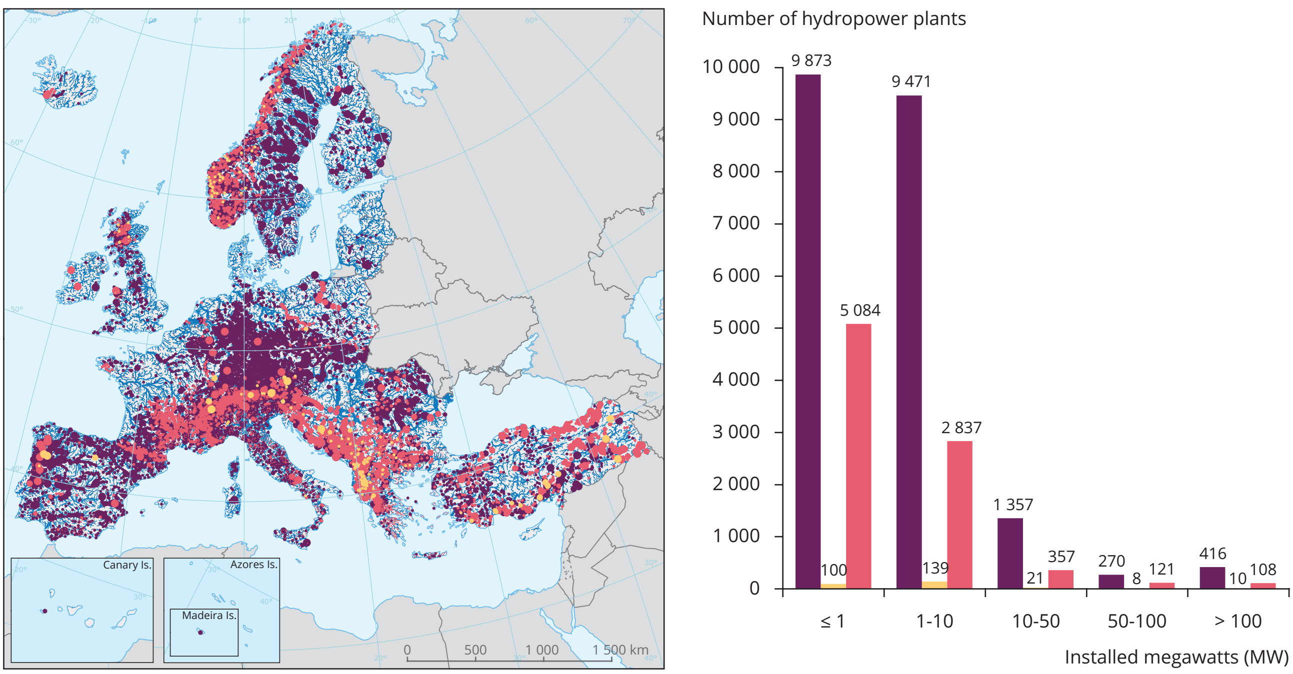
Hydropower has a long history in Europe and currently generates around 10 % of EU net electricity (Eurostat, 2019b) and more than 33 % of renewable electricity in the EU in 2015 (Eurelectric and VGB Powertech, 2018). Norway and Switzerland are also countries where hydropower is especially important. At the same time, the construction and operation of hydropower plants has major impacts on water bodies and adjacent wetlands, such as changes in the flow regime and sediment transport, loss of key habitats and river fragmentation.

In the second RBMPs, 22 WFD countries reported significant pressures in the form of barriers, hydrological alterations and abstractions related to hydropower production, affecting approximately 9 000 surface water bodies (6 % of total water bodies). In addition, hydropower is the most common reason for designating water bodies as heavily modified, applicable to approximately 6 000 water bodies in 25 WFD countries (half of these water bodies are in Norway).

In Europe, currently more than 21 000 hydropower plants exist (Figure 3.3). The majority (ca. 90 %) are hydropower plants with less than 10 MW installed capacity (WWF et al., 2019). Large hydropower plants (capacity of more than 10 MW) represent only 10 % of all hydropower facilities, but they generate almost 90 % of the total hydropower energy produced (Devoldere et al., 2011). Germany has the largest number of hydropower plants (more than 7 700), while Austria, France, Italy and Sweden each have more than 2 000 hydropower plants (Kampa et al., 2011). Furthermore, in Norway and Spain there are more than 1 000 existing hydropower plants (WWF et al., 2019).

The main types of hydropower plants based on the ability to store water are (1) run-of-river plants, (2) storage plants and (3) pumped storage plants (Image 3.3). Run-of-river plants do not have reservoirs and run on the natural discharge of the river. Storage plants require the construction of a dam and a reservoir to store water. In many regions of Europe, run-of-river plants are the most common type of hydropower plants, but storage and pumped storage plants account for a higher share of the installed capacity.

Figure 3.3 Recorded hydropower plants in Europe



Reference data: ©ESRI

Recorded hydropower plants in Europe

Installed megawatts (MW)

- ≤ 1
- 1-10
- 10-50
- 50-100
- > 100

River network

Outside coverage

Hydropower plant category

- Existing dam
- Under construction
- Planned dam

Note: Distribution of hydropower plants (left) and distribution of hydropower plants by status and size class (right).

Source: WWF et al. (2019). Reproduced under the terms and conditions of Creative Commons attribution licence CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0).

Image 3.3 **Images of small hydropower plant (left) and large hydropower plants, storage, and run-of-river (centre and right)**

Sources: Left: Tangopaso (https://commons.wikimedia.org/w/index.php?curid=23481491). Centre: Bair175 (https://upload.wikimedia.org/wikipedia/commons/f/fe/Altakraftverket%2C_Norge.jpg); reproduced under the terms and conditions of Creative Commons attribution licence CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/deed.en). Right: © Peter Kristensen, EEA.

The greatest development of hydropower in Europe has taken place over the last century, harnessing most of the large hydropower potential on the continent. Nonetheless, new hydropower plants are still under development. Several hydropower plants in Europe are under construction (278) and many more are planned to be constructed (8 507). The Western Balkans and Turkey in particular have ambitious plans to significantly increase their exploitation of hydropower (WWF et al., 2019). Furthermore, in other parts of Europe, there is an increasing number of applications for new hydropower plants, especially small ones up to 10 MW. For example, in Italy there are more than 500 applications to build new hydropower plants of 1 MW, and in Scotland there have been more than 700 applications for new hydropower developments in the last 15 years (Bussettini, 2019; Fyfe, 2019).

Impacts

Hydropower generation has impacts on aquatic ecology, natural scenery and ecosystems. The possible key ecological impacts of hydropower are described below (ICPDR, 2013).

Hydropower dams and weirs **interrupt the river's longitudinal continuity**. Migrating fish species, such as eel and salmon, are particularly affected by the fragmentation of their habitats. In addition, when fish pass through hydropower turbines as they move downstream, a high proportion of them are injured or killed. The impact of acting as migration barriers is common to most types of hydropower plants.

Furthermore, hydropower plants change the river hydromorphology. Hydrological processes and sediment transport lose their natural dynamics, leading to altered natural structures and habitats.

Hydropower plants **change the river flow regime**. In rivers that are impounded for hydropower (typical for storage hydropower plants), flow velocity is reduced, which can lead to fish becoming disoriented. Reduced flow velocity results in other negative impacts such as increased deposition of fine sediment in the impoundment.

Another impact from hydropower results from rapidly changing flows called **hydropeaking**, which is mainly typical of large hydropower plants in combination with reservoirs. Hydropeaking can cause severe morphological and ecological effects on a river and particularly on fish populations.

Often at run-of-river hydropower plants a portion of the river water is diverted, e.g. through a canal, to produce energy. This leads to large flow reductions immediately downstream of the river diversion and to changes in flow patterns further downstream.

Water storage and river regulation through hydropower plants often also **alter physico-chemical conditions** downstream, with changes in water temperature, supersaturation of oxygen and altered patterns of ice formation in winter.

There is usually not just one hydropower plant or dam in a river system; instead, several can be present on the main river as well as on tributaries. The **cumulative effects** of multiple hydropower plants, in combination with barriers that do not serve electricity generation, need to be considered (Kampa and Berg, 2020). In a chain of impoundments containing several hydropower plants, the total effects can endanger whole fish populations in a river basin.

Measures and management challenges

In several countries, measures are being implemented to mitigate the impacts of hydropower plants on water bodies. The main measures are targeting upstream fish migration (especially fishways), downstream fish migration (e.g. fish guidance systems and bypasses, fish-friendly turbines), habitat restoration, sediment management and the implementation of ecological flows.

Most EU countries have relevant legislation in place to ensure minimum ecological flows and upstream continuity via fishways at hydropower plants. However, legislative requirements are lacking to address other types of hydropower impacts, such as on downstream fish migration, sediment transport and hydropeaking, because there are still open questions that need to be addressed by research (Kampa et al., 2011). For instance, knowledge is lacking on measures to mitigate impacts on downstream migration of fish at hydropower turbines, especially in large rivers.

Hydropower plants generally operate under a permit/licensing scheme, whereby conditions for the operation are set. However, many hydropower plants were licensed before the adoption of key EU water policy such as the WFD in 2000 and national laws protecting rivers. In addition, in many countries, licences have unlimited or very long duration (e.g. up to 100 years). The large number of such licences on old hydropower plants, whose operating conditions are difficult to change, remains a big challenge to the implementation of mitigation measures (Kampa et al., 2017).

Since 2000, the WFD has been a strong driver for modifying the licensing procedures for new hydropower plants and for revising licences of existing plants in many countries. In case of new hydropower plants, licences are issued that include requirements for implementing mitigation measures, to comply with national or regional mitigation requirements for hydropower plants.

Furthermore, reconstruction, repowering and subsidies are used to introduce ecological demands into the licences. There are plans to reconstruct many existing hydropower plants, as a lot of facilities across Europe are over 40 years old.

The reconstruction and modernisation of old hydropower plants can often significantly increase their power output and offer an alternative to the construction of new plants, which would affect further stretches of free-flowing rivers.

Overall, as the energy systems of European countries depend on energy produced via hydropower, there is a need for measures that mitigate ecological impacts with the least possible effect on energy production for existing and new hydropower plants.

Large-scale strategies for more sustainable hydropower are being developed. Examples include Sweden's new national plan for the revision of hydropower licences in the next 20 years, including the Hydroelectric Environmental Fund for mitigation measures based on industry contributions (SWAM, 2019). Switzerland's Water Protection Act set mitigation targets for hydropower by 2030, offering financing of mitigation measures via an electricity surcharge (Kampa, et al., 2017). In addition, at the transboundary level, guiding principles for sustainable hydropower development have been developed for the international Danube basin (ICPDR, 2013). At the same time, though, there is a worrying trend towards developing many new hydropower plants, especially in the Western Balkans and Turkey, and a rising number of applications to develop small new hydropower plants across Europe.

3.2.4 Inland navigation

Overview

Navigation affects most of the major rivers in Europe because of the presence of inland waterways on the large European rivers and intensive leisure boat activity on the smaller rivers. Furthermore, many canals were developed during the early period of industrialisation and some navigable rivers and canal systems are used only for leisure boats nowadays. To allow natural rivers to be used as modern shipping lanes, numerous changes have been made to rivers and their floodplains. Inland navigation is typically associated with a range of hydromorphological alterations, such as channelisation, channel deepening, channel maintenance, installation of groynes and flow regulation, which adversely affect water ecosystems (ICPDR, 2007; BMU/UBA, 2016). The alterations are bigger when smaller rivers are made navigable for ships that are too large for the natural size of the river. In the second RBMPs, a relatively small number of river and lake water bodies (approximately 700 water bodies across 13 WFD countries) were reported as being affected by pressures from inland navigation. However, navigation issues are of considerable importance in some of the largest river basins in Europe, such as the Danube and the Rhine.

Navigation intensity has been increasing in Europe since the 1960s, in terms of both the volume of goods transported and average vessel size (Graf et al., 2016). Nowadays, there are more than 37 000 km of European inland waterways, spanning 20 Member States and connecting hundreds of cities and industrial sites (DG Mobility and Transport, 2016). The uses of inland waterways include navigation for transporting freight and passengers and for leisure (Image 3.4). Most of the commercial goods transport by inland ships in Europe concerns five countries: Belgium, France, Germany, the Netherlands and Romania (EC, 2018b). More than two thirds of all goods transported on European inland waterways are carried on the river Rhine, which is the backbone of inland navigation in Europe (EPRS, 2014). The total volume of goods transported on European inland waterways is approximately 550 million tonnes. However, this equates to only around 6 % (in 2017) of the total volume of all goods transported in the EU (Eurostat, 2019c).

In addition, inland waterways are used for water tourism, sports, fishing and angling, and for recreational purposes. The recreational water use of navigable rivers can be of great economic significance in certain regions, as it supports several thousand jobs in Europe (PIANC et al., 2004).

The infrastructure network of inland waterways includes the natural navigable rivers, artificial canals that link navigable rivers and inland ports. European inland waterways are part of the Trans-European Transport Network (TEN-T), which aims to integrate land, marine and air transport networks throughout Europe.

Image 3.4 Examples of inland navigation vessels for recreational and commercial purposes

Sources: © Peter Kristensen, EEA.

Impacts

The main impacts from inland navigation on aquatic ecosystems are related to **hydromorphological pressures**, such as the construction of groynes, the protection of river banks with rip-rap and the deepening and maintenance of the channel (e.g. through dredging). Altering the shape of river courses to improve navigation affects the characteristics of river beds, river banks and the dynamics of sediment transport. The effects can spread upstream and downstream over many years. Permanent changes to water levels and flows affect the whole river valley bottom and the ecology of floodplains. Navigation works tend to be designed to stabilise river channels in both space and time, which constrains the natural dynamics of the river, which are important for creating and renewing key habitats (ECMT, 2006). Thus, navigation requirements result in stabilised, ecologically uniform river channels, which lack natural in-stream structures and connectivity with the nearby floodplains (ICPDR, 2007).

Ship traffic also causes waves, which can disturb the reproduction habitats of fish and benthic invertebrates and have an impact on aquatic plants. In addition, the engines of ships can cause an unnatural suspension of fine sediments, leading to reduced light for plant and algal growth (ICPDR, 2007). Furthermore, navigable rivers are usually affected by numerous impoundments to achieve a uniform water level, which, at the same time, disrupt river continuity and fish migration.

In addition to hydromorphological impacts, inland navigation can be a potential **source of pollution** coming from ship waste (oily and greasy ship waste, cargo waste, waste water and household waste from passenger ships) or bilge water. There is also a risk of accidental spills, involving oil or hazardous substances, resulting from collision of or damage to ships (ICPR, 2015; EC, 2018b). For example, on the river Rhine, in 2018 and the years before, oil released from shipping was the most frequently reported pollutant in sudden pollution incidents (ICPR, 2015).

Finally, to maintain navigable water levels in artificial canals that connect different river systems, water is often moved between rivers, not only altering hydrology but also **spreading invasive alien species**. Furthermore, shipping is an important dispersal vector for invasive species between river systems, either by transport on the vessels or by release of bilge water.

Measures and management challenges

In some countries and regions in the EU, such as the international river basins of the Rhine and Danube, actions have been taken or are ongoing to reconcile inland waterway development with river restoration objectives. Key measures to mitigate the impacts of inland navigation on rivers and lakes include the reconstruction of groynes, the removal of hard bank reinforcements and their replacement with soft engineering solutions, the reconnection of side arms, floodplains and oxbow lakes to restore river habitats, as well as the use of more ecologically oriented dredging for the maintenance of waterways.

The environmental objectives of the WFD are a major driver for the development of such measures within the RBMPs. In addition, to support the objective of more sustainable inland waterway transport, several European guidelines have been developed to demonstrate good practices for waterway development that are compatible with environmental protection requirements (e.g. PIANC *Guidelines for sustainable inland waterways and navigation* (PIANC, 2003) and Platina *Manual on good practices in sustainable waterway planning* (Platina, 2010)).

Furthermore, the issue of pollution from inland navigation needs to be addressed with appropriate measures. For instance, to deal with pollution and emissions from navigation on the Rhine, a convention on the collection, deposit and reception of waste produced during navigation on the river waterways was adopted in 2009 (ICPR, 2015). Deliberate or accidental losses of pollutants from inland navigation are being recorded in the international warning and alarm plan for the Rhine (ICPR, 2019).

Large-scale strategies for more sustainable inland navigation at national or regional levels are being developed. An example is the 'Blue Ribbon' programme in Germany, which is aimed at creating a system of ecologically reshaped waterways by funding the renaturation of federal waterways and their floodplains. The programme focuses on the sections that are no longer needed for cargo shipping (minor waterways) but it also implements 'ecological stepping stones' in the major waterways (BMU/UBA, 2016). At the transboundary level of the Danube basin, a joint statement on inland navigation and environmental sustainability in the Danube provided principles and criteria for environmentally sustainable inland navigation, including the maintenance of existing waterways and the development of future waterway infrastructure (ICPDR, 2019).

At the same time, however, there may be an increase in inland waterway transport, in view of EU targets to shift part of long-distance road freight to rail and waterborne transport (see Commission White Paper on the roadmap to a single European transport area (EC, 2011b)). However, plans for inland navigation in Europe need to take account of the changing climatic conditions. Severe droughts in 2018 led to low river flows, which made parts of major European waterways, such as the Rhine and the Danube, unnavigable for larger cargo barges.

3.3 Abstractions and water scarcity

Overview

Climate change, population growth, urbanisation and intensifying economic activities make water scarcity a critical concern in Europe. Water scarcity occurs when the demand for water for human needs frequently (though not necessarily year round) exceeds the capacity of the natural system to supply it; it is the consequence of anthropogenic impacts on the availability of water resources (EEA, forthcoming). In some areas of Europe, water abstractions are characterised by seasonality, adding to the existing water scarcity drivers of weather phenomena, temperatures and geographical location (EEA, forthcoming).

In the second RBMPs of WFD countries, around 8 000 surface water bodies (about 6 % of total) were affected by significant pressures from abstraction, with the highest shares in Hungary, Spain, Cyprus and Bulgaria. For around half of these surface water bodies, significant pressures from abstractions are linked to agriculture, while abstractions for public water supply and industry are also major pressures.

Over recent decades, groundwater aquifers have also been affected by overexploitation in many parts of Europe (EEA, 2019g). In the second RBMPs, water abstraction was a significant pressure for 17 % of the groundwater area in Europe, with the highest shares in Hungary, Malta and Cyprus. The reported groundwater water abstractions are mainly for public water supply, followed by agriculture and industry.

In 2017, water use in Europe by different economic sectors was made up as follows: agriculture (58 %); cooling water for energy production (18 %); mining, quarrying, construction and manufacturing industries (11 %); households (10 %) and service industries (3 %) (EEA, 2019c). Water use refers to the net water abstracted, which is estimated as the difference between the volume of water abstracted and the volume of water returned to the environment before or after use. The average return ratio of water used for cooling lies at around 80 %, while only about 30 % of the total water abstracted for agricultural purposes in Europe returns to the environment (EEA, forthcoming). The low water returns to the environment combined with high water consumption makes agriculture one of the sectors that puts significant pressure on renewable water resources (EEA, forthcoming), especially in southern European countries, which record up to 80 % of water use for agriculture.

Between 2000 and 2017, water abstraction in the EU-27 and the UK decreased by 17 %, while the gross added value generated from all economic sectors increased by 59 % in the same period. Despite this positive trend, water scarcity and drought events continue to cause significant risks in southern Europe, as well as in specific areas of other European regions (EEA, 2019c). The frequency of either droughts or water scarcity and areas affected are increasing and continuously expanding towards central and western Europe (EEA, forthcoming). According to recent projections, further intensification and a longer duration of water scarcity is expected under global warming in the EU, specifically in the Mediterranean countries (Bisselink et al., 2020) (see Map 3.2). By 2030, half of the EU's river basins are expected to experience water scarcity and stress (Trémolet et al., 2019).

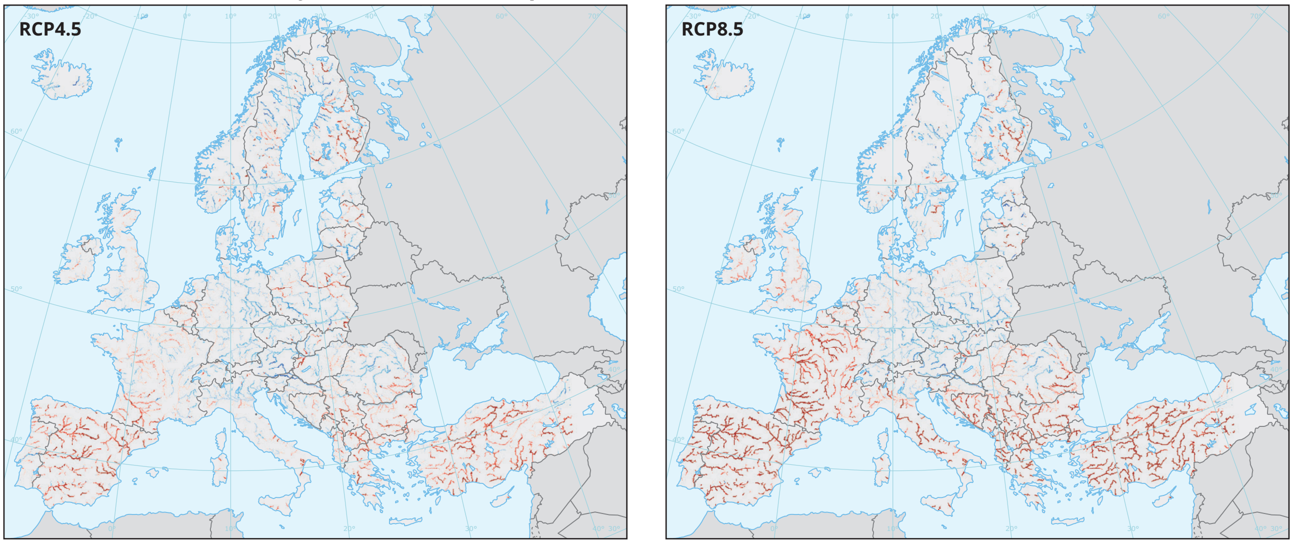
Impacts of abstractions and water scarcity

Water scarcity and drought events are an increasing problem in many areas of Europe, both permanently and seasonally. The environment needs water to sustain aquatic ecosystems and ecosystem services. Low water availability affects surface water and groundwater, altering the hydrological regime, degrading ecosystems and leading to severe ecological impacts that affect not only biodiversity and habitats but also the quality of water and soil (e.g. affecting water temperature, reducing the dilution capacity of pollutants and causing saline intrusions (EEA, 2019b)).

In particular, (over) abstraction of surface water bodies can cause the drying out of water courses and wetland areas in Europe and the lowering of river water levels (EEA, 2018c). This is a common problem in areas with low rainfall and high population density and in areas with intensive agricultural or industrial activity (EEA, 2018c). The drying out or low flow of river courses can have adverse ecological effects, such as a decline in species richness and vegetation encroachment. For example, water abstraction converted naturally perennially flowing rivers to intermittently flowing rivers in Spain, leading to a decline of 35 % in fish species richness (Benejam et al., 2010).

In addition, the (over) abstraction of groundwater bodies can cause the lowering of groundwater levels (EEA, 2018c), with further impacts on groundwater-dependent aquatic ecosystems. In coastal areas, saltwater can intrude into the groundwater aquifers from which freshwater is abstracted, leading to salinisation and rendering the aquifers unusable as a drinking water supply (EEA, 2018b).

Map 3.2 **Projected change in 10-year river water deficit between the present (1981-2010) and the end of the 21st century (2071-2100) in Europe, under two emissions scenarios**



Reference data: ©ESRI

Relative change in 10-year river water deficit between present (1981-2010) and the end of the century (2071-2100) under RCP4.5 (left) and RCP8.5 (right) scenarios

Percentage of change in 10-year river water deficit

≤ -75, -75 to -50, -50 to -25, -25 to 0, 0 to 25, 25 to 50, 50 to 75, > 75

Outside coverage

0 500 1 000 1 500 km

Notes: These maps show the relative change in 10-year river water deficit under the 95th percentile for two greenhouse gas emissions scenarios (RCP4.5 and RCP8.5).

Source: Bisselink et al. (2020).

Measures and management challenges

Water scarcity is a complex phenomenon that entails multiple and often interconnected causes. Thus, an integrated water management approach, including coherent and consistent policy instruments, education, economic tools, structural interventions, where needed, and recourse to new technologies, appears most suited to attain European goals and the Sustainable Development Goals for water. Several measures are used to address the adverse impacts of water abstractions and water scarcity on the environment, and these can be roughly divided into demand-side and supply-side measures.

In the past, European water management largely focused on increasing supply by, for example, drilling new wells and constructing reservoirs (EEA, 2018b). However, as Europe cannot endlessly increase its water supply, various policies and measures put an emphasis on managing water demand and making the transition from crisis management to risk management (EEA, forthcoming). Measures to reduce demand can include the use of economic instruments, including water pricing, water loss controls (e.g. detection and repair of leaks), increased efficiency of domestic, industrial and agricultural water use (e.g. via drip irrigation in agriculture), and water-saving campaigns supported by public education programmes (EEA, 2018b). In addition, monitoring, metering, authorising water abstractions and defining environmental flows have progressed, but their enforcement still needs to improve further (EEA, forthcoming). In some countries, especially in southern Europe, efforts to address overabstraction and illegal abstractions via permits and to secure long-term sustainability remain inadequate (Trémolet et al., 2019; Ross, 2016).

At the same time, the increasing demand for water for socio-economic activities under a changing climate forces Member States to explore additional measures to secure their water supply. Innovative measures to supply water using unconventional resources (e.g. desalination, water reuse and rainwater harvesting) are already implemented in many Member States (EEA, forthcoming). Other, more traditional, water supply measures, such as new reservoirs for water storage or interbasin water transfers, may be considered when other demand options have been exhausted (EEA, 2018b). Overall, further evidence-based exchange is needed among experts and countries on the kind of water supply-side options that are more sustainable and need further promotion.

Relying on only one type of measure may not be enough to achieve environmental objectives. Instead, a combination of measures, which may include measures to reduce demand and to supply water, is desirable to tackle the impacts of water abstractions and water scarcity from a consistent and long-term perspective. Techniques may range from water pricing incentives to the reduction of network leakages rates (Trémolet et al., 2019).

Strategic planning instruments have also been in use in European countries, such as drought management plans in Spain. These enable the planning, monitoring and mitigating of water scarcity situations and enhance decision-making during periods of drought (EC, 2007; Stein et al., 2016; Stein and Landgrebe, 2019).

Finally, land management and land use planning are essential for water management in water-scarce areas and can be used to foster measures for natural water retention such as wetland restoration (EEA, 2018b). Natural water retention measures and aquifer recharge are promising options for tackling water scarcity and water stress, but to be effective they must be implemented at a sufficient scale and thus require further assessment (EEA, forthcoming).

3.4 Aquaculture

Overview of aquaculture

Aquaculture is the farming of aquatic organisms (e.g. fish, molluscs) under controlled conditions; it is an alternative to catching wild fish and takes place in both inland and marine areas. Marine aquaculture production has been increasing in Europe since the early 1990s, mostly as a result of the growing salmon production in Norway (EEA, 2018b). Over the same period, inland aquaculture has been relatively stable (EEA, 2018b). In 2017, the production of finfish (particularly salmon, trout, seabass, carp and tuna) and molluscs (mussels, oysters and clams) together accounted for almost the entire aquaculture production of almost 1.5 million tonnes in the EU and had a value of approximately EUR 5 billion (Eurostat, 2019a). Freshwater aquaculture contributes to 20% of total EU aquaculture production in terms of volume in the last ten years (EUMOFA, 2021).

Aquaculture production, both inland and marine, can put significant pressures on European waters when it comes to point and diffuse source pollution, changes in flow, dredging and the introduction of alien species. In the second RBMPs, around 1 400 surface water bodies (mainly rivers) were reported to have significant pressures from aquaculture in 20 European countries, with the highest shares in Finland, Bulgaria, Hungary and Czechia. Water abstraction for fish farms were the most frequently reported aquaculture pressures, followed by point source pollution, hydrological alterations and diffuse source pollution.

Three major types of **freshwater aquaculture** in European waters can be distinguished (EUMOFA, 2021):

1. *Extensive pond farming.* This consists of maintaining ponds (natural or artificial) with low fish density and natural fish feed. Production in extensive farms is generally low (less than 1 t/ha per year). It is practised across Europe and is particularly common in central and eastern Europe.

2. *Semi-intensive freshwater aquaculture*. The production of the pond is increased by adding supplementary feed, allowing higher stocking densities and production per hectare.

3. *Intensive freshwater aquaculture* in tanks. Fish are bred until they reach a marketable size. There are two techniques: either river water enters the tanks upstream and leaves downstream or the water remains in a closed circuit and is recycled and 'recirculated' in the tanks.

In addition, three major types of **marine aquaculture** exist:

1. *Extensive brackish water aquaculture in artificial lagoons*. The semi-extensive nature is characterised by introducing hatchery fry and providing additional feed.

2. *Intensive sea farming*. Sea cages hold fish captive in a large pocket-shaped net anchored to the bottom and maintained on the surface by a rectangular or circular floating framework.

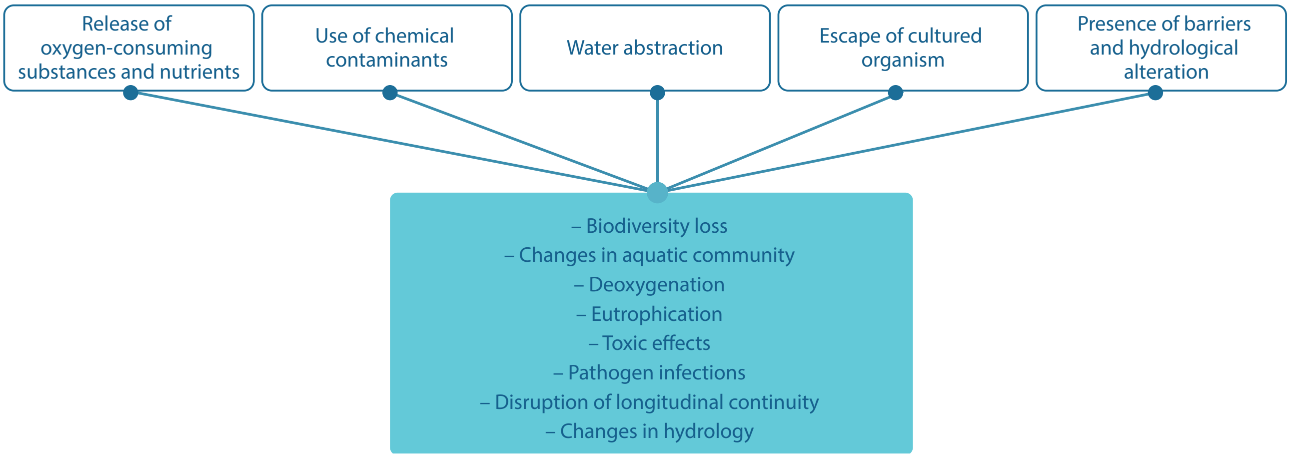
3. *Intensive aquaculture in tanks*. Artificial shore-based tanks can be used to breed marine fish. Recirculating the water creates a closed and controlled environment that is necessary for optimal production in hatcheries and nurseries for marine species.

Impacts

The pressures and impacts of aquaculture depend on farm location, type of cultured organism, methods used, intensity and the sensitivity or vulnerability of the environment to possible pressures (Jeffrey et al., 2014). Potential impacts of aquaculture on aquatic ecosystems are shown in Figure 3.4 and are discussed as follows.

Aquaculture releases **oxygen-consuming substances** and nutrients (as excretory products and uneaten fish food) as well as **chemical contaminants** (e.g. disinfectants, veterinary medicinal products, trace metals) into water. The released pollutants can cause deoxygenation of the water, causing adverse impacts on the benthic fauna and contributing to local algal blooms and eutrophication. Anti-corrosion materials (e.g. copper, zinc-plated steel) and antifouling paint used in

Figure 3.4 Aquaculture pressures and potential environmental impacts



Source: EEA.

aquaculture systems can leak into the sea from fish cages and ropes, with toxic effects on ecosystems.

Cultured organisms that escape from aquaculture production sites can interbreed and compete with wild stocks and can also introduce pathogens. Sea lice infestations, for example, can threaten wild fish populations by reducing the survival and reproduction rates of wild salmonids. A number of studies links the presence of fish farms to outbreaks of lice in the environment, particularly in the case of salmon (Science for Environment Policy, 2015).

Fishponds are also often associated with **barriers and hydrological alterations**, which can adversely affect the upstream and downstream migration of fish and other organisms. The presence of barriers may reduce flow velocity and thus support eutrophication effects. Barriers may also disrupt the natural transport of sediment, affecting the stability of river beds and related ecosystems downstream.

Water intakes for aquaculture production are associated with **water abstraction**, which can contribute to decreasing groundwater levels and to low flow in rivers.

Norway, being the biggest aquaculture producer in Europe, annually produces a report on the risks related to aquaculture production covering different environmental impacts, including nutrient pollution, chemical contamination, sea lice infestations and escapes of cultured salmon (Grefsrud et al., 2021).

Measures and management challenges

A broad range of management and technical measures exist to tackle the adverse impacts of aquaculture on European waters, in particular limits on production, improving the siting of aquaculture operations and developing codes of best management practices. At national and regional levels, an important regulatory instrument is to set limits on production (EC, 2016b). For example, in 2019, Denmark decided to stop creating new aquaculture facilities and the expanding of existing ones. This is because coastal areas and inland waters are overloaded with nitrogen, and mitigation measures have not been enough to tackle the issue. In Denmark, there is also government finance to support the removal of weirs on rivers built for use in fish farming facilities (Salmon Business, 2019; Tyrrell, 2019).

Improving the siting of aquaculture operations can be illustrated by the Norwegian Aquaculture Act, which requires an environmental impact assessment for new aquaculture sites. The Act calls for fish farms to be located in areas with good biological recipient conditions, high bearing capacity and generally good self-cleaning properties (FAO, 2017).

Technical methods, management systems and practices should be incorporated into more formal 'codes of practice' adopted voluntarily across the whole aquaculture industry. Codes of best management practices should promote the following (Phillips et al., 2001):

1. reduced use of fertilisers, antibiotics and chemicals, their replacement with non-harmful or less harmful substances, or the introduction of new physical biofouling management techniques to reduce the impact of nutrients and chemical discharges (Science for Environment Policy, 2015);

2. implementation of zonal or area management plans, as part of river basin management plans, to reduce the overall disease and parasite burden on sites (Science for Environment Policy, 2015);

3. transport of fish as fertilised eggs (not as living animals) to reduce the spread of diseases from introduced aquaculture species (Peeler et al., 2011)

4. sterilisation of farmed species to control the impact of escapees and alien species (Science for Environment Policy, 2015);

5. treatment of waste water from closed systems (tanks, ponds), i.e. with techniques comparable to urban and animal farming waste treatment.

Furthermore, setting up best available techniques, similar to those drafted for other sectors under the Industrial Emissions Directive (IED), would be a potentially effective way of addressing the environmental impacts from the aquaculture sector.

Within the EU, production from aquaculture is not expected to grow significantly in the future, despite the higher level of subsidies put in place (Guillen et al., 2019). Nevertheless, the present and future adverse impacts of aquaculture on European waters need to be addressed. Aquaculture is recognised as a source of significant pressure on waters, and the programmes of measures to implement the WFD and Marine Strategy Framework Directive (MSFD) need to contain explicit actions to reduce pressures from aquaculture where relevant. Further integration of measures at the farm site level with regulatory measures at the river basin, national and EU levels is required to reduce the adverse effects of aquaculture production on European waters.

3.5 Invasive alien species

Overview

Alien species are plants and animals that have been deliberately or accidentally introduced outside their natural range. Having found good living conditions, such species may spread quickly and thus become 'invasive'. Once established, they are difficult or impossible to control.

In the aquatic environment, alien species are non-native plants or animals that compete with, and could even eradicate, natural aquatic species. Invasive alien species (IASs) are thus a significant pressure on the good ecological status of surface waters, aquatic habitats and species in general. In the second RBMPs, 15 European countries reported IASs as a significant pressure for approximately 2 700 water bodies (2 % of total), with the highest shares being reported in Spain, the Netherlands, Norway and Slovakia.

It is estimated that there are about 750 freshwater species that are established as alien or suspected to be alien in European inland waters (Nunes et al., 2015). Species such as the Chinese mitten crab or the zebra mussel are a major threat to Europe's aquatic biodiversity. The number of IASs in European freshwaters has been rising, having increased sevenfold over the last 100 years (European Network on Invasive Alien Species, EASIN (Cid and Cardoso, 2013). According to recent data from EASIN, the highest numbers of freshwater alien species have been registered in river basin districts in France, Germany, the Netherlands, Belgium, Sweden and Ireland ([13]).

Alien species are mainly introduced to freshwaters via aquaculture following releases and via escapes of aquarium species. Furthermore, introductions through inland canals or shipping (e.g. with ballast water) and fisheries or angling are also quite widespread but make up a lower share of alien species introductions (Nunes et al., 2015). Climate change is obviously an additional reason, for example if the temperature increases, the currently natural thermal barriers that normally limit the establishment of IASs will become more suitable for them. This will potentially lead to a geographical redistribution of species and create invasive alien aquatic communities (IUCN, 2017).

In European seas, more than 1 360 marine alien species have been observed, of which almost 1 100 have been introduced since 1950. These consist primarily of crustaceans and molluscs, followed by plants, microorganisms and fish. The rate of introductions in the marine environment is continually increasing, with almost 300 new species reported since the year 2000 (EEA, 2012b).

Impacts

IASs threaten native wildlife, alter communities, affect food webs and introduce new constraints to the recovery of native biodiversity. Some also cause economic damage.

Examples of invasive plants are curly waterweed (*Lagarosiphon major*), floating pennywort (*Hydrocotyle ranunculoides*) and large-flowered waterweed (*Egeria densa*). Such plants may cover large areas of water and wetlands, making the survival of natural vegetation and ecosystems impossible. Invasive plants have disrupted navigation and damaged waterworks by blocking pipes and pumps. For example, the total annual control costs to control damage caused by floating pennywort in the Netherlands are around EUR 1 million (BirdLife International, 2021b) . This also includes damage to pumping intakes for cooling water for nuclear power plants, resulting in safety problems (Sarat et al., 2015).

Some invasive aquatic invertebrates have had major effects on the ecosystems that they invade, e.g. the red swamp

([13]) European Commission Joint Research Centre, European Alien Species Information Network (EASIN) (https://easin.jrc.ec.europa.eu).

crayfish and the distribution of the crayfish plague. The plague is estimated to have an economic cost in Europe of over EUR 53 million/year (EC, 2019e). The zebra mussel (*Dreissena polymorpha*) forms dense encrustations, which cause serious damage to infrastructure, clogging up the water intake of industrial and drinking water plants. The killer shrimp (*Dicerogammarus villosus*) can feed on a variety of freshwater invertebrates, including other native shrimp species, fish eggs and young fish, and it can significantly alter ecosystems (BirdLife International, 2021b). Alien species may also act as carriers of fungal organisms or spread diseases (Strayer, 2010).

Invasive freshwater fish, for example introduced by stocking, have disrupted the food web by predating the native smaller fish and their food and simplified the original communities (BirdLife International, 2021a). Escapes from aquaculture (e.g. salmon) have changed the genetic behaviour of natural populations.

Measures and management challenges

According to the IAS Regulation (1143/2014/EU), all Member States should implement strategic plans and measures to combat the adverse effects of IASs. These should include prevention, early detection and rapid eradication measures as well as management measures.

Prevention measures are pathway oriented and are aimed at preventing the intentional or unintentional introduction of IASs. One example is ballast water management (under the Ballast Water Management Convention), under which the ballast water of ships has to be treated, filtered or exchanged in the open sea before entering freshwater ecosystems to avoid the introduction of IASs, for example the Chinese mitten crab. To avoid further spread of invasive plants between unconnected water bodies by, for example, water sport equipment (such as boats and trailers), public awareness raising, also for angling, hunting or zoos, is carried out. Other measures are reducing nutrients for plant reduction or physical barriers.

The basis for **early detection and rapid eradication** measures are surveillance and monitoring to detect the presence of IASs by, for example, establishing an early detection network, citizen science initiatives, eDNA monitoring and remote sensing techniques to detect invasive floating plants. Cutting, mowing or hand weeding of submerged plants, and trapping, hunting and fishing for fish and crustaceans are also measures used to eradicate IASs.

Management measures are aimed at minimising the harm that IASs cause. Examples are the commercial use of the Chinese mitten crab for consumption, biological control (manipulation) of the food web of an ecosystem and the use of herbicides to control massive invasive plant growth.

In addition to the IAS Regulation, other policies tackle aquatic alien species as well. Under the WFD, alien species have been identified and monitored as a pressure in European water bodies. However, only a small number of measures to reduce the pressure of alien species were implemented within the second RBMPs (EC, 2019a). Other relevant policies include the MSFD, which sets specific objectives for managing alien (non-indigenous) species in European seas to achieve good environmental status, and the regulation concerning the use of alien and locally absent species in aquaculture (Council Regulation 7087/2007/EU).

Currently, there is no direct cross-linkage between management strategies under the IAS Regulation, the WFD or the MSFD. However, there is immense potential for the more efficient protection of naturally occurring aquatic communities, as measures to protect aquatic species under the IAS Regulation are also suitable for fulfilling the goals of the WFD and the MSFD. Nearly all Member States have national strategies for preventing and mitigating the impact of IASs, and these should be more closely coordinated with the programmes of measures under the WFD RBMPs and the MSFD. Considering the significant increase in alien species in freshwaters and the marine environment in recent decades, there is a risk that the number of alien species continues to rise, which would have a considerable impact on biodiversity if harmonisation and efficient management strategies are not implemented.

4 Cross-cutting issues for key European water management challenges

4.1 Introduction

Chapter 3 presents selected key water management challenges that put European water bodies most at risk of not achieving the environmental objectives of the Water Framework Directive (WFD). The drivers and pressures of these challenges are described and their key impacts on water ecosystems outlined. Furthermore, summaries of key measures available to tackle the issues and of management challenges of EU-wide relevance are presented.

A broad range of technical and management measures are already available; details of specific measures required will be provided in the third WFD planning cycle. The third river basin management plans (RBMPs) are expected to include measures and actions whose implementation is continued from previous planning cycles as well as new measures.

By 2015, when the second RBMPs were published, only some measures of the first programmes of measures had been completed in the river basin districts. The lack of finance and the unexpected long planning times were identified as the main obstacles to the implementation, along with missing mechanisms for implementing measures (e.g. national regulations not yet adopted) and governance issues (EC, 2019a).

In 2021, the European Commission will provide an overview of progress on implementing the measures of the second programme of measures. The Fitness Check of the WFD and the Floods Directive (EC, 2019c) has already indicated that the main reasons that the WFD's objectives have not been fully reached yet are insufficient funding, slow implementation and insufficient integration of environmental objectives in sectoral policies, including gaps in EU water legislation. Similarly, the evaluation of the Urban Waste Water Treatment Directive (UWWTD) concluded that it is overall fit for purpose, although there is scope to enhance its positive effects and to step up the implementation in a number of Member States. However, the UWWTD does not deal adequately with emerging pollutants such as pharmaceuticals and microplastics (EC, 2019b).

It is thus expected that the measures required to tackle the key European water management challenges presented in this report can be mobilised through better implementation of the existing legislative framework on water (basic measures under the WFD) and the introduction of supplementary measures that further reduce key pressures.

At the same time, the summaries of measures and management responses to several key water management challenges indicate that the following are cross-cutting issues of EU-wide relevance in implementing measures:

- There is a need for better harmonisation of the objectives and management responses of different directives and strategies, which set the EU policy context for taking actions and measures.

- There is a need to coordinate sectoral developments with river basin management planning under the WFD.

- The funding of measures is also an issue.

These cross-cutting issues are discussed in this chapter, with emphasis on:

- their role in improving and accelerating the implementation of measures to achieve the WFD's objectives;

- the identification of actions and coordination requirements at the EU-wide level.

In short, in this chapter, it is argued that the implementation of measures to tackle key European water management challenges can be further enhanced and accelerated via better coordination of EU strategies and environmental policies, especially in terms of their management responses to reduce pressures in the water environment. Furthermore, water policy objectives need to be better integrated into other EU policy areas and strategies that deal with the sustainable growth of different sectors, such as the agriculture, energy and transport sectors. In addition, the funding of measures can be optimised, for example by mainstreaming water issues in sectoral funding ('water-mainstreaming') and by mobilising funding beyond EU and other public funds. Finally, the potentially crucial role of measures that deliver multiple benefits across different policy objectives is discussed.

The cross-cutting issues discussed in this chapter are outlined in Figure 4.1.

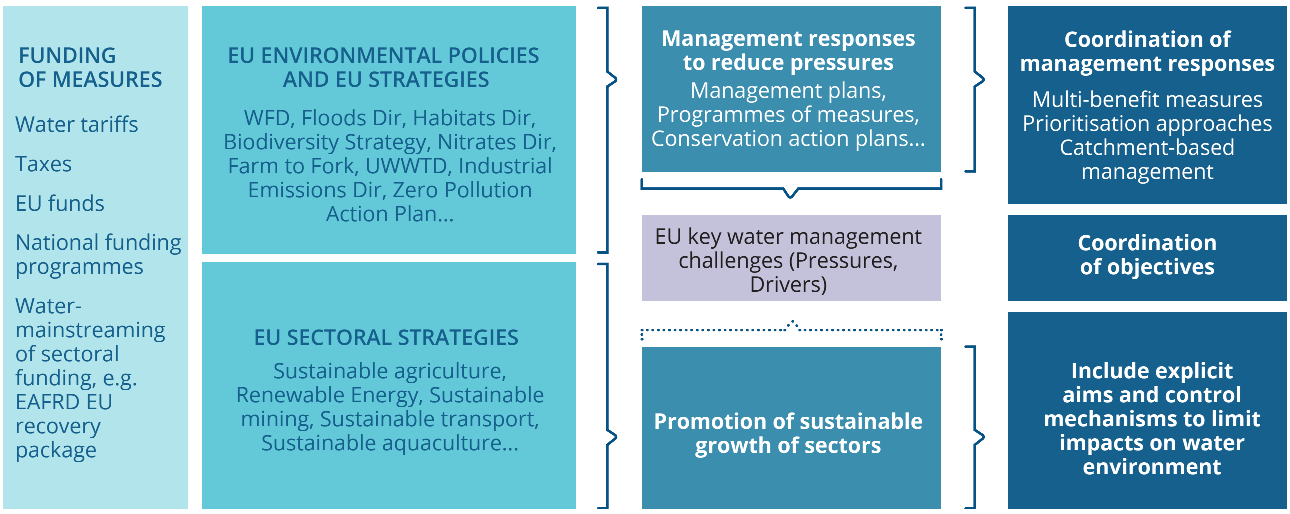
4.2 Coherence of EU policy targets and management responses

The degradation of freshwater ecosystems, water abstraction and scarcity, and nutrient and chemical pollution are key European water management challenges that affect a large share of European water bodies, as described in Chapter 3. To address these management challenges, targets and goals are set in European strategies as part of the European Green Deal and other major EU policies previously adopted. The set EU targets and goals are linked to several management responses and measures, which are required by a broad set of EU environmental directives. These linkages are illustrated in Figure 4.2.

To meet EU targets and goals on water resources and aquatic ecosystems, greater coherence is needed over the specific objectives and management responses of the relevant EU directives and policies. To implement the European Green Deal, better harmonisation and more effective coordination is needed between management responses, planning and implementation of measures, in particular nature conservation plans, programmes of measures under the WFD and the Floods Directive, and other management plans and strategies with implications for pressures on water.

For better harmonisation, we should make better use of multi-benefit measures, such as nature-based solutions, addressing the goals of different policies (see Section 4.5). The planning of multi-benefit measures also considers different water uses and socio-economic issues. Those issues are also addressed by an ecosystem-based management approach, which is a tool for focusing on the full array of the ecosystem, such as provision of high-quality drinking water, reduction of flood risks or recreation, rather than on reaching environmental objectives of specific directives (Grizzetti et al., 2016; Hornung et al., 2019). This would be best practice for water management under the specific directives.

Figure 4.1 Cross-cutting issues for key European water management challenges



Note: EAFRD, European Agricultural Fund for Rural Development.

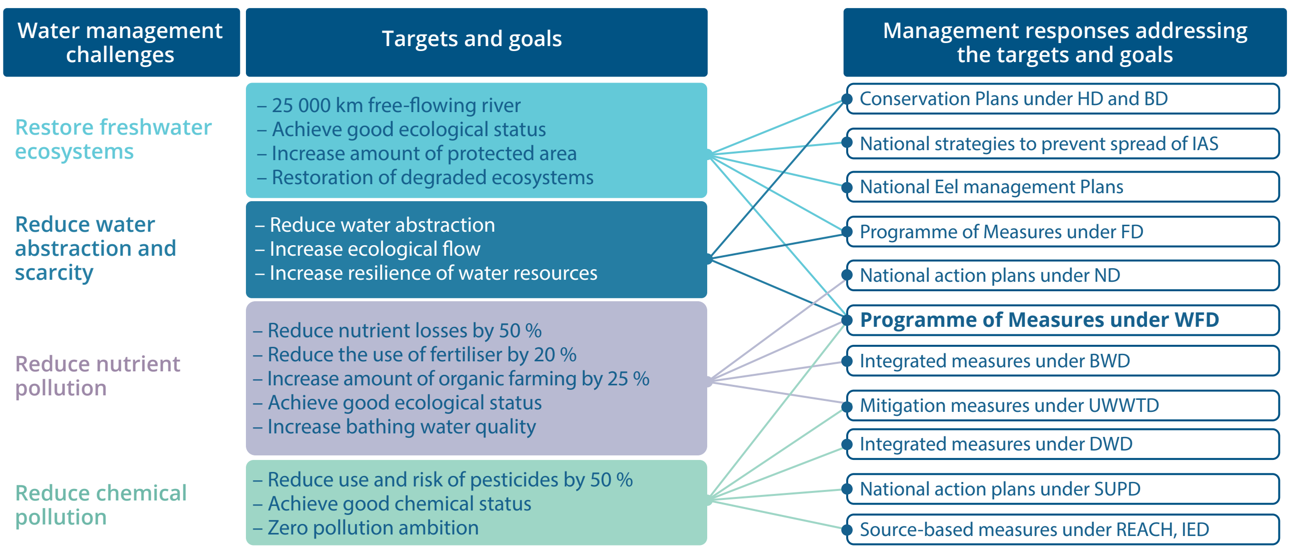
Catchment-based approaches, which encourage the integration of all water and land uses on a catchment scale, are also in line with the goals of European strategies. Good examples on a river basin scale are the international river commissions (e.g. the International Commissions for the Protection of the Rhine, Danube, Elbe and other rivers), in which EU Member States and other countries also are involved. Catchment-based approaches require engagement of and delivery by stakeholders at the catchment and local levels in coordination with responsible authorities. At the same time, engagement of all stakeholders in the catchment increases the likelihood that the measures implemented will be accepted. This is particularly important when trying to address multiple stressors for both water and land (DEFRA, 2013).

Land management and land use planning are essential for the management of water resources in water-scarce areas. Important wetlands, which help to store water, have been drained throughout Europe. One priority should be to retain rainwater where it falls, enabling water to infiltrate the soil surface, through the re-establishment of wetlands and increased recharge of aquifers. Investment in maintaining and increasing soil organic matter would enable soils to absorb more water, as would planning and regulating the crops grown within a river basin, including changing to crops better adapted to dry conditions or growing a range of crops that require water at different times of the year.

There are several EU water-related directives that require national action plans or implementation programmes to address specific issues for the protection of surface waters and groundwater. The implementation of those national plans with management solutions, such as the action plan to avoid water pollution with pesticides from agriculture, is a prerequisite to achieving European targets and goals, if their activities are adapted to the individual country conditions.

To sum up, key European water management challenges are addressed in the targets of EU strategies and policy initiatives, which are further operationalised in the management responses of the various water and environmental directives. Responses to tackle key water management challenges need to become more coherent and harmonised, and this is one of the ambitions of the European Green Deal. To achieve this, clear links need to be established between EU strategy targets and binding requirements for implementing environmental directives on the ground.

Figure 4.2 Overview of key European water management challenges, EU goals and targets, and management responses addressing the challenges



Notes: BD, Birds Directive; BWD, Bathing Water Directive; DWD, Drinking Water Directive; FD, Floods Directive; HD, Habitats Directive; IAS, invasive alien species; IED, Industrial Emissions Directive; ND, Nitrates Directive; SUPD, Sustainable Use of Pesticides Directive; REACH, Regulation on registration, evaluation, authorisation and restriction of chemicals.

4.3 Coherence of sectoral strategies with water policy objectives

European water bodies are used for a variety of economic activities, including navigation for trade and transport, agricultural and industrial processes involving water abstraction, hydropower production, extraction of minerals and aquaculture. From the assessment of their status and the pressures and impacts on European waters (EEA, 2018b), it is evident that the driving forces behind whether or not they achieve good status are economic sector activities. Recent policy reviews have shown that there is still much scope to further mainstream environmental policy actions into sectors to reduce the driving forces behind aquatic biodiversity loss (Rouillard et al., 2016). We need to ensure that economic sectors drawing on substantial water use adopt management practices that can keep water ecosystems healthy and resilient. Managing water in a green economy means using water in a sustainable way in all sectors and ensuring that ecosystems have both the quantity and the quality of water needed to function (EEA, 2018b).

Principles of sustainable water management have already been introduced in some sectoral activities, and the WFD has played an important role in taking up sustainability aspects. Several sustainable sector strategies have been developed in the last 10-15 years to promote the growth of a particular economic sector while drawing out a roadmap (or guidelines) for reducing the pressures and impacts of the sector's activities on water resources. The following good practice examples illustrate how sustainable water management solutions can work in sectors.

Agriculture represents one of the most water-intensive sectors. Excessive use of pesticides constitutes a source of diffuse pollution for water, while pollution from nitrates affects over 17 % of the area of groundwater bodies. The EU common agricultural policy (CAP) regulates the main aspects of agricultural production across Member States. In terms of water, Article 38 of the 2013 Rural Development Programme Regulation provides financial resources for agricultural activities to achieve compliance with the WFD and other environmental legislation. Recent reforms of the CAP have led to a general decoupling of agricultural subsidies from production and the implementation of a cross-compliance mechanism, whereby farmers must comply with a set of statutory management requirements, including those that relate to water management. A range of other measures to improve water quality have also been suggested in the CAP and national agricultural policies. These comprise increased manure storage, the use of cover crops, riparian buffer strips, wetland restoration and reduced use of pesticides in areas close to surface waters and groundwater infiltration hotspots. Overall, the water environment could benefit from more integration of water sustainability aspects in agricultural production (see Box 4.1). The combination of innovative technologies, such as drip irrigation, and financial incentives, such as water tariffs, could be beneficial in saving water in the European agricultural sector. In this way, private action can contribute to a more sustainable agricultural sector.

Mining can lead to groundwater and surface water chemical pollution, and it can also lower groundwater tables and disrupt flows. These pressures threaten the status of water ecosystems well beyond business operations, as the discharge of pollutants is longer than the mine's lifespan. Measures that can be taken to address mining impacts on water resources (e.g. treatment and reuse of excess water, use of chemicals with low environmental impacts, barriers and drainage systems to protect groundwater) generally constitute the bulk of best available techniques to be implemented by the extractive industry. Interventions and principles are laid out in the EU Directive on the management of waste from extractive industries (EU, 2006b), which obliges firms to issue an extractive waste management plan (EWMP) in their licensing and permit applications. Acknowledging the impacts of mining on water resources and considering measures to counteract these is now an integrated part of mining business activities (see Box 4.2).

Box 4.1 Restricting pesticide use and other sustainable farming initiatives

Belgium sets out different measures to integrate pesticides with sustainable water management (NAPAN, 2014). One focuses on restrictions in buffer zones, which are set at 2-30 m depending on the size of the water body and the extent of land use.

In France, economically-based measures have been set up. The French Agency for Food, Environmental and Occupational Health & Safety (ANSES) has implemented an ecophyto plan, which aimed to halve pesticide use by 2018. To that end, environmental taxes on sales of pesticides were introduced.

The United Kingdom implements a catchment-sensitive farming programme. The scheme investigates the impacts of agricultural practices and the relevance of applied measures and draws out best practices in the sector (Thorén, 2017).

In Ireland, farmers and growers are not allowed to apply organic or chemical fertiliser or dilute slurry when heavy rain is forecast within 48 hours or where the ground slopes steeply and a risk of water pollution exists (Amery and Schoumans, 2014).

Box 4.2 Acknowledging water and environmental aspects in the mining sector

In a brochure on water management, the European Aggregates Association acknowledges 'that any extraction of a mineral resource will potentially generate qualitative and quantitative impacts on water resources' and describes the sector's role in relation to river basin management planning, including limiting the impacts on water quantity and quality. In other publications, the European Aggregates Association focuses on gravel-processing sites and suggests different measures focusing on reducing the impacts on water, including recycling of process water (European Aggregates Association, undated).

In addition, Euromines, the European metals and minerals mining industry, promotes different activities in relation to sustainable development and environmental protection (Euromines, 2012). Euromines requires its members to perform an environmental impact assessment and to continuously update their effective environmental practices. However, the guidelines developed by Euromines call for environmental protection from exploration to mine closure, while the impact of mining on water ecosystems does not end with extracting operations (Euromines, 2012).

Energy production from hydropower installations also affects aquatic ecosystems by altering flows of water bodies, disrupting river continuity and causing degradation of ecosystems. Although most hydropower development in Europe has already taken place, new hydropower plants are being developed, especially in the Western Balkans, and many more (especially small plants) are at the application phase in other parts of Europe. To balance energy production with the protection of aquatic ecosystems, several strategies for more sustainable hydropower projects are being promoted in different countries and regions in Europe (see examples from Sweden, Switzerland and the Danube in Section 3.2.3). These give strategic directions for the revision of licences of existing hydropower plants and for the further development of new hydropower to mitigate or prevent hydropower affecting the water environment.

Sustainable **navigation** strategies and guidelines are being introduced at the EU, national and even regional/river basin levels (see examples of European guidelines and national or regional programmes and strategies for sustainable inland navigation in Section 3.2.4). These strategies and guidelines call for sustainable navigation across inland waters through a variety of cross-cutting criteria and measures. These include the preservation of river banks, stringent fuel standards, more efficient infrastructure to reduce navigation times and the coupling of waterways with external activities, such as sustainable tourism. At the same time, the Trans-European Transport Network (TEN-T) seeks to integrate inland navigation into sustainable means of transport in the EU by 2030 and calls for European navigable waterways to attain 'good navigation status' (GNS). Although the concept of GNS evolves, and guidelines for its achievement (Muilerman et al., 2018) are applied, further efforts are needed to ensure that the WFD's objectives of good ecological status or potential and the concept of GNS are coherent (CIS WFD, 2017).

Aquaculture affects water quality (through increased nutrient load and emissions of cleaning agents and medicinal products) and the hydromorphology of aquatic ecosystems. Aquaculture can also affect wild stocks if cultured organisms escape into the natural water environment. At the same time, aquaculture can also act as a catalyst for ecosystem balance, e.g. by retaining water in the landscape and buffering extreme rainfall patterns with drought and flood protection through large ponds (Jeffrey et al., 2014). Here, sustainability plans have great potential. The EU legislation in place aims to minimise the adverse environmental effects of aquaculture; for instance, the planning and development of new aquaculture operations must be in line with the Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) Directives. According to these directives, environmental concerns must be included early in the planning process to help avoid or minimise negative impacts. In terms of regulation, measures for the aquaculture sector include consistent licensing to include mitigation measures in a coherent framework, as well as developing a best practices protocol to ensure interoperability and clarity for aquaculture owners. Regulatory codes for monitoring and sustainable management practices (see Box 4.3) should follow, including the use of the latest water purification and monitoring technologies. Finally, aquaculture should be integrated into further spatial planning tools, especially in the light of RBMPs, and sufficient polluter-pays sanctions should be put in place. Aquaculture is a key component of both the common fisheries policy and the blue growth agenda to support sustainable growth in the sector; therefore, further coherence of their targets with EU water policy objectives needs to be achieved.

Box 4.3 Code of good practice for aquaculture in Scotland

The Scottish Salmon Producers Organisation has approved a code of good practice for finfish aquaculture to couple production with health and sustainability aspects. The organisation has committed to sustainable development practices in aquaculture, ranging from the sustainable use of the natural heritage to the sustainability of feed ingredients. One of the main targets of the code is minimising the environmental impact of aquaculture sites in the Scottish environment, including freshwater and seawater lochs and tanks. The code is audited by independent auditors, which ensures compliance with reliable sustainability standards (Scottish Salmon Producers' Organisation, 2020).

Policies and strategies that define operations and give directions for further growth of sectoral activities play a key role in ongoing and future developments that affect European waters. Despite different priorities and investment cycles, over the past 15 years many sectors have made attempts to acquire up-to-date knowledge and act on environmental aspects, including by implementing sustainable water resource management. This development was partly set in motion by regulation and, to a certain extent, by private initiatives. Some private businesses, for instance those in the Scottish aquaculture industry (see Box 4.3) or those that are part of the European Mining Association (see Box 4.2), have incorporated sustainability in their codes of practice. Economic instruments, such as a pesticide tax in France and an electricity surcharge to fund sustainable hydropower in Switzerland, further represent a relevant trend. New technologies used in specific sectors have also helped, e.g. drip irrigation to reduce pressure on scarce water resources. More initiatives of this kind are needed across all key sectors that have an impact on water resources. In particular, a consistent combination of multiple policy tools from the WFD, the CAP and the energy and climate package is required.

Water sustainability elements brought into sectoral strategies need to be consistently enforced and implemented on the ground. However, in some cases, not enough information is available on the extent to which sustainability aspects are being implemented. Enhanced resources for enforcement, capacity-building and incentives to transition towards sustainable business models are needed, especially at the local level. Cooperation at the local, national and EU levels is needed for the exchange of best practices and sustainable technologies, so that Member States can fully embrace the sustainable water management transition.

4.4 Funding of measures

Measures to tackle key pressures and impacts, which lead to failure to achieve the WFD's objectives, can only be carried out with sufficient funding. Adequate financing of WFD measures is as essential for fulfilling the goals of the directive as administrative and technical capacity, scientific knowledge and political willingness. Funding obstacles have been identified as the most common reason for delaying or not completing the implementation of supplementary measures in the first programmes of measures; this is also one of the key reasons for delays in or non-completion of basic measures at the EU level (EC, 2019a).

The sources of funding for WFD measures are a combination of EU, national, regional and municipal funds and direct financing by sectors and the public as consumers. For financing measures in the RBMPs, the WFD relies to a certain extent on the **recovery of the costs of water services** (WFD, Article 9), especially through the water prices charged. Box 4.4 presents the example of the 'water cent' in Germany, which is an additional charge levied on groundwater abstraction and which is used to fund pollution reduction measures in agriculture. In France, the river basin agencies (*agences de l'eau*) collect water abstraction and discharge charges from water users in a given river basin and allocate those funds as grants to water users in the same basin. Most of these funds initially financed piped water and the expansion and improvement of the sewerage network, as well as investments in waste water treatment plants. In 2016, the French river basin agencies received an additional mandate through the biodiversity law, which requires that they also fund projects with a climate adaptation and biodiversity focus (Trémolet et al., 2019). In Denmark, fish care management is financed by funds from Danish fishing licence fees and includes activities such as improving the living conditions and habitats of fish (Danish Fisheries Agency, 2020). Similar schemes are found in other European countries.

Box 4.4 'Water cent' in Germany

Of the 16 German federal states, 13 have introduced the water cent as a charge for water abstraction from surface water and groundwater (UBA, 2012). The first federal state to introduce the water-cent did so in the late 1980s, while several other states followed after the adoption of the Water Framework Directive (WFD) in 2000 (Vollmer et al., 2018). The objective of this instrument is, on the one hand, to encourage the conservation of precious water resources. On the other hand, the collected surcharges have mainly been used to compensate farmers for reducing their use of nitrogen and pesticides to reduce pollution levels in key drinking water sources. In at least one federal state, however, plans have been announced to use the revenue from the water cent (the cost of which was recently increased) for flood protection measures as well (Südwest Presse, 2018).

For several decades now, a large part of the funding available for water resource management has been invested to improve water quality through investments in the sewerage network and waste water treatment. In a recent study, the Organisation for Economic Cooperation and Development (OECD) estimated that all EU countries together spend on average EUR 100 billion per year on water supply and sanitation (OECD, 2020). This needs to increase to meet compliance with the UWWTD and the Drinking Water Directive. The total cumulative additional expenditure by 2030 for water supply and sanitation amount to EUR 289 billion for the EU Member States and the United Kingdom. The main sources of finance for water supply and sanitation expenditure in the EU are revenues from water tariffs, taxes and EU funds. Some countries rely heavily on EU funding, which is bound to decrease over time, and these countries will need to find new financing sources. When assessing Member States' capacity to finance the water sector, it will be difficult for some to increase the levels of public budgets allocated to water supply and sanitation. Although affordability constraints are mentioned to justify tariffs below cost recovery levels, data show that, in most EU Member States, more than 95 % of the population could afford to pay more (OECD, 2020).

Concerning EU funding sources targeting the WFD, it is worth noting that the WFD does not have its own specific EU funding for implementation, and that it is instead integrated into the budget of the EU LIFE financing instrument for environment and climate (Carvalho et al., 2019). LIFE funding amounted to EUR 3.4 billion for the period 2014-2020. As a result of this vast difference in EU funds, the success of implementation of EU water policy is highly dependent on using financial instruments in other sectoral policies, or 'water-mainstreaming', as well as on national funding. A common approach to water-mainstreaming has been to establish standards and certification schemes to promote best practice technologies or best management practices (e.g. the Industrial Emissions Directive, IED). Recently, environmental safeguards and economic incentives were introduced in EU Structural and Investment Funds, including the European Agricultural Fund for Rural Development (EAFRD), the Cohesion Fund and the Regional Development Fund, in a drive to reduce the environmental impact of economic development (Carvalho et al., 2019).

In this context, it becomes important to understand the **synergies between water policy and other policy areas**. In the CAP (reform 2014-2020), there are, for example, various instruments to improve sustainability (also in terms of EU water policy objectives): cross-compliance, which links certain CAP payments with specific environmental requirements, the green direct payment scheme, which rewards farmers for respecting three obligatory agricultural practices with potential indirect impacts on water quality (maintenance of permanent grassland, ecological focus areas and crop diversification), and rural development, which provides financial incentives for actions going beyond compulsory legislation (EC 2013).

Funding options from other policy areas are also of relevance to hydromorphological measures, such as the removal of barriers for re-establishing river connectivity, which can be funded in various ways, such as through the European Fisheries Fund (EFF). It may fund measures relevant to the rehabilitation of inland waters, including spawning grounds and migration routes for migratory species. In some countries, there are specific schemes funding the removal of barriers that serve a specific sector. In Denmark, for instance, many weirs were built for fish farming facilities. Removing a weir at a fish farm means that the farmers must change their entire water circulating system at a cost (from a flow-through to a recirculated system). To support fish farm weir removal on Danish streams and rivers, a governmental finance support scheme was set up (AMBER Consortium, 2021).

Furthermore, the new biodiversity strategy for 2030 envisages that at least EUR 20 billion a year should be unlocked for spending on nature (EC, 2020b). As the new biodiversity strategy for 2030 includes specific aims for water ecosystems (e.g. at least 25 000 km of rivers to be restored into free-flowing rivers by 2030 and restoring degraded ecosystems), part of the forthcoming funding sources should be invested in water-related measures.

Overall, there is a need to explore these issues in depth and effectively communicate further policy synergies that can be used to increase the scope of funding for WFD measures. For instance, there is potential for more funding synergies with the rural development programmes (which link to land use and planning issues) and the green infrastructure strategy (which links to the development of infrastructure in urban or rural settings). Urban rivers and lakes, especially, are often the target of combined aquatic ecosystem restoration and green infrastructure for reducing flood risk, thereby also securing funding from multiple sources (EEA, 2016b).

As previously noted, **national funding** also plays a significant role in funding WFD measures. In many countries, the first RBMPs were an opportunity to set up **coordinated programmes** to fund hydromorphological measures, which were among the measures specifically requested by the WFD for the first time. Examples of such national programmes include the following:

- In Scotland, the Water Environment Fund was set up to improve the physical condition of water bodies to meet WFD objectives (Box 4.5).
- In Finland, the national fish pass strategy was adopted in 2012 to steer the construction of fish passages during the first three periods of water management planning up to the end of 2020 (Vehanen et al., 2015).

- In Ireland, an environmental river enhancement programme was developed between 2008 and 2012 that dealt in part with enhancing river morphology (O'Grady et al., 2013).

- In Germany, the blue ribbon programme was adopted to promote the renaturalisation of watercourses and natural floodplains in secondary waterways in particular. The programme (see also Section 3.2.4) started in 2017 and will run until 2050. It is estimated that, for only half of the priority restoration options to be carried out on waterways, a budget of EUR 50 million/year would be required (BMVI and BMU, 2018).

Overall, however, public funds alone will not be sufficient to support the large number of measures needed to achieve the WFD's goals. Thus, **innovative financing mechanisms** are needed, and some have already been set up in European countries. For example, in Sweden, an industry fund (Hydropower Environmental Fund) was set up in 2019 to fund mitigation measures in the hydropower sector related to the country's new national plan for the revision of hydropower licences in the next 20 years (SWAM, 2019). The fund consists of contributions from all of the main hydropower producers in the country and will support mitigation measures at hydropower plants that could not otherwise afford this type of interventions.

In addition, the EU has been developing standards to further link financial investment with environmental protection (see the action plan for financing sustainable growth (EC, 2018a)), which could restrict investment in sectors that cause impacts on water bodies (e.g. transport, energy production). Building on the 2018 action plan, the EU's renewed sustainable finance strategy-will provide a roadmap with new actions to increase private investment in sustainable projects to support the different actions set out in the European Green Deal and to manage and integrate climate and environmental risks into our financial system (EC, 2020d).

All in all, as adequate financing of measures is essential for fulfilling the goals of the WFD, it is key to mobilise, as far as possible, additional funding from EU, national and other sources. EU funds targeted at WFD measures are limited; therefore, the success of implementation depends on identifying synergies and financing opportunities with other policy areas, including sectoral ones (e.g. agricultural policy, fisheries policy, biodiversity policy). Furthermore, public funds (EU and national) need to be complemented with other innovative financing mechanisms, especially those that involve industrial and other private sector partners.

Box 4.5 The Water Environment Fund in Scotland

The aim of the Scottish Government's Water Environment Fund (SEPA, 2021) is to improve the physical condition of water bodies to meet the objectives of the Water Framework Directive (WFD). The programme also aims to bring wider benefits to designated nature conservation sites, local fisheries and angling opportunities, community amenity and urban green space.

Launched in 2008, the Water Environment Fund provided funding of more than GBP 14 million (EUR 16.3 million) between 2013 and 2018 around the country. It is administered by the Scottish Environment Protection Agency, which works in partnership with local authorities, land managers, fishery trusts and angling associations, local communities and volunteers. One of the objectives of the programme is to build a greater understanding of the benefits of river restoration in Scotland and the techniques available to achieve it.

The programme has led to river channel restoration (including remeandering), floodplain afforestation, the removal of flood embankments, wetland and peatland restoration, the removal of culverts and barriers to fish migration, and the elimination of non-native species along river banks. The fund also promotes catchment-scale restoration and explores synergies with natural flood management.

Source: SEPA (2021).

4.5 Measures with multiple benefits

Measures with multiple benefits can be understood as actions that are beneficial to the achievement of the environmental requirements of more than one policy instrument or to the improvement of one or more ecosystems (e.g. groundwater, surface waters, floodplain, soil). Furthermore, their combined effect can lead to improved functioning of ecosystem services, for example self-purification, water storage or nutrient sequestration, and recreation.

Several water management measures can deliver multiple benefits, such as river and floodplain restoration, integrated freshwater and coastal zone management, or projects such as 'Room for the River' (see Box 4.6). Buffer strips can also deliver multiple benefits by reducing nutrient input by erosion in surface waters and, on a larger scale, reducing nutrient input into marine waters as well as increasing terrestrial biodiversity. Extensification of land use reduces nutrient and pollution inflow into soil and groundwater, improves the local hydrological regime, avoids the impacts of droughts and makes the landscape more pleasant for recreation. Furthermore, water saving and conservation bring additional benefits by ensuring sufficient water for environmental needs and reducing pollution discharges and energy use.

Multi-benefit measures are also related to source reduction approaches. Within European strategies, such as the Eight Environment Action Programme, the biodiversity strategy or Farm to Fork strategy, the goals are sustainable resource efficiency and integrated nutrient management. Certain multi-benefit measures combine pollution reduction with the reuse of resources, for example the reuse of phosphorus retained in waste water or sewage sludge and their use in agriculture. This is also in line with the goals of the European Green Deal on circular economy actions.

Management measures that work with nature, and not against it, often result in a win-win situation. Multi-benefit measures serving nature conservation and water policy objectives (from the WFD) can be related to the protection of aquatic species listed in the annexes of the Habitats Directive, such as the sturgeon, the eel or the salmon, which have high protection status. A prerequisite for such migratory fish species is longitudinal continuity of rivers and connection to the sea. In addition, this is in line with the targets of the Eel Regulation (EC, 2007) and the target of the new biodiversity strategy to achieve 25 000 km of free-flowing rivers by 2030. Multi-benefit measures to restore longitudinal continuity of rivers for migratory fish species are, for example, the removal of dams and obstacles. To also ensure their reproduction in rivers and streams, habitat improvement is crucial by, for example, focusing on sediment improvement to restore spawning grounds.

Natural water retention measures (NWRMs) can be used as measures to meet the requirements of the WFD, the Floods Directive and climate adaptation. According to EC (2014) 'Natural Water Retention Measures (NWRM) are multi-functional measures that aim to protect and manage water resources and address water-related challenges by restoring or maintaining ecosystems ...'. In a recent EU project, about 45 NWRMs with multiple benefits for urban areas, forests, rivers and agricultural areas were identified and linked to ecosystem service benefits; they were also illustrated in several European case studies (NWRM project, 2021).

A multi-benefit measure that is increasingly acknowledged for its importance is the restoration of floodplains, which can both reduce flood risk and improve the ecological and quantitative status of waters. Natural floodplains act as water retention systems and support the ecological flow. Measures to restore floodplains can contribute to achieving many objectives, including the good status objective of the WFD and national water policies (EEA, 2010).

Nature-based solutions aim for, for example, multi-functional nature-based catchment management and ecosystem restoration. A list of some 300 different nature-based measures and their linkage to ecosystem services shows how diverse the use and their applicability can be in several sectors, such as flood protection, climate change adaptation, sustainable urban development and water management (Sutherland et al., 2014).

In addition to establishing linkages between the WFD, the Floods Directive and nature conservation policy, measures with multiple benefits can also contribute to linking to the Marine Strategy Framework Directive (MSFD) (EU, 2008). This is mainly because of the planning and implementation of measures as part of the RBMPs to improve water quality in coastal areas and for the benefit of the marine environment. In the second RBMPs, some 70 % of all river basin districts reported a link between the WFD and the MSFD; they also indicated a large number of measures listed under the WFD as also relevant for reaching the objectives of the MSFD, in particular measures to reduce nutrient pollution from both diffuse and point sources and the reduction of hazardous substances (EC, 2019a).

Overall, a wide variety of multi-benefit measures are already available. They can help improve and coordinate the achievement of objectives across policies and can also mobilise diverse sources of funding for measures. Multi-benefit measures are suitable to shift the focus of management from single-issue solutions towards an approach based on protecting and re-establishing various ecosystem services to effectively address key European water management challenges.

Box 4.6 Room for the river in the Netherlands

One example of implementing nature-based solutions in the context of improving risk management and the resilience of aquatic ecosystems is the 'Room for the River' programme in the Netherlands. The strategy developed focuses on making more space for water to improve flood prevention by lowering high-water levels and to improve the spatial quality of the area, reconnecting people and rivers. Several projects were carried out at 30 locations in the Netherlands; these included relocating dykes, constructing high-water channels and lowering floodplains (Dutch Water Sector, 2019). For example, in the city of Nijmegen a 350 m-long dyke was relocated and an ancillary channel was built. This project offers multiple benefits, including reducing the water level by 35 cm; it also brings new potential for the development of the city by creating an urban river park with potential for recreation and nature (EC, 2015). The total costs for this project were EUR 360 million.

Abbreviations

Abbreviation	Name
BOD	Biological oxygen demand
CAP	Common agricultural policy
DOC	Dissolved organic carbon
EASIN	European Network on Invasive Alien Species
EEA	European Environment Agency
EFF	European Fisheries Fund
E-PRTR	European Pollutant Release and Transfer Register
EU	European Union
EWD	Extractive Waste Directive
EWMP	Extractive waste management plan
FRMP	Flood risk management plan
GNS	Good navigation status
IAS	Invasive alien species
IED	Industrial Emissions Directive
MSFD	Marine Strategy Framework Directive
NBS	Nature based solutions
NWRM	Natural water retention measure
PAH	Polycyclic aromatic hydrocarbon
PFASs	Per- and polyfluoroalkyl substances
RBMP	River basin management plan
TEN-T	Trans-European Transport Network
UWWTD	Urban Waste Water Treatment Directive
WFD	Water Framework Directive
WISE	Water Information System for Europe

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