European Environment Agency

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

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Executive summary (2 pages)

Key management challenges for European waters in particular related to the degradation of freshwater ecosystems, pollution from chemicals and nutrients as well as water abstraction and scarcity are addressed by different EU strategies and policies, which are further operationalized in management responses of water and environmental 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, such as the new Biodiversity Strategy 2030, the Farm to Fork Strategy, the Chemicals Strategy for Sustainability and the forthcoming Zero Pollution Action Plan. The ambitious targets of these strategies address main pressures on European waters, such as disrupted river continuity by aiming to restore 25,000 free flowing rivers by 2030 or the high nutrients and chemicals discharge from agriculture aiming to reduce by 50% the loss of nutrients and the use and risk of pesticides.

A key source of information for defining key management challenges for European freshwaters are 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 being under significant pressures on their hydromorphology, pressures from diffuse and point sources of pollution and water abstraction.

The present report aims to give a European overview of the main drivers and pressures that are at the core of key water management challenges and put European water bodies most at risk of achieving key environmental objectives. Identifying the pressures and drivers of key water management challenges at European level can help in shaping priorities of the main issues that should be tackled with measures.

Based on the analysis of significant pressures and drivers affecting water bodies in the latest RBMPs, ten European key water management challenges have been selected to be presented. Next to describing the main sources and sectoral activities behind key pressures and the main associated impacts, a summary is provided of key measures which are available to tackle these challenges in European countries. Most of the selected pressures and drivers with regard to pollution, hydromorphology and abstractions affect a large share of European water bodies and are reported by a large number of countries. Some others such as mining, navigation, aquaculture and invasive alien species seem to affect a small share of European water bodies, but they can be of high importance and intensity in specific regions of Europe, thus significantly contributing to the failure of achieving good water status on a regional level. The table below summarises the European key water management challenges presented in the report.

Pressure/sector/activity	European water bodies affected in second RBMPs	Impacts (summary)	Measures and management challenges (summary)
Pollution: **Point source** (urban wastewater, 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 Potential risks from microplastics	Installation and enhancement of sewers and treatment to reduce pollution from urban waste water and industry (UWWTD) Reduction at source Storage and treatment of storm waters to reduce overflows

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Pressure/sector/activity	European water bodies affected in second RBMPs	Impacts (summary)	Measures and management challenges (summary)
			Emerging pollutants: Enhanced treatment
Pollution: **Diffuse source** with nutrients, chemicals (agriculture, atmospheric deposition)	22 % of surface water bodies 30 % of groundwater area	Eutrophication and algae blooms impacting biota Groundwater nitrates affects drinking water quality Pesticides threats on 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 (incl. Nitrates Directive) New Integrated Nutrients Management Strategy Implementation of the revised CAP, financing instruments Measure against air pollution (incl. Industrial Emissions Directive)
Pollution: **Non-connected dwellings**	10 % of surface water bodies 7.5 % of groundwater area	Loads of disease-causing organisms impacting human health Local oxygen depletion Nutrient input leading to eutrophication and oxygen depletion	Connection to waste water systems or local treatment Need to further harmonise WFD & UWWTD to tackle issue Homeowner responsibility and enforcement, including exploring obligation to connect where there is a centralised collection system.
Pollution: **Mining**	7.5% of groundwater area < 1% of surface water bodies Reported in 17 WFD countries as point or diffuse source pressure	Changes in surface and groundwater hydrology Sediment load Acidification Altered in-stream habitat and morphology	Site adapted measures to reduce mining pressures to hydrology and quality Rehabilitation of abandoned mining sites Need for more synergies between WFD and 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	Restoration measures Strategies for restoring continuity / prioritisation Removal of artificial structures such as 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 morphology dynamics and sediment supply Impacts on nutrient cycling	Floodplain and river restoration measures Multi-benefit measures More systematic inclusion of floodplain restoration in RBMPs/FRMPs Targeted financing for floodplain restoration
Hydromorphological pressures: Hydropower	6 % of surface water bodies	Interruption of river continuity and impacts on migrating fish	Various mitigation & restoration measures

Pressure/sector/activity	European water bodies affected in second RBMPs	Impacts (summary)	Measures and management challenges (summary)
		Altered sediment transport Changed flow regime with morphological and also ecological effects Altered physicochemical conditions Cumulative effects	Strategies for sustainable hydropower Permit/licensing system Construction of new hydropower plants
Hydromorphological pressures: Navigation	< 1 % of surface water bodies but of high importance 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/guidelines for sustainable inland navigation Mitigation of impacts from prolongued periods of low water
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 Heating at power plants Lowered groundwater levels Salinization of aquifers	Demand-side measures Supply-side measures Permit/licensing systems Water pricing Measures for illegal abstractions 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) Lack of explicit obligations for aquaculture under WFD, MSFD
Invasive alien species (IAS) (aquaculture, pet/aquarium species, shipping fisheries/angling)	2 % of surface water bodies but already reported as significant pressures in 15 WFD countries	Altered biota communities Impacts on food webs Constraint on recovery of native biodiversity Change of genetic behaviour of natural populations	Prevention, early detection & rapid eradication, management measures Few measures so far in RBMPs National strategies for IAS Need of cross-linking management efforts under IAS Regulation, WFD, MSFD

A broad range of technical and management measures are already available to tackle the selected European key 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 European key 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, in particular 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.

The use of multi-benefit measures, such as water retention measures, nature based solutions or land use change measures is an effective solution for coordinating management responses and to meet the objectives of different EU policies that target water ecosystems. Enhancing the use of multi-benefit measures can help to shift 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.

Second, 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 or national level, 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.

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

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 of the European Green Deal.

The European Green Deal adopted in the end of 2019 (EC 2019b) set a new milestone in European environmental policy and 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 in terms of restoring ecosystems, reducing pollution from different sources and using resources more efficiently. At the same time, many actions are ongoing and further efforts needed across Europe to achieve the objective of the Water Framework Directive (WFD) in terms of achieving good status of all bodies of surface water and groundwater at the latest by 2027. In this context of existing but also new policies, European countries are called to address a number of key water management challenges, in particular related to the degradation of freshwater ecosystems, pollution from chemicals and nutrients as well as water abstraction and scarcity.

1.1 Aims of this report

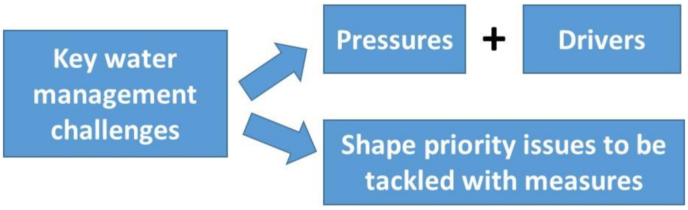
This report builds on the EEA assessment of 2018 of the status and pressures of European waters (EEA, 2018)[1]. In its 2018 assessment, the EEA concluded that European waters remained under significant pressures linked to changes in their hydromorphology, pressures from diffuse and point sources of pollution and water abstraction and that limited progress was noted in improving water status from the first to the second planning cycle of the WFD. The pressures on European waters often act at the same time and affect the good functioning of ecosystems, contribute to biodiversity loss and threaten the valuable benefits that water brings to society and the economy. However, no detailed presentation of the main drivers and pressures causing less than good status of EU water bodies was made in the 2018 EEA assessment. The present report takes the 2018 presentation of water status and pressures one step further and aims at giving a European overview of the main drivers and pressures that are at the core of key water management challenges at 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 achieving the WFD environmental objectives. The presentation of these European key water management challenges aims at improving our understanding of the main sources and sectoral activities behind key pressures and the main associated impacts. In addition, a summary is provided of key measures which are available to tackle these challenges across the majority of European countries and of management issues of EU-wide relevance.

Identifying the pressures and drivers of key water management challenges at European level can help in shaping priorities of the main issues that should be tackled with measures especially in the River Basin Management Plans (RBMPs) under the WFD (**Fejl! Henvisningskilde ikke fundet.**). The identification of European key water management challenges can also support later assessments 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.

[1] EEA, 2018, European waters – assessment of status and pressures 2018.

Figure 1 European key water management challenges



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

- **Pollution pressures** – includes point source pollution, diffuse source pollution including scattered dwellings and pollution pressures from mining,
- **Hydromorphological pressures** – includes issues related to barriers, loss of lateral connectivity, pressures from hydropower and pressures from inland navigation,
- **Abstractions and water scarcity**,
- **Aquaculture**, and
- **Invasive alien species**.

European key water management challenges were selected that affect a sufficiently large share of European water bodies and that were long time important enough to develop a rather solid basis of knowledge and information to describe the scope of the issue at European level (see section 3 for more information).

This EEA report also discusses cross-cutting issues of EU-wide relevance to measures implementation for addressing the main drivers and pressures of European key 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 for European waters. The European Commission published in 2019 the evaluation of water legislation – the Fitness Check and this provides the main directions for revisions and future water policies[2].

1.2 Policy context

The key aspects and aims of the European Green Deal are shown in Figure 2**Fejl! Henvisningskilde ikke fundet.Fejl! Henvisningskilde ikke fundet.**. The 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 (EC, 2020b) and a Zero Pollution Action Plan. The targets of these strategies are expected to have far-reaching impacts on several European key water management challenges presented in this report. Further EU strategies with

[2] European Commissions, EU Water Legislation - Fitness Check https://ec.europa.eu/environment/water/fitness_check_of_the_eu_water_legislation/index_en.htm

high-level targets for water are the 8th Environmental Action Program, but also the implementation of the Sustainable Development Goals (EC 2016) (see Table 1).

Figure 2 Key aspects and aims of the European Green Deal

Source: Communication from the European Commission on the European Green Deal (EC 2019b)

Table 1 Overview of EU policies and strategies and key targets related to water

EU Strategy	Key targets related to water
Green Deal (EC 2019b)	Roadmap with actions until 2050 to boost the efficient use of resources by moving to a more circular economy and stop climate change, revert biodiversity loss and cut pollution
Farm to Fork Strategy (EC, 2020d)	- 50% reduction of use and risk of pesticides - 50% of nutrient losses - 20% reduction of the use of fertilizer - 50% reduction of the use of antimicrobials - 25% to increase the amount of organic farming
Biodiversity Strategy for 2030 (EC, 2020a)	- 30% of EU land and sea protected, a third of which under 'strict protection' - No deterioration of any protected habitats and species by 2030: trend to be positive for at least 30%. - >10% to increase biodiverse landscape features - Increased efforts to restore freshwater ecosystems and the natural functions of rivers - Restore at least 25,000km free flowing rivers - removal of primarily obsolete barriers and restoration of floodplains and wetlands

	- Member States 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 Water Framework Directive to be met by 2027 - 50% reduction of use and risk of pesticides - Reduction of pollution from fertilizers by 50% and by 20% their use - Enabling actions to transformative change such as promotion of Nature-Based Solutions
Chemicals Strategy for Sustainability – Towards a Toxic-Free Environment (EC, 2020a)	- Banning the most harmful chemicals - Account for the cocktail effect of chemicals - Phase out per - and polyfluoroalkyl substances (PFAS) - Boost for production and use of chemicals that are safe and sustainable by design throughout their life cycle - Promote EU's resilience of supply and sustainability of critical chemicals
Zero Pollution Action Plan	- *Will be developed in the next two years* (EC, 2019) -
A new Circular Economy Action Plan (EC 2020)	- Focus on the sectors that use most resources, such as plastics, water and nutrients
Climate Adaptation Strategy (EC 2013)	- Reduce water abstraction - Increase water retention - To make water resources more resilient to climate change
8th Environmental Action Program (EAP) (EC, 2020e)	- Pursuing a zero-pollution ambition for a toxic free-environment, including for air, water and soil - Protecting, preserving and restoring biodiversity and enhancing natural capital, notably air, water, soil, and forest, freshwater, wetland and marine ecosystems - Integrated assessments on the Floods Directive, Urban Waste Water but also Nitrates Directive and integration of freshwater and marine ecosystem-based approach in the economic transition - Full use of nature-based solutions
Sustainable Development Goals (SDGs)	Goal 6 Ensure availability and sustainable management of water and sanitation for all: - Improve water quality by reducing pollution - Substantially increase water use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater - Implement integrated water resources management at all levels, including through transboundary cooperation as appropriate - Protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

The targets and actions in the above EU strategies are in general implemented via specific environmental directives and policies such as the WFD, Floods Directive, Habitats and Birds Directives, but also Directives related to specific issues, like the Urban Waste Water Treatment Directive (UWWTD), the Nitrates Directive or the Sustainable Use of Pesticides Directive. The water-related contributions of these directives to the EU strategies are briefly described in the following.

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 above-mentioned targets and goals and is therefore key for water management. In 2009, EU Member States published the first and, in 2015, the second river basin management plans (RBMPs) for achieving the environmental objectives of the WFD. At present, EU Member States are finalising the third RBMPs to be published in 2021 that 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 WFD and assessments of the latest 2nd RBMPs are available in the European Commission's 5th WFD implementation report published in 2019[3]. The Commission also evaluates the Programmes of Measures foreseen to be implemented during the 2nd RBMP period (2016-2021) both at European and national level. EU Member States reported in December 2018 the progress in implementing measures and the Commission evaluation of the progress will be published within 2021.

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

Targets for the restoration of aquatic ecosystems are also considered by the Habitats Directive (EEC 1992), aiming at the conservation of rare habitat types and threatened or endemic animal and plant species, and the Birds Directive (EEC, 1979) on the protection of 500 wild bird species including their respective habitats in form of protected areas. These areas are part of the Natura 2000 network set up in the Habitats Directive.

The Urban Waste Water Treatment Directive (UWWTD) (EU 1991a) specifically addresses the reduction of nutrient and chemical pollution to waters. Other Directives and legislations related to chemicals in waters are the REACH Regulation (EU 2006b) on registration, evaluation, authorisation and restriction of chemicals and the Directive on industrial emissions for integrated pollution prevention and control (IED). Furthermore, the Nitrates Directive (EU 1991b) as well as the Directive on the sustainable use of pesticides (EU 2009) aim to avoid nutrient and chemical pollution from agriculture into soil and waters and 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) and the Eel Regulation support targets of the EU Biodiversity Strategy. The Bathing Water Directive (EU 2006a) and the Drinking Water Directive (EU 1998) set quality standards for waters, relevant for human health. For safe use, sources of pollution on a catchment scale need to be considered. However, a link to directives addressing chemical or nutrient pollution (see above) is crucial.

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

1.3 Structure of report

Section 2 recaps the key findings of the 2018 EEA assessment of status and pressures of European waters. The results of the 2018 assessment have been updated to include reporting information from more countries (28 Member States plus Norway) compared to those assessed

[3] European Commissions 5th Water Framework Directive implementation report https://ec.europa.eu/environment/water/water-framework/impl_reports.htm

in 2018. Section 2 thus presents an updated summary of the information published by the EEA in 2018 (which was based on 25 Member States).

Section 3 presents the drivers and pressures of selected European key water management challenges giving an overview of each issue in Europe, the main impacts on water ecosystems and key measures available to tackle the issue. Section 3 also briefly explains how the European 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 section 4, the report discusses certain cross-cutting issues of EU-wide relevance to measures implementation for addressing European key 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 and
4. the role of multi-benefit measures.

2 Status and pressures of Europe's waters in 2nd RBMPs

In 2019, the European Commission published its report on the assessment of the second RBMPs (EC, 2019a,b), including detailed analysis of Member States' programmes of measures, as well as 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 water (EEA, 2018)[4]. In addition, the Water Information System for Europe (WISE) WFD visualisation tool presents more, and more detailed, results[5].

This chapter is an updated version of part of the executive summary[6] of the EEA 2018 report on the state of Europe's water. While 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 below on water status and pressures cover EU28 Member States[7] and Norway. Throughout this report, the term *WFD countries* has been used to cover the countries that implement the WFD: the 27 EU Member States, Norway and United Kingdom.

2.1 Improvements in monitoring and assessment

With the second RBMPs, the quantity and quality of the available evidence on status and pressures has grown significantly. Many Member States and river basin districts (RBDs) 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, like pollution, habitat degradation, hydrological changes and others 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 in good or high ecological status or potential, with lakes and coastal waters having better status than rivers and transitional

[4] https://www.eea.europa.eu/publications/state-of-water

[5] https://www.eea.europa.eu/themes/water/european-waters/water-quality-and-water-assessment/water-assessments

[6] More detailed information is available in the 2018 EEA report and the WISE Freshwater WFD visualisation tool.

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

waters[8]. There has been limited change in ecological status since the first RBMPs were reported, although this comparison is difficult to make since the data underpinning the 1st RBMPs was of much lower quality than the data for the 2nd 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 has improved from the first to the second RBMPs.

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. In the second RBMPs, 31 % of surface water bodies are in good chemical status, while 35 % have not achieved good chemical status and for 34 % their status is unknown[9].

In many Member States, relatively few substances are responsible for failure to achieve good chemical status. Mercury causes failure in a large number of water bodies. If the widespread pollution by ubiquitous priority substances, including mercury, is omitted, the proportion of water bodies in good chemical status increases to 64 %, with 3 % that have not achieved good status and 34 % whose status is unknown[10]. 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 (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 sources (33 %), particularly from agriculture and atmospheric deposition, particularly of mercury (31 %), followed by point sources (15 %) and water abstraction (6 %)[11]. The main impacts on surface water bodies are nutrient enrichment, chemical pollution and altered habitats due to morphological changes.

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[8] Compared to the results in EEA (2018) there is an increase in the proportion of surface water bodies with high or good ecological status (from 40 % to 44 %) due to better than average ecological status in the extra included countries (Greece, Ireland, Lithuania and Norway). See also https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_Status_Compare/SWB_EcologicalStatus_Category?:embed=y&:isGuestRedirectFromVizportal=y&:display_count=n&:showAppBanner=false&:origin=viz_share_link&:showVizHome=n

[9] Compared to the results in EEA (2018) there is a marked increase in the proportion of surface water bodies with unknown chemical status (from 16 % to 34 %) due to nearly all surface water bodies in Norway and Ireland having unknown chemical status. The high proportion of unknown status reduces the percentage in good or failing to achieve good chemical status. See also https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_SWB_SWPrioritySubstanceWithoutUPBT/Category?:embed=y&:display_count=n&:showAppBanner=false&:showVizHome=n&:origin=viz_share_link

[10] The high proportion unknown status also reduces the proportion in good chemical status from 81 % to 64 %.

[11] Compared to the results in EEA (2018) there is a decrease in the proportion of surface water bodies affected by the listed pressures (between 3 to 7 percentage points), because of better status and less pressures in the extra included countries (Greece, Ireland, Lithuania and

2.3 Groundwater: Status and pressures

The WFD requires Member States to designate separate groundwater bodies and ensure that each one achieves 'good chemical and quantitative status'[12]. 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 reduced 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 intrusions.

In the EU, 75 % and 90 % of the area of groundwater bodies, respectively, is in good chemical and quantitative status[13]. 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.

2.4 Overall progress since the first RBMPs

Overall, the second RBMPs show limited change in all four measures of status[14], as most of the water bodies had the same status within both cycles. However, fewer water bodies with unknown status increased both the proportion with good status and the proportion with less 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[15] 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.

Norway). See also https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WISE_SOW_PressuresImpacts/SWB_Pressures?:embed=y&:showAppBanner=false&:showShareOptions=true&:display_count=no&:showVizHome=no

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

[13] Compared to the results in EEA (2018) there are a minor increase of one percentage point in good quantitative and good chemical status.

[14] Surface water ecological and chemical status and groundwater chemical and quantitative status.

[15] '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.

- 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 lag-time 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 Section 3, the key pressures and their drivers on European water bodies are illustrated in more detail for a number of selected European key 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).

3 Selected European key water management challenges

As explained in section **Fejl! Henvisningskilde ikke fundet.**, the selected European key 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 WFD environmental objectives, and affecting water bodies in the 2nd RBMPs (EEA 2018a).

Ten European key water management challenges are being presented, which are related to pollution issues, hydromorphological pressures, abstractions and water scarcity, but also problems related to aquaculture and invasive alien species. These European key water management challenges arise from ongoing human activities (such as agriculture or energy production) but also partly from historic human activities (e.g. obsolete barriers on rivers or abandoned mines) and new developments (e.g. new hydropower plants).

The ten European key water management challenges have been selected based on the analysis of significant pressures affecting water bodies in the 2nd RBMPs (see EEA 2018 assessment of status and pressures of European waters). Pressures were selected that affect a sufficiently large share of European water bodies and reported by a large number of WFD countries. In addition, European key water management challenges have been selected, which were long time important enough to develop a rather solid basis of knowledge and information to describe the scope of the issue at European level.

Even though some of the selected water management challenges such as mining, navigation, aquaculture and invasive alien species seem to affect a small share of European water bodies, they do pose a risk to aquatic ecosystems in a large number of WFD countries. In addition, they can be of high importance and intensity in specific regions of Europe significantly contributing to the failure of achieving good water status on a regional level.

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

Table 2 summarises the European key water management challenges presented in the report.

Table 2 Overview of drivers and pressures of European key water management challenges

Pressure/sector/activity	European water bodies affected in second RBMPs	Impacts (summary)	Measures and management challenges (summary)
Pollution: **Point source** (urban wastewater, 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 Potential risks from microplastics	Installation and enhancement of sewers and treatment to reduce pollution from urban waste water and industry (UWWTD) Reduction at source Storage and treatment of storm waters to reduce overflows Emerging pollutants: Enhanced treatment

Pressure/sector/activity	European water bodies affected in second RBMPs	Impacts (summary)	Measures and management challenges (summary)
Pollution: **Diffuse source** with nutrients, chemicals (agriculture, atmospheric deposition)	22 % of surface water bodies 30 % of groundwater area	Eutrophication and algae blooms impacting biota Groundwater nitrates affects drinking water quality Pesticides threats on 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 (incl. Nitrates Directive) New Integrated Nutrients Management Strategy Implementation of the revised CAP, financing instruments Measure against air pollution (incl. Industrial Emissions Directive)
Pollution: **Non-connected dwellings**	10 % of surface water bodies 7.5 % of groundwater area	Loads of disease-causing organisms impacting human health Local oxygen depletion Nutrient input leading to eutrophication and oxygen depletion	Connection to waste water systems or local treatment Need to further harmonise WFD & UWWTD to tackle issue Homeowner responsibility and enforcement, including exploring obligation to connect where there is a centralised collection system.
Pollution: **Mining**	7.5% of groundwater area < 1% of surface water bodies Reported in 17 WFD countries as point or diffuse source pressure	Changes in surface and groundwater hydrology Sediment load Acidification Altered in-stream habitat and morphology	Site adapted measures to reduce mining pressures to hydrology and quality Rehabilitation of abandoned mining sites Need for more synergies between WFD and 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	Restoration measures Strategies for restoring continuity / prioritisation Removal of artificial structures such as 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 morphology dynamics and sediment supply Impacts on nutrient cycling	Floodplain and river restoration measures Multi-benefit measures More systematic inclusion of floodplain restoration in RBMPs/FRMPs Targeted financing for floodplain restoration
Hydromorphological pressures: Hydropower	6 % of surface water bodies	Interruption of river continuity and impacts on migrating fish Altered sediment transport	Various mitigation & restoration measures Strategies for sustainable hydropower

Pressure/sector/activity	European water bodies affected in second RBMPs	Impacts (summary)	Measures and management challenges (summary)
		Changed flow regime with morphological and also ecological effects Altered physicochemical conditions Cumulative effects	Permit/licensing system Construction of new hydropower plants
Hydromorphological pressures: Navigation	< 1 % of surface water bodies but of high importance 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/guidelines for sustainable inland navigation Mitigation of impacts from prolongued periods of low water
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 Heating at power plants Lowered groundwater levels Salinization of aquifers	Demand-side measures Supply-side measures Permit/licensing systems Water pricing Measures for illegal abstractions 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) Lack of explicit obligations for aquaculture under WFD, MSFD
Invasive alien species (IAS) (aquaculture, pet/aquarium species, shipping fisheries/angling)	2 % of surface water bodies but already reported as significant pressures in 15 WFD countries	Altered biota communities Impacts on food webs Constraint on recovery of native biodiversity Change of genetic behaviour of natural populations	Prevention, early detection & rapid eradication, management measures Few measures so far in RBMPs National strategies for IAS Need of cross-linking management efforts under IAS Regulation, WFD, MSFD

The following sections give a brief overview of the selected European key 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 which are available to tackle the issue and of management challenges of EU-wide relevance (ongoing challenges and new challenges ahead). 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 were used as a basis to derive 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 shall provide further details on the main drivers and pressures which are important at the river basin district level and on specific measures required in the new WFD planning cycle.

3.1 Pollution

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

A range of pollutants still reach European surface waters and groundwaters via different pathways with 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 due to the identification of specific drivers and causes of pollution. Point sources from urban waste water or industry can be easily address and managed; In contrast to diffuse pollution, where the measures may be more difficult to implement.

Point source pollution is mainly caused by urban inhabitants with 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 much of the European countries.

Diffuse source pollution occurs mainly from agriculture, run off from urban areas, but also atmospheric deposition or non-connected dwellings. EU action on curbing diffuse nutrient pollution has a long history. Member States currently use a large number of 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 downstream or through the aquifers (groundwater), and discharged into coastal waters.

The impacts of water pollution are diverse. Nutrients, like phosphorous or nitrogen, lead to eutrophication with algal blooms and oxygen depletion affecting fish and other aquatic communities. Pesticides or heavy metals harm the environment and human health.

According to the 2nd RBMP 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 ([16]).

Key pressures from point source pollution and diffuse source are described in the following sections. Main pressures from point sources are waste water releases from households and industry. For diffuse sources, focus is on pressures from agriculture, nutrients and pesticides in particular. Other sectoral pressures with main impacts on aquatic ecosystems are non-connected dwellings and mining. These pressures are addressed in two separate sections.

3.1.1 Point source pollution (urban waste water, industry)

Overview

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

([16]) Source: https://www.eea.europa.eu/themes/water/european-waters/water-quality-and-water-assessment/water-assessments/pressures-and-impacts-of-water-bodies; download 17.06.2020

In Europe, point source pollution discharges have markedly decreased over the last decades caused by 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 2nd RBMPs, 15 % of all surface water bodies are affected by point source pollution, from which two-thirds are assigned to urban waste water from treatment plants and some 20 % to industrial waste water ([17]). 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 m^3 waste water every year (EC, n.d.; Van den Roovaart, et al., 2017). Three quarters of them treat water from urban sewage systems with a size of agglomeration of more than 2 000 population equivalents (EC 2019a). 90 % of the population in EU Member States are connected to sewage systems. The highest rates of above 80 % are located in Central and Northern Europe, where also the best level of treatment (e.g. nutrient removal) has been implemented in the majority of waste water treatment plants ([18]).

Waste water from industry has decreased over the last decade. This is caused by increased regulations (e.g. Industry Emissions Directive – IED or the European Pollutant Release and Transfer Register – E-PRTR), improvements in treatment and implementation of best available techniques reference documents, e.g. BREF ([19]). Furthermore, relocation of various heavy polluting and energy intensive manufacturing industries outside Europe has also led to water quality improvement ([20]). The connection of industrial waste water to urban waste water treatment plants to avoid industrial emissions to water has marginally increased (EEA 2019a). Industries with still high direct releases to water are e.g. pulp and paper, steel, energy supply or chemicals, whereas manufacturing or food production tend to be more connected to urban waste water treatment plants (EEA 2019a). This is also due to the recommendation of the best available technique reference document for industrial installations (Canova, et al., 2018).

Also, storm water causes problems dependent on the sewer system. In case of heavy rains, overflows from combined sewer systems are discharged into surface waters with a mixture of rainwater and untreated waste water. This can lead to a temporally high pollution pressure.

Impacts

Impacts from point source pollution to waters are caused by oxygen consuming substances, like ammonium or other substances, indicated by the measurement of the biochemical oxygen demand (BOD), nutrients such as phosphorus and nitrogen, hazardous substances, emerging pollutants, pathogens, like bacteria, viruses, or 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 causes impacts on aquatic communities, e.g. the loss of several macroinvertebrates and acute toxic impacts on fish.

Overall, concentrations of oxygen consuming substances (BOD, ammonium) and nutrients (nitrate and phosphate) have decreased over the last 25 years (**Fejl! Henvisningskilde ikke fundet.**). It needs to be mentioned, that nitrate as well as phosphorus in rivers is not solely

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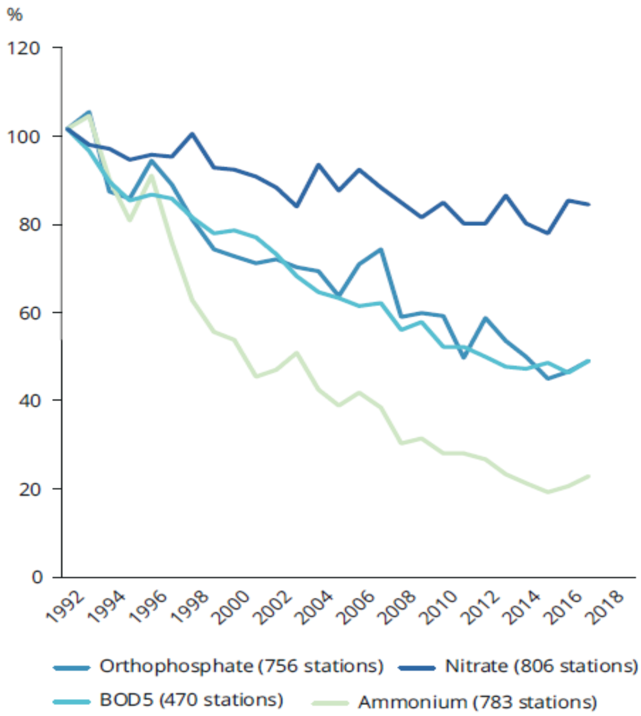
([17]) Source: https://www.eea.europa.eu/themes/water/european-waters/water-quality-and-water-assessment/water-assessments/pressures-and-impacts-of-water-bodies; download 17.04.2020

([18]) Source: https://www.eea.europa.eu/data-and-maps/indicators/urban-waste-water-treatment/urban-waste-water-treatment-assessment-4

([19]) https://eippcb.jrc.ec.europa.eu/reference/

([20]) Source: https://www.eea.europa.eu/data-and-maps/indicators/industrial-pollution-in-europe-3/assessment attributable to point sources of pollution. Those substances can also be released from diffuse sources.

Figure 3 Trends in biochemical oxygen demand (BOD), ammonium, orthophosphate and nitrates in rivers



Notes: Insert notes here

Source: (EEA 2019b)

Hazardous substances are defined as toxic, persistent, and liable to bio-accumulate (Article 2, 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 adoption of cessation proposals by the European Parliament and the Council (WFD, Art. 16 (6)). Those substances are for example 4-Nonylphenol (surfactant) or pBDEs (flame retardants) used in many industrial productions. Beside the risk of hazardous substances, emerging pollutants are present in low concentrations and include inter alia pharmaceuticals and personal care products, chemical degradation products, or endocrine-disrupting compounds. The knowledge of long-term effects of these pollutants as well as the cocktail effect in waters is rather unknown (EEA 2018a).

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

Measures and management challenges

Due to the successful implementation of the Urban Waste Water Treatment Directive (UWWTD), point source pollution pressure from urban waste water has significantly decreased.

This is the result of the improved rate of population connected to sewage systems, but also the implementation of second (biodegradation) and third (nutrient removal) treatment levels all over Europe ([21]).

Measures to further reduce point source pollution from urban waste water but also industry include e.g. construction and adaptation, expansion, optimization of existing treatment plants, connection of households to sewer systems or consolidation and closure of non-effective treatment plants.

Improved efforts to retain chemicals in waste water treatment plants should go hand in hand with clear efforts to reduce them at source. Such measures can range from raising consumer awareness, to 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 of phosphates in consumer detergents to avoid eutrophication in surface waters. The remaining allowed use of phosphates was legally fixed in Regulation 648/2004/EC (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 to automatic dishwasher detergents for consumers as of 1 January 2017 ([22]).

Furthermore, measures can be assigned to stricter requirements like lower targets for concentrations of specific pollutants in the discharged waste water by the responsible authority. This has been applied to protect drinking water resources of Lake Constance, the biggest lake in Germany. All treatment plants at the tributaries of the lake reduced markedly their phosphorous concentrations in the waste water discharge. Till today, Lake Constance is at good ecological status with drinking water quality (International Commission for water protection of Lake Constance (IGKB), 2014).

Even though considerable success has been achieved to reduce 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 European countries, or economic background, treatment has to be further improved in eastern parts of Europe in particular. A lower storm overflow is necessary with the help of nature-based solutions. To increase treatment, the implementation of the fourth treatment level is in progress. This level consists of innovative treatment techniques (e.g. oxidation with ozone, activated carbon filtration, membrane filtration) (UBA, 2014, EEA, 2019c). For example, by 2040, 100 of the 700 wastewater treatment plants in Switzerland will be equipped with a fourth purification level after decision in a plebiscite ([23]). The investment requirement of CHF 1.2 billion will be financed through a nationwide wastewater tax, which is a maximum of CHF 9 per inhabitant and year ([24]).

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

3.1.2 Diffuse source pollution

Overview

In Europe, agriculture is the main diffuse source for water pollution with high emissions of nutrients, like nitrogen and phosphorus, as well as chemicals such as pesticides (EEA 2018b). Drivers for nutrient surpluses in soil and water pollution are excess use of fertilizer for crop production coming from mineral fertilizers and manure from livestock farming. Nutrients (as well as pesticides) enter the water cycle via erosion, surface run-off, leaching, or via inflow from

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([21]) Source: Source: https://www.eea.europa.eu/data-and-maps/daviz/changes-in-wastewater-treatment-in-8

([22]) Source: https://ec.europa.eu/commission/presscorner/detail/en/IP_11_1542

([23]) Source: https://www.vdi-nachrichten.com/technik/die-vierte-reinigungsstufe/

([24]) Source: https://www.vdi-nachrichten.com/technik/die-vierte-reinigungsstufe/

polluted drainage and groundwater to surface waters with impacts to 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 30 % of the groundwater area leading to failure of good ecological and chemical status.

Nutrients are key for plant growth. In the EU, nitrogen surplus from agriculture is estimated to a total of approximately 27 million tons per year (Misselbrook et al., 2019), and since 2010, no improvement to reduce nitrogen surplus has been seen ([25]). Today, the highest total nitrogen surpluses occur generally, although not exclusively, in Western Europe.

Based on reported long-term data of nitrate in European waters, nitrate concentration in rivers showed a decreasing trend (**Fejl! Henvisningskilde ikke fundet.**). The decline reflects the effects of improvements in waste water treatment, but also reductions of agricultural inputs. In contrast to rivers, nitrate concentration in groundwater does not show any trend during the last decades ([26]).

Pesticides are used to prevent or control any pest causing harm for agricultural products (FAO 2002). Pesticide sales data in Europe show, that in the time period 2011 to 2016, pesticide sales had an amount of 400 000 tonnes per year (EEA 2018c). Despite the high amount of pesticide sales, only 0.4 % of all surface water bodies and 6.5 % of groundwater area fail good chemical status based on exceedances of pesticide standards according to the status assessments in the 2nd RBMP (Mohaupt,, Völker,, Altenburger,, Birk,, Kirst,, Kühnel,, Semeradova, et al., 2020). Based on WISE – Waterbase reporting data for European surface water monitoring stations suggest that in the time period 2007 to 2017, 5–15 % showed exceedances by herbicides and 3–8 % by 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,, Völker,, Altenburger,, Birk,, Kirst,, Kühnel,, Küster, et al., 2020). Atmospheric deposition plays a role as a diffuse source for water pollution with chemicals, such as mercury and polycyclic aromatic hydrocarbons (PAH). PAH emissions occur during all combustion processes involving organic materials such as wood, coal, or oil. Mercury is released into the atmosphere, mainly by coal combustion, spreading over great distances and wash-out with rain to soil and waters (BMU/UBA, 2016). It can lead to accumulation in biota, especially fish, which is a risk for fish-eating animals and a potential risk for human health, e.g. (Zupo, et al., 2019). In Europe, mercury from atmospheric deposition is the main reason for failing good chemical status in more than 30 % of all surface water bodies (EEA 2018b)).

Impacts

Nutrients and pesticides releases as well as sediment run-off from agriculture have high impacts on surface waters and groundwater. *The presence of too many nutrients* leads to eutrophication with high levels of algae and aquatic plant growth in surface. Algae blooms also reduce transparency and lead to a lack of oxygen with a high risk for fish and other aquatic communities. In lakes, high nutrient concentrations can induce potentially toxic blue-green algae proliferation, that can be detrimental to human health. Coastal water bodies show similar reactions to excessive nutrient inputs (Ibisch et al., 2016).

Figure 4 **Toxic blue-green algae bloom in a dam in Germany**

([25]) Source: https://www.eea.europa.eu/data-and-maps/indicators/agriculture-nitrogen-balance-1, download 16.04.2020

([26]) Source: https://www.eea.europa.eu/data-and-maps/indicators/nutrients-in-freshwater/nutrients-in-freshwater-assessment-published-9

Source: © J. Völker

Elevated groundwater nitrate concentrations are affecting raw water for drinking water and thus create a risk to human health. Groundwater containing nitrates can also be emitted into surface water bodies that are fed by groundwater (BMU/UBA, 2016).

Pesticides input from diffuse sources can have impacts to aquatic communities, if they are directly exposed to pesticides inflow from farmland via erosion or indirectly through trophic chain (Hasenbein, et al., 2016; Maksymiv, 2015). Pesticides can also threaten human health, if contaminated surface waters or groundwater are used for drinking water supply. Furthermore, aquatic communities are exposed to mixtures of different pesticide substances. The knowledge on their combined effects of these mixtures to the aquatic environment is rare (Mohaupt,, Völker,, Altenburger,, Birk,, Kirst,, Kühnel,, Semeradova, et al., 2020).

Sediment run-off from agricultural fields can result in accumulation of fine sediments (see **Fejl! Henvisningskilde ikke fundet.** in section **Fejl! Henvisningskilde ikke fundet.**), which overlay the natural riverbed resulting in the loss of habitats, e.g. spawning ground for trout and salmon ([27]).

Measures and management challenges

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

Further strategies to reduce diffuse nutrient pollution are extensification and expanding the scope of organic farming, the use of precision farming with new digital technologies and innovative monitoring concepts (e.g. remote sensing) as well as the reduction of livestock density. Technical measures include catch cropping, the use of ground coverings and of tillage methods, establishing buffer strips with strict use restrictions, or increase manure storage capacity at farm level. Manure storage can improve the timing of application to minimise the risk of excessive leaching into the water environment. Advisory services should lead to better

([27]) Source: https://www.eea.europa.eu/archived/archived-content-water-topic/water-pollution/diffuse-sources informed farmers with concrete and relevant information and increase the acceptance to implement measures.

To reduce pesticide pollution, relevant measures include for example minimising the risk of off-site pollution caused by spray drift, drain-flow and run-off, or reducing or eliminating applications along infrastructure close to surface water or groundwater. Other measures comprise the preference to use pesticides that are not classified as dangerous for the aquatic environment, the establishment of untreated buffer zones, or ban, or restriction in the use of pesticides. Some European countries (Denmark, France, the UK and Sweden) use reduction targets and timelines within National Pesticide Action Plans for a stepwise reduction of pesticides (EC and Directorate-General for Health and Food Safety, 2017).

Even though water quality has improved over the last decades, pollution from diffuse sources in particular agriculture still remains a severe water management problem in Europe and a major cause for failing good ecological and chemical status of surface waters and groundwater under the WFD. To protect water ecosystems, there will be a need to strengthen the implementation of agricultural measures (both basic and supplementary) and a need for further efforts to adapt measures to regional pressures (EC 2019e). Specific implementation challenges also remain in addressing water quality issues in 'hotspots' with high nutrient loads as a result of farming, via better coordination of national/regional sectoral administrations (e.g. agriculture, water), and balanced fertilizers application (EC, 2017b). Simultaneously, adaption of financing instruments is necessary within the reform of the CAP. Still, basic measures need to be more strictly implemented to fully comply with the Nitrates Directive (EEA 2018b, 2019b).

Box 1 Non-connected dwellings

Non-connected dwellings is a diffuse source pollution pressure caused by discharge from households not connected to urban waste water treatment plants or other collection systems ([28]).

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 ([29]). Based on the 2nd RBMP, 21 WFD countries reported significant diffuse source pollution pressures caused by discharges not connected to sewage systems in 10 % of all surface water bodies. Furthermore, about 7.5 % of all groundwater area is affected by this pressure ([30]).

If the waste water is not properly treated by the installation and maintenance of individual appropriate systems, discharges of untreated waste water to waters can lead to nutrient input, or load of disease-causing organisms with potentially human health risks in e.g. bathing waters ([31]).

Measures to reduce water pollution are mainly technical and include *inter alia* waste water package plants, sand filters, drain fields, seepage pits or constructed wetlands with varying purification efficiencies (Vorne, Virpi et al., 2019). Furthermore, national regulatory frameworks have been elaborated to require the installation of appropriate treatment systems, e.g. in Bulgaria, which requires 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 in responsibility of the homeowners, and technical

([28]) Source: https://www.eea.europa.eu/archived/archived-content-water-topic/wise-help-centre/glossary-definitions/scattered-dwellings, modified.

([29]) Source: https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=ten00020&plugin=1

([30]) Source: https://www.eea.europa.eu/data-and-maps/dashboards/wise-wfd, 30.03.2020

([31]) Source: https://www.eea.europa.eu/themes/water/european-waters/water-use-and-environmental-pressures/uwwtd/urban-waste-water-treatment or financial support by local, regional, or national authorities is rather rare. This makes it difficult to enforce those treatment techniques in single houses or very small agglomerations.

There is still a huge knowledge gap on the impacts of discharges from non-connected dwellings, because neither the UWWTD nor the WFD directly regulate mitigation measures, and reporting obligations solely address connected dwellings with more than 2 000 population equivalents. This hinder information and conclusions on the implementation and use on the effectiveness of individual technical treatment systems. There is a need to further improve the knowledge on this issue, the adaption and harmonization of both WFD and UWWTD measures and reporting, further financial support for homeowners, and control of implemented techniques (EC 2019a; Grebot, et al., 2019).

3.1.3 Mining

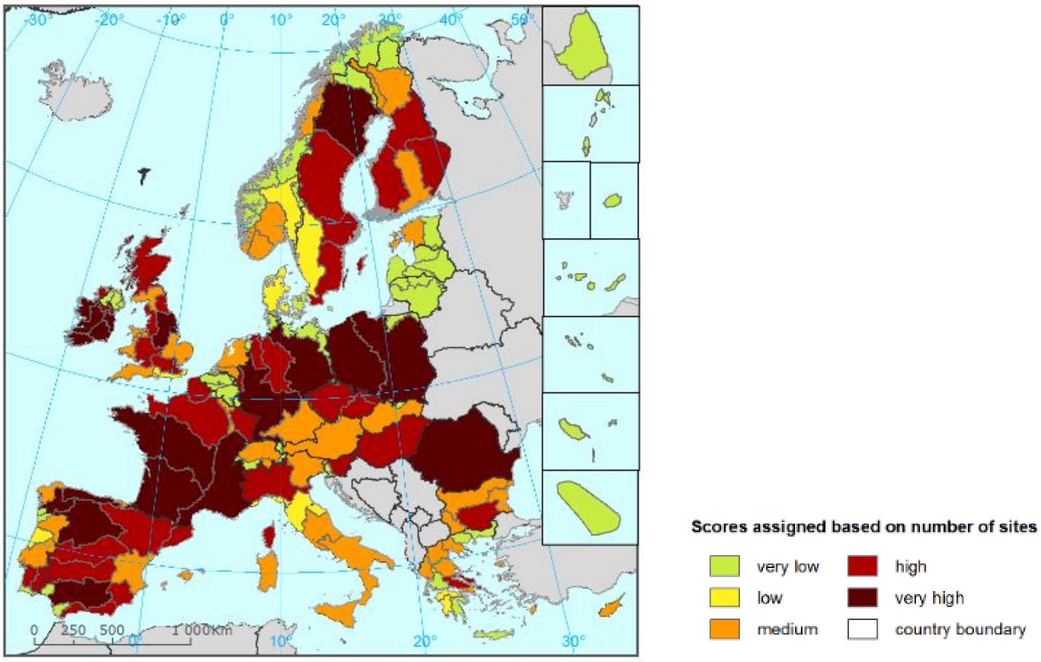
Overview

Mining has been undertaken in Europe for many hundreds of years. Today many mines have been closed but both recent and abandoned mines still affect the quantitative, chemical and ecological quality of water. This section covers both mining and extraction (gravel, peat) activities. Main pressures and impacts include acidification caused by lowering pH and discharge of heavy metals, other chemical pollution or pollution resulting by saltwater intrusion, alteration in flow, or lowering water table caused by an excessive dewatering during mine operation or after mining activities have stopped. Recovery of affected aquatic ecosystems – including groundwater - may take decades.

In the 2nd RBMP, 17 WFD countries reported mining as significant point and/or diffuse source pressure, affecting ca. 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 included the UK, Norway, Germany, Hungary, Bulgaria, Spain, and Italy.

Other analyses of mining pressures and their potential risks to water show a slightly different picture due to the use of other sources of data. In **Fejl! Henvisningskilde ikke fundet.** below, countries are scored based on mining activities (existing and abandoned mines) and Czechia, France, Germany, Poland, Romania, Sweden, Spain and United Kingdom are the Member States with the highest potential risk of mining pressures (WRc, 2012).

Figure 5 Potential risk of specific mining activities in European river basin districts



Notes: Map produces by CENIA, CR on behalf of European Commission ©; DG Environment, September 2012.

Source: WRc (2012)

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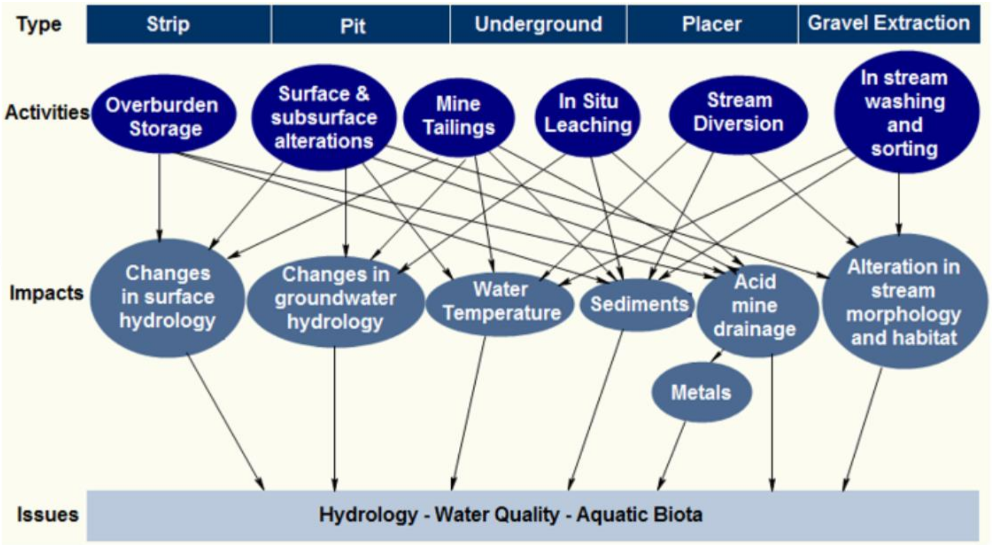
Mining activities include the extraction of coal and lignite, minerals mainly potassium, rock salt and magnesium-containing minerals, clay, peat, metals such as copper and gold as well as stones, gravel, or sand (aggregates). It is estimated that in EU more than 32 000 sites with mining activities exist,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

On the number of abandoned mines, European-wide data are rare, e.g. (EC, 2017a), and the number of abandoned mines is likely to be much higher than of active ones based on available data on certain countries, like Slovakia and Hungary. Slovakia has registered more than 17 000 and Hungary has reported some 6 000 abandoned mining sites (UNCCD, 2000). The bulk of mine water problems in Europe are in fact 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

Main impacts to aquatic ecosystems are changes in surface and groundwater hydrology, sediment load, water quality, acidification and alteration in stream habitat and morphology (**Fejl! Henvisningskilde ikke fundet.**).

Figure 6 Impacts of mining activities on water



Notes: Insert notes here

Source: http://ubclfs-wmc.landfood.ubc.ca/webapp/WID/course/land-use-impacts-on-water-3/mining-impacts-16/ .

All types of mining have the potential to directly disrupt groundwater *hydrology*, which in turn can affect surface waters that are in hydraulic continuity with the affected groundwater systems (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 acidification or salinization. The acid runoff further dissolves heavy metals such as copper, lead, mercury into groundwater or surface water. Problems that can be associated with mine drainage include iron hydroxide precipitation during oxygenation of mining water, contaminated drinking water (e.g. with metals or sulphate), impacts on aquatic plants and animals, or the corroding effects of the acid on parts of infrastructures ([32]). Salinization is caused by the extraction of salts, e.g. potassium. High salt content altered aquatic communities and salt intrusion into the groundwater can endanger the quality of drinking water.

Placer mining or gravel extraction, and lead to increased sediment loading and decrease water clarity. Furthermore, *hydromorphology* is impacted by replacing coarse substrates such as gravels and boulders resulting in fewer invertebrate species.

Impacts of the removal of peat are increased sedimentation, increasing dissolved organic carbon (DOC) and phosphorus concentration, 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 into the watercourses or lakes and the load of solid peat particles causes silting of downstream water bodies.

Hydraulic fracturing to extract shale oil or shale gas potentially threatens drinking water resources (mainly groundwater) with the contamination with chemicals used in the hydraulic fracturing process. Surface water contamination can occur if the wastewater, 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 (Umweltbundesamt, 2012). Based on the shale gas information platform by EC, the UK is the only country in Europe,

[32] Source: https://www.usgs.gov/special-topic/water-science-school/science/mining-and-water-quality?qt-science_center_objects=0#qt-science_center_objects; 14.05.2019

where companies pursue hydraulic fracturing (which is haltered since 2019)([33]), whereas a ban in France and Bulgaria and tests in Poland occur ([34]). In Estonia, mines cover ca. 1 % of the whole territory and about 16 million tonnes of shale oil were extracted in 2012 with high impacts on waters ([35]).

Mining accidents can have tremendous impacts to the aquatic environment, for example the spill of cyanide rich waste water in Baia Mare, Romania in 2000. After a dam brake in the retreatment plant of gold mining company, large number of fish were killed in the Somes River, and also Tisza River and Danube. Furthermore, drinking water resources were contaminated (UNEP/OCHA, 2000).

Measures and management challenges

Measures to reduce pressures from mining activities for surface waters include re-use or recycling of excess water, diversion of run-off systems, or the use of reagents or chemicals with a low environmental impact, drainage systems, removal of suspended solids or liquid particles, or removal of dissolved substances by e.g. adsorption or nanofiltration. For groundwater, physical barriers, drainage systems techniques, or covering techniques are listed as effective measures to protect aquatic ecosystems (EU, 2018). These measures are part of the BAT (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 have to submit an extractive waste management plan (EWMP) as part of their permit applications.

After closure of mines, restoration is foreseen to rehabilitate impacts of former activities to soil and water. Many countries have national plans, like the rehabilitation for the Avoka river in Ireland ([36]) or the Landscape Evaluation Tool for Open Pit Mine Design in Greece (Mavrommatis, and Menegaki, 2017). In Saxony, Germany, numerous post-mining lakes were created as part of the brown coal refurbishment. Most of these lakes are already being used for tourism purposes ([37]).

Current mining activities are strongly regulated by Member States under National Laws. In most countries, Water Acts and Water Laws include protection of waters from mining activities. Additional legislations and regulations are implemented for the protection of groundwater, e.g. decree on activities that affect the quality of groundwater in Hungary or the Groundwater Exploration Act in Sweden (Endl, and Berger, 2016). The legislative instruments on international and national level regulating the current mining sector should ensure that the objectives of the Water Framework Directive (2000/60/EC) and Groundwater Directive (2006/118/EC) are achieved (WRc, 2012).

Measures under the WFD also aim at reducing water abstraction related to mining which is commonly used to control quantitative impacts from quarrying activities but could also be of use for deep mining (underground mining). Measures controlling substances are specific to individual substances, diffuse pollution or point source pollution. For example, to reduce diffuse discharge from saline waters into groundwater, 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 wastewater by 20 % ([38]).

([33]) Source: https://www.theguardian.com/environment/2019/nov/02/fracking-banned-in-uk-as-government-makes-major-u-turn

([34]) Source: https://ec.europa.eu/energy/topics/oil-gas-and-coal/shale-gas_en

([35]) Source: https://www.academia.edu/4412537/Poster_of_Analyses_of_Estonian_oil_shale_resources

([36]) Source: http://www.mineralsireland.ie/MiningAndTheEnvironment/Rehabilitation.htm

([37]) Source: https://www.bergbau.sachsen.de/8193.html

([38]) Source: https://www.kpluss.com/en-us/sustainability/environment/water/

Data on implemented measures under the WFD and under the EWD are rare. In the context of the WFD, information on mining is part of different reporting obligations, e.g. WFD emissions inventory, pressures characterisation of water bodies or the failing of Environmental Quality Standards for e.g. heavy metals caused by mining activities for chemical (priority substances) or ecological status assessment (river basin specific pollutants). If mining activities cause significant pressures putting at risk the achievement of WFD objectives for surface water or groundwater, measures need to be included in the RBMPs. In the context of the EWD, mining operators have to draw up an extractive management plan (EWMP) as part of permit applications. Among other issues, EMWPs should cover the monitoring of surface and groundwater quantity and quality and the management of excavated material as well as mining waste (EC 2019f). Due to the relevance of both Directives 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, construct hydropower plants 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, 2018; EEA, 2019).

Hydromorphology plays a key role for aquatic ecosystems. For example, water flow and substrate provide physical habitat 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 Catchments Unit, 2016; Houlden, 2018).[39]

In the second RBMPs, hydromorphological pressures are the most commonly occurring pressure on surface waters, affecting 34 % of all such water bodies (EEA, 2018). The most reported hydromorphological pressures are physical alterations related to flood protection, urbanisation, agricultural development and navigation as well as 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 identified hydro-morphological pressures are not clearly apportioned to specific drivers (EC, 2019).

Further, 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 elaborating on the role of hydropower, navigation, flood protection and agricultural drainage as major drivers of impacts on hydromorphology in Europe. Also, separate sections address the role 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 so far in terms of their extent and implications on European scale. One of these aspects is the issue of changed sediment dynamics due to hydromorphological pressures which is gaining more and more attention and will require targeted management interventions in the near future (see **Fejl! Henvisningskilde ikke fundet.**2). In the meantime, the 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 2 Sediment quantity and hydromorphology

Sediment and sediment transport are essential and integral natural elements of the hydromorphology of rivers, lakes, estuarine and coastal systems. Sediment is also vital to the ecology of these systems, providing and supporting habitats as well as nutrients for aquatic plants, invertebrates, fish, and other organisms. Although the WFD does not explicitly take account of sediment, ecological status is clearly dependent on habitat (including sediment

[39] https://www.catchments.ie/hydromorphology-what-is-it/ and http://www.hrwallingford.com/news/Hydromorphology-the_forgotten_facet_of_the_WFD

quantity) and clearer understanding is needed on the role of sediments in the WFD and related legislation such as the Floods Directive and 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 a barrier in the hydrological system as they interrupt the continuity of sediment transport through rivers systems. Sediments trapped in reservoirs cause a deficit of sediments downstream reservoirs leading to erosion, morphological and ecological consequences in the downstream rivers (Kondolf et al, 2014). Also, 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 & 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. To date, most European countries though do not have sediment management plans in place (Dworak and Kampa, 2019).

Some major European river basin commissions have taken up the challenge to work towards transboundary sediment management plans as part of river basin management planning, such as the Rhine and Danube commissions (Brils, 2008). Also, 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 sediment in river basin management (SedNet, 2017). A transboundary dimension to 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 which result from changes to physical characteristics of water bodies. It requires action in those cases where hydro-morphological modifications are having an impact on the ecological status interfering with the ability to achieve the WFD 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 or implementing natural water retention measures.

At the same time, WFD measures for hydromorphological pressures should not be taken in a silo approach but it is beneficial, both in terms of the effects to be achieved and funding opportunities, 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, 2019).

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 reduce the ecological connectivity of a water body, impeding the flows of water, nutrients and sediment, create obstructions for species movement (particularly migratory species), often alter the quantity, quality and timing of river flows, both upstream and downstream, and can impact surrounding riparian zones and flood plains (Freshwater Information System, 2019).

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

In the second RBMPs, barriers are a significant pressure for almost 30 000 surface water bodies (20 % of total) 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 heavily modified water bodies in Europe.

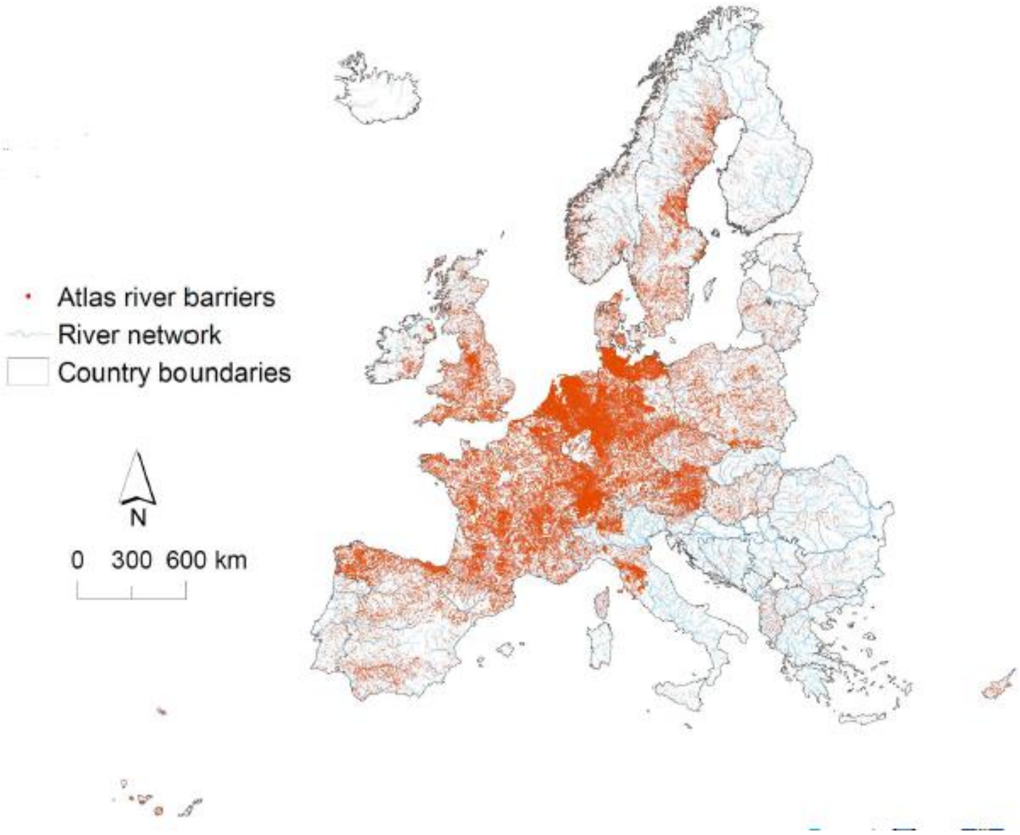
A large number of barriers are reported in the RBMPs to be used for hydropower (dams for hydropower production), flood protection and irrigation (water storage reservoirs). However, for a large share of water bodies affected by barriers (ca. 40 %), the uses which the barriers serve are unclear, either being unknown or not explicitly reported or obsolete. Indeed, many barriers on European rivers originated in the 10th to 19th centuries to operate mills and a high proportion of these are by now redundant. It is estimated that alone in France, Spain, Poland and the UK, there are up to 30 000 mainly small dams which 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 recently published Pan-European Atlas of In-Stream Barriers.[40] 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 found that more than one third of barriers on European rivers are unrecorded, bringing the total to well over 1 million. 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). [41]

Figure 7 Man-made river barriers in Europe included in the AMBER Atlas

[40] Produced by the EU Horizon 2020 project Adaptive Management of Barriers in European Rivers (AMBER): https://amber.international/european-barrier-atlas/

[41] WWF, 2020, More than 1 million barriers destroying Europe's rivers, new research shows, accessed 27th July 2020, https://www.wwf.eu/wwf_news/media_centre/?uNewsID=364559



Notes: Insert notes here

Source: https://amber.international/european-barrier-atlas/

Impacts

Man-made 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* is one of the main adverse ecological consequences of dams and reservoirs to 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 up and downstream directions and habitats are isolated through fragmentation. This transforms natural fish fauna and leads to local extinction of fish species (Gough et al., 2018).
- *Sediment*: Dams block transport of sediments in rivers, leading to accumulation and poor water quality in the reservoir, deprivation of sand and gravels downstream of dams, higher risk of erosion downstream of dams and in river deltas, and to 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 the height and location of barriers. A major impact on a river could be caused by a single, very damaging structure or by the accumulated effects throughout the length of the river of a series of small structures, which may have only a small impact individually (EEA, 2018). The location of barriers in a catchment determines, to a large extent, their impacts on sediment fluxes, 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 migrations, 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 higher 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 impact key ecological processes just as strongly. Because of their very 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

Already in the first RBMPs, several European countries planned measures to improve the ecological conditions of rivers impacted 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, the setting of ecological flows and measures for sediment management.

The implementation of such measures is closely linked to the environmental objective of the WFD to restore continuity for migrating species in regulated rivers. A number of other EU policies are also supporting the restoration of river continuity and the rehabilitation of surface waters that are impacted by barriers, including the Birds and Habitats Directives (2009/147/EC and 92/43/EEC), the new EU Biodiversity Strategy for 2030 (EC, 2020) and the Eel Regulation (Council Regulation (EC) No 1100/2007). The new EU Biodiversity Strategy 2030 has actually included 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, 2020).

Overall, due to the very high number of barriers present on rivers in Europe, there is a need for prioritisation of 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 include the Benelux treaty on free fish migration (adopted in 1996), continuity restoration initiatives in the international river basins of the Rhine[42] and the Danube (Shepherd, 2012) as well as national programmes and priority networks for river continuity restoration in specific countries such as France, Austria, Germany and Finland (Kampa et al, 2017; Ollikainen & Vilhunen, 2019).

The implementation of measures is affected by significant gaps in knowledge concerning barriers, their abundance, distribution in the European river networks (especially of small barriers) and their ecological effects. Recent AMBER study (see above) might have summarised many of the needed basic information. Also, knowledge still needs to be solidified on the effects of some of the key measures. For instance, barrier removal is increasingly viewed as a necessary

[42] http://www.salmoncomeback.org/

management measure to reinstate natural connectivity. However, we so far have little 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). Also, knowledge is lacking on measures to mitigate impacts on downstream migration of fish at hydropower turbines especially in large rivers.

An additional implementation challenge arises from the large number of barriers with an unknown or obsolete use. Funding measures to make barriers with obsolete use 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 built elsewhere in Europe driven by policies for energy production, transport, flood protection and securing water supply (e.g. new hydropower plants in the Balkans, see WWF (2019))[43]. 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 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, 2018).

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

Flood protection structures play a key role in this context. Flood events are one of the most common and most dangerous natural hazards affecting European society with almost 3 700 flood events having occurred in Europe between 1980 and 2015 (EEA, 2016). Since decades, European countries have taken flood protection measures that mostly involve conventional engineering flood protection structures to mitigate the catastrophic consequences of floods. At the same time, flood protection structures and measures (such as levees, retention basins, channel straightening, removal of vegetation and sediment) are among the main causes for 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 areas 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 channelization 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, 2012); only in south-western Sweden, almost 70 % of wetlands have been lost due to drainage over the last 50 years (Franzén et al. 2016). In many European countries mainly in northern and central Europe, more than 40 % and up to 100 % of farmland is being drained (based on data from ICID, undated).[44]

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[43] WWF, 2019. Hydropower pressure on European. The story in numbers.

[44] http://www.icid.org/imp_data.pdf

In the second RBMPs under the WFD, almost 15 000 surface water bodies (about 10 % of total) are affected by physical alterations of their channel, bed, or riparian area due to 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 European countries.

Impacts

Both flood protection infrastructures and drainage affect *floodplains and the connectivity of rivers and streams to floodplains,* as they cause changes to the land area surrounding water bodies. 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, sediment, biota as well as 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. Further, physical processes are disturbed related to the natural water retention capacity of floodplains as well as sediment dynamics.

Artificial bank protections that serve flood protection (embankments, levees or dikes) 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 flow velocities; in its 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.[45]

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).[46] Further, the *regular maintenance of drainage ditches and rivers (via dredging and weed cutting) leads to physical disturbances and morphological changes in water bodies* (Vartia et al., 2018).

Figure 8 Embankments for flood protection (left) and agricultural drainage (right)

Notes: Insert notes here

[45] REFORM wiki “Embankments, levees or dikes“, available online at http://wiki.reformrivers.eu/index.php/Embankments,_levees_or_dikes#Useful_references

[46] https://www.researchgate.net/publication/241682569_Effects_of_Agricultural_Drainage_on_Aquatic_Ecosystems_A_Review

Sources: Left photo on embankment (Rinaldi et al. 2016), right photo on drainage (Swedish Board for Agriculture & Swedish Agency for Marine and Water Management, 2015)

Measures and management challenges

The restoration of bank structures, the reconnection of floodplains or backwaters (such as oxbows 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, 2018). For example, in the international Rhine basin, about 125 km² of floodplains were reactivated by 2012 with a target of 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 of banks by 2020 (ICPR, 2015). With increasing awareness on the importance of floodplains, the numbers of examples of restoration measures or works aiming to improve river-floodplain systems' functioning are rising (EEA, 2019).

The improvement of lateral connectivity between rivers and their floodplains is a key element for the achievement of the environmental objectives of the WFD. Especially multi-benefit measures which 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), for improving riparian habitats, reducing hydromorphological pressures as well as 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 disasters. 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 of 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.[47]

It is difficult to predict how exactly pressures on European floodplains and lateral connectivity of rivers may develop in the future. Climate change though, in particular in northern Europe, is bound to lead to increased precipitation and flood events. In its 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, forthcoming).[48] At the same time, European targets of the new Biodiversity Strategy need to be met, whereby the restoration of floodplains and wetlands is mentioned as a means for restoring at least 25 000 km of free-flowing rivers by 2030 (EC, 2020).

Despite the obvious importance of floodplain restoration, it has not been systematically included in river basin or flood risk management plans yet. For developing 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, 2019).

[47] https://www.dutchwatersector.com/news/room-for-the-river-programme

[48] EEA, forthcoming, Water and Agriculture report.

3.2.3 Hydropower

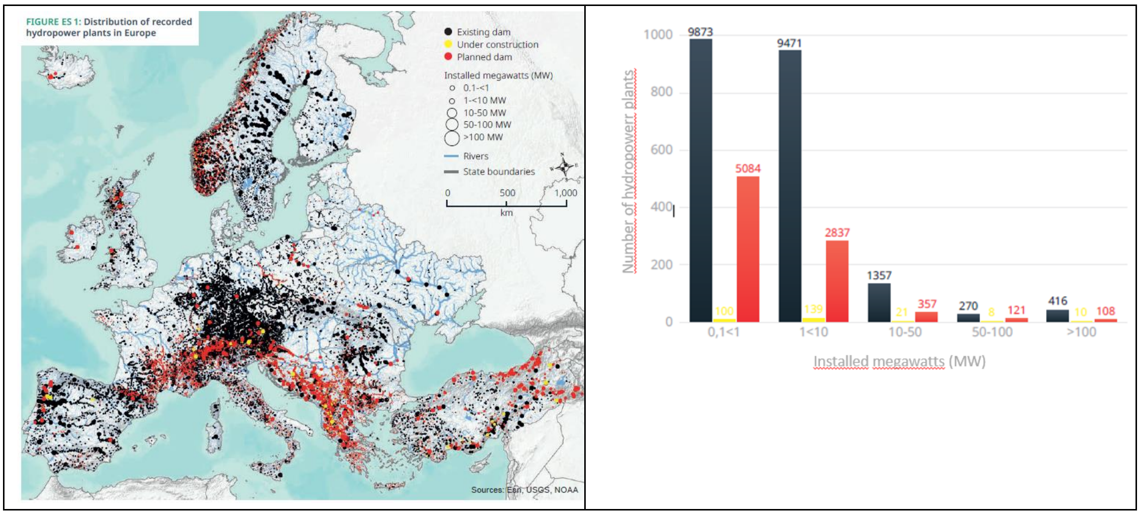
Overview

Hydropower has a long history in Europe and currently generates around 10 % of the European net electricity (Eurostat, 2019) and more than one third of renewable electricity in EU (in 2015, based on Eurelectric & VGB Powertech (2018)). Norway and Switzerland are also countries with especially high importance of hydropower. At the same time, the construction and operation of hydropower plants causes 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 water use for designating heavily modified water bodies, related to ca. 6 000 heavily modified water bodies in 25 WFD countries (half of these water bodies are in Norway).

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

Figure 9 Recorded hydropower plants in Europe



Notes: Left, Distribution of hydropower plants; Right, Distribution of hydropower plants by status and size class.

Source: WWF, 2019

The main types of hydropower plants based on the ability to store water are 1) run-of-river, 2) storage and 3) pumped storage plants. Run-of-river plants are plants without reservoirs, which 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 10 Images of small hydropower plant (left) and large hydropower plants, storage and run-of-river (centre and right)

Notes: Insert notes here

Sources: 1) By Tangopaso - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=23481491, 2) https://vaw.ethz.ch/en/research/hydraulic-engineering/ethohydraulics.html, 3) https://upload.wikimedia.org/wikipedia/commons/f/fe/Altakraftverket%2C_Norge.jpg

The largest development of hydropower in Europe took 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). Especially, the Balkans and Turkey have ambitious plans to significantly raise their hydropower exploitation (WWF, 2019). Also, 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 requests for new hydropower plants of 1 MW and in Scotland, there have been more than 700 applications for new hydropower development in the last 15 years (Bussettini, 2019; Fyfe, 2019).

Impacts

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

Hydropower dams and weirs cause an *interruption of the longitudinal river continuity*. Migrating fish species such as the eel and salmon are particularly affected by the fragmentation of their habitats. In addition, when fish pass through hydropower turbines as they move river 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 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 which are impounded for hydropower (typical for storage hydropower plants), flow velocity is reduced which can lead to the loss of orientation of fish. 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 for 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 as well as changes in flow patterns further downstream.

Water storage and river regulation through hydropower plants often also *alter physical and/or chemical conditions* downstream, with changes to water temperature, super saturation of oxygen and altered patterns of ice formation in winter.

Hydropower plants and dams are often not standing alone in a river system, but 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 & Berg, 2020). In a chain of impoundments containing several hydropower plants, the sum total of 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 as well as 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. Legislative requirements though are largely missing to address other types of hydropower impacts, such as on downstream fish migration, sediment transport and hydropeaking because of still open questions that need to be addressed by research (Kampa et al., 2011).

Hydropower plants generally operate under a permit/licensing scheme, whereby conditions for the operation are set. However, many hydropower plants were licensed prior to the adoption of key EU water policy such as the WFD in 2000 and national laws protecting rivers. In addition, in many countries, licenses are of unlimited or very long duration (e.g. up to 100 years). The large number of such licenses on old hydropower plants, whose operation 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 in modifying the licensing procedures for new hydropower plants and for revising licenses of existing plants in many countries. In case of new hydropower plants, licenses are issued which include requirements for implementing mitigation measures, to comply with national or regional mitigation requirements for hydropower plants.

Also, reconstruction, repowering and application for subsidies is used for introducing ecological demands into the licences. There are plans to reconstruct many existing hydropower plants as a lot of facilities across Europe are more than 40 years old. The reconstruction and modernisation of old hydropower plants can often significantly increase power output and be an alternative to the construction of new plants that would impact further stretches of free-flowing rivers.

Overall, as the energy systems of European countries depend on energy produced via hydropower, we need to find ways to implement 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 licenses in the next 20 years, including a 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). Also, at 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 of development of many new hydropower plants especially in the 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 due to 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 early industrialisation and some navigable rivers and canal systems are nowadays used for leisure boats only. In order for 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 channelization, channel deepening, channel maintenance, installation of groynes and flow regulation, which adversely impact water ecosystems (BMU/UBA, 2016; ICPDR, 2007). The alterations are bigger when smaller rivers are made navigable for sizes of ships, which 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 spread in 13 WFD countries) were reported as impacted by pressures from inland navigation. However, navigation issues are of high 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 both in terms of the volume of transported goods and average vessel size (Graf et al., 2016). Nowadays, there are more than 37 000 kilometres of European inland waterways spanning 20 Member States and connecting hundreds of cities and industrial sites (DG Mobility and Transport, 2019). The uses on inland waterways include navigation for transporting freight, transporting passengers and leisure. Most of the commercial goods transportation by inland ships in Europe concerns five countries: the Netherlands, Germany, France, Belgium and Romania (EC, 2018). More than two-thirds of all goods of 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 only to around 6 % (in 2017) of the total volume of all goods transported in the EU (Eurostat, 2019).

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

The infrastructure network of inland waterways includes the natural navigable rivers, artificial-built 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 the European Community.

Figure 11 Examples of inland navigation vessels for commercial and recreational purposes

Notes: Insert notes here

Source: https://ec.europa.eu/transport/modes/inland/promotion/naiades2_en; https://www.wikiwand.com/en/River

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, deepening and maintenance of the channel (e.g. via dredging). Altering the shape of river courses to improve navigation affects the characteristics of river beds, river banks and the dynamics of sediment transportation. 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 river dynamics of the river that are important for creating and renewing key habitats (ECMT, 2006). Thus, navigation requirements result in stabilized, 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 impact aquatic plants. In addition, the engines of ships can cause an unnatural suspension of fine sediments, leading to reduced light for plant and algae growth (ICPDR, 2007). Further, 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, wastewater and household waste of passenger and hotel ships) or bilge water. There is also a risk of accidental spills, involving oil or hazardous substances, resulting from ship collision or damage (EC, 2018; ICPR, 2015). For example, on the river Rhine, in 2018 and the years before, oil released from shipping was the most frequently reported pollutant among suddenly occurring pollution incidents (ICPR, 2019).

Finally, to maintain navigable water levels in artificial canals that connect different river systems, water is often moved between rivers causing hydrological alterations but also the *spreading of invasive alien species*. Also, shipping is an important dispersal vector for invasive species between river systems, either by transport at 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 replacement with soft engineering solutions, the re-connection of side arms, floodplains and oxbows to restore river habitats, as well as the use of more **ecologically orientated dredging** for 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 indicating good practices for waterway development which is compatible with environmental protection requirements (e.g. PIANC guidelines for sustainable inland waterways and navigation (of 2003), PLATINA Manual on Good Practices in Sustainable Waterway Planning (of 2010)).

Also, 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 on national or regional level are being developed. Examples include the 'Blue Ribbon' Programme in Germany which aims at creating a system of ecologically re-shaped 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 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, though, 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 / Roadmap to a Single European Transport Area (EC, 2011)). Future plans for inland navigation in Europe however need to take account of the changing climatic conditions. Intense recent droughts in 2018 led to very 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 refers to long-term water imbalances, combining low water availability with a level of water demand which exceeds the supply capacity of the natural system.[49] In some areas of Europe, water abstractions are characterised by seasonality, adding up to the existing water scarcity drivers of weather phenomena, temperatures, and geographical location (EEA 2019b).

In the second RBMPs of WFD countries[50], around 8 000 surface water bodies (about 6 % of total) were affected by significant pressures from abstraction, with the highest share 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 the last decades, groundwater aquifers have also been affected by overexploitation in many parts of Europe (EEA 2019a). In the second RBMPs, water abstraction was a significant pressure for 17 % of groundwater area in Europe with the highest share in Hungary, Malta and Cyprus. The reported groundwater water abstractions mainly serve public water supply, followed by agriculture and industry.

In 2017, the water consumption in Europe by different economic sector was made up as follows: agriculture (58 %), cooling water for energy production (18 %), mining, quarrying, construction and manufacturing industries (11 %) and households (10%) (EEA 2020).[51] Water consumption refers to the net water abstraction, 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 (ibid.). The low water return to the environment combined with high water consumption makes agriculture one of the sectors that cause significant pressures on renewable water resources (EEA forthcoming), especially in southern European countries which record up to 80 % of water use for agriculture (EEA 2018a).

Between the year 2000 and 2017, the EU-28 could decrease water abstraction by 17 %, while increasing its Gross Added Value by 59 % in the same period (EEA forthcoming). Despite this positive trend, water scarcity remains a significant issue for many river basins across Europe, especially in the south. Furthermore, drought events are becoming more frequent and intense due to climate change. They are also striking various areas all across Europe, spanning even up to the Arctic circle (EEA, 2020). According to recent projections, an 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 **Fejl! Henvisningskilde ikke fundet.**).[52] By 2030, half of the EU's river basins are expected to experience water scarcity and stress (Trémolet et al. 2019).

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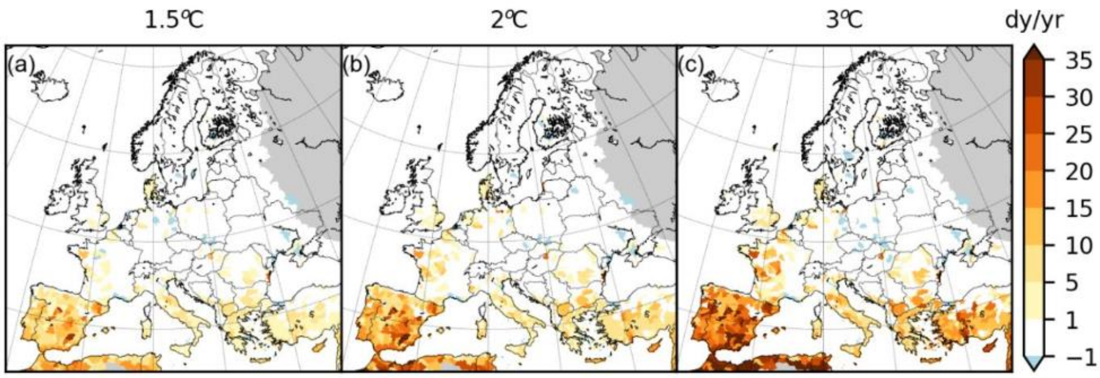
[49] https://ec.europa.eu/environment/water/quantity/about.htm

[50] Throughout this report, the term WFD countries has been used to cover the countries that implement the WFD: the 27 EU Member States, Norway and United Kingdom.

[51] EEA, 2020, Indicator Use of Freshwater Resources in Europe, https://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources-3/assessment-4

[52] JRC Peseta IV, Task 10 report, https://ec.europa.eu/jrc/sites/jrcsh/files/pesetaiv_task_10_water_final_report.pdf

Figure 12 Projected change in water scarcity in the EU under global warming



Notes: Projected change in water scarcity days (WEI+ > 20%) in a year compared with present day for a global temperature increase of (a) 1.5°C, (b) 2°C, and (c) 3°C. The results of both the 1.5°C and 2°C warming levels are based on the average of the 11 climate model simulations from both the RCP4.5 and RCP8.5 emission scenarios, while the results of the 3°C warming level are solely based on the 11 simulation of the RCP8.5 emission scenario.

Source(s): Bisselink et al., 2020

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 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 or causing saline intrusions) (EEA, 2018).[53]

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 affects, such as the decline in species richness and vegetation encroachment. For example, water abstraction converted naturally perennial-flowing rivers to intermittently flowing rivers in Spain, leading to a decline in fish species richness by 35 % (Benejam et al., 2010).[54]

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 salinization and rendering the aquifers unusable as a drinking water supply (EEA 2018a).

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[53] SoW 2018

[54] Benejam, L., Angermeier, P.L., Munné, A., García-Berthou, E., 2010. Assessing effects of water abstraction on fish assemblages in Mediterranean streams. Freshw. Biol. 55, 628−642.

Measures and management challenges

Water stress is caused when demand is relatively high and abstractions take up a significant share of annually renewable freshwater resources or even exceed annual water capacity with withdrawals from non-renewable reserves. In this sense, water scarcity and stress is a complex phenomenon which entails multiple causes that are often interconnected. Thus, an integrated water management approach appears most suited to attain the European and Sustainable Development Goals for water. This includes coherent and consistent policy instruments, education, economic tools, structural interventions where needed, and recourse to new technologies among others. At the moment, water scarcity and droughts policies are mostly legislated and implemented at national level. Several measures are used to address the adverse impacts of water abstractions and water scarcity. These can be roughly divided into demand-side and supply-side measures.

Various policies and measures put an emphasis on managing water demand (demand-side measures). These include disincentivising pricing mechanisms, enhanced awareness-raising, advanced metering, subsidies, and fiscal incentives. For instance, the introduction of water metering mixed with pricing and non-pricing instruments has already lowered the water consumption per capita in large parts of Europe (Dige et al. 2017). In some countries, however, especially in Southern Europe, efforts to address over-abstraction and to secure long-term sustainability remain inadequate (Trémolet et al. 2019). Permit and licensing mechanisms have not been fully effective in averting illegal abstraction and over-abstraction in certain European regions (Ross, 2016).

Supply-side measures include the creation of reservoirs, rainwater harvesting, inter-basin water transfers, desalination and water reuse. Some supply-side measures present their own challenges, e.g. by causing physical alterations in the water environment. Some other supply-side measures do not structurally impact water per se, but rather aim at its infrastructure thereof. These include leakage detection and improvement of irrigation techniques. The common agricultural policy of the EU (CAP) supports farmers to invest in water saving irrigation infrastructures and techniques. At the same time, water efficiency should be promoted across economic sectors in an integrated manner. Overall, further evidence-based exchange is needed among experts and countries on the kind of water supply-side options which are more sustainable and need further promotion.

All in all, both demand and supply-side measures have their advantages and shortcomings. Relying on one type of measures only, is not enough to achieve environmental objectives. Instead, a combination of both sets is desirable to tackle the impacts of water abstractions and scarcity from a consistent and long-term perspective. Techniques may range from water pricing incentives to the reduction of network leakages rates for agricultural businesses (Trémolet 2019).

Strategic planning instruments have also been in use in European countries, such as drought management plans in Spain. These enable to plan, monitor, and mitigate water scarcity situations and enhance decision-making during periods of drought (Stein et al. 2016, 2020; EC 2007).

Preventive actions and recovery policies should be informed by identifying measures based on an ecosystem-based management approach (EEA forthcoming). This presupposes that ecosystemic preservation is just another goal to be pursued alongside production, employment and other policy targets, which have serious implications for water ecosystems in the EU. Integrated water management and nexus approaches to managing the complex system of water-food-energy-environment are becoming increasingly implemented to ensure cross-compliant policy responses to water abstraction challenges among others (ibid.). Both approaches have in common that they take into account environmental as well as sectoral needs (EEA 2018a).

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 (EEA-39) since the early 1990s, mostly due to growing salmon production in Norway (EEA, 2018). For the same period, inland aquaculture has been relatively stable (EEA, 2018). In 2017, EU production of both inland and marine aquaculture was almost 1.5 million tons with a production value of approximately 5 billion EUR (Eurostat, 2019). Overall, though, aquaculture in the EU is of relatively small importance compared to other economic sectors and to other parts of the world (Guillen et al., 2019). In 2017, the production of finfish (particularly, salmon, trout, seabass, carp, and tuna) and molluscs (mussels, oysters and clams) accounted together for almost the entire aquaculture production by weight in the EU (Eurostat 2019). Aquaculture of freshwater fish accounts for about 23 % of total production and is thus smaller than molluscs and crustaceans (ca. 50 %) and marine fish (ca. 27 %) (EC, 2015).

Aquaculture production, both inland and marine, can put significant pressures on European waters related to point and diffuse source pollution, changes in flow, dredging and the introduction of alien species. In the 2nd RBMPs, around 1 400 surface water bodies (mainly rivers) were reported with significant pressures from aquaculture in 20 European countries, with the highest share in Finland, Bulgaria, Hungary, and Czech Republic. Water abstractions for fish farms were the most frequently reported aquaculture pressures, followed by point source pollution, hydrological alterations, and diffuse source pollution.

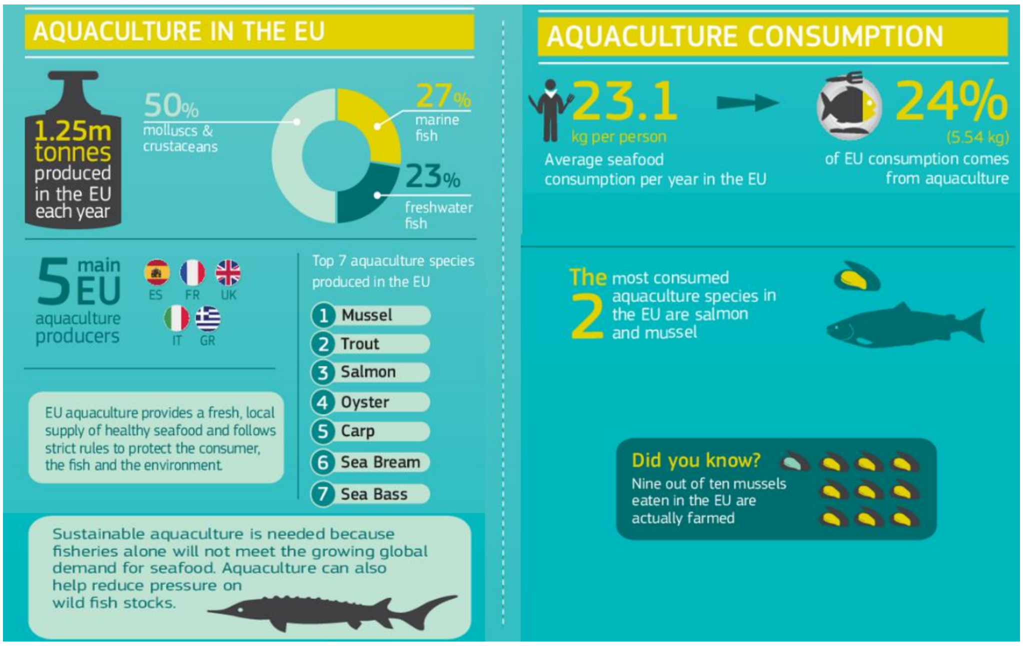
Three major types of *freshwater aquaculture* in European waters can be distinguished (European Commission, n.d.; 2012):

- *Extensive pond farming* which 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/y). It is practiced across the whole Europe and is particularly common in Central and Eastern Europe.
- *Semi-intensive freshwater aquaculture*, whereby the production of the pond is increased by adding supplementary feed, allowing for higher stocking density and production per hectare.
- *Intensive freshwater aquaculture* in tanks, where fish are bred until they reach 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 (European Commission, n.d.; 2012):

- Extensive brackish water aquaculture in artificial lagoons. The semi-extensive nature is characterised by introducing hatchery fry and providing additional feed.
- 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.
- Intensive aquaculture in tanks: Artificial shore-based tanks can be used to breed marine fish. Recirculation of the water creates a closed and controlled environment that is necessary for optimal production in hatcheries and nurseries for marine species.

Figure 13 Aquaculture in the EU



Notes: xxx

Source(s): EC (2015), Modified from infographic on "Facts and figures on EU aquaculture production and consumption in an EU and global context", available online: https://ec.europa.eu/fisheries/cfp/aquaculture/facts_en

Impacts

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, 2014). Potential impacts of aquaculture on aquatic ecosystems include the following:

Aquaculture releases *oxygen consuming substances* and *nutrients* (as excretory products and uneaten fish food) as well *chemical contaminants* (e.g. disinfectants, veterinary medicinal products, trace metals) into water. The released pollutants can cause de-oxygenation 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-platted steal) and antifouling paint used in aquaculture systems can leak to the sea from fish cages and ropes, with toxic effects on ecosystems.

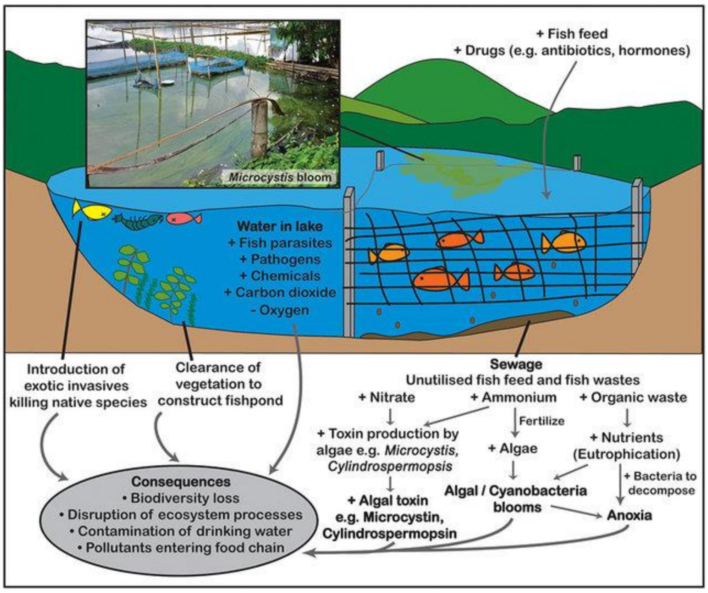
Cultured organisms which *escape from aquaculture production* sites can interbreed and compete with wild stocks as well as introduce pathogen infections. *Sea lice infestations*, for example, can threaten wild fish populations by reducing the survival and reproduction rates of wild salmonids. A number of studies links the presence of fish farms to the outbreak of lice into the environment, particularly in the case of salmon (EC, 2015b).

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 abstractions* that can contribute to decreasing groundwater levels and low flow situations in rivers.

Yet, certain aquaculture practices such as extensive exploitation can also have positive effects on the natural environment. By acting as water reservoirs, aquaculture ponds can help to manage flooding during periods of high rainfall and retain water for irrigation during dry periods. Aquaculture can also serve biodiversity purposes. Net-pen farms, for example, can become aggregating sites for wild fish, and act as small-scaled marine protected areas due to the prohibition of fishing within farm leasehold areas.

Figure 14 Examples of potential environmental impacts of aquaculture



Notes: xxx

Source(s):
https://www.researchgate.net/publication/288315760_Establishing_the_impacts_of_freshwater_aquaculture_in_tropical_Asia_the_potential_role_of_palaeolimnology/figures, 2015

Measures and management challenges

A broad range of management and technical measures exist to tackle the adverse impacts of aquaculture on European waters. At national and regional level, an important regulatory instrument is to set limits to production levels as this can mitigate negative impacts of aquaculture on the water environment (European Commission, 2016). Denmark, for example, decided in 2019 to stop the creation of new aquaculture facilities and the expansion of existing ones in the country. This is because coastal areas and inland waters are overloaded with nitrogen and mitigation measures have not been enough in tackling the issue. In Denmark, there is also government financing to support the removal of weirs on rivers built for use in fish farming facilities.[55]

Improving the siting of aquaculture operations is another management measure to reduce adverse impacts. The Norwegian Aquaculture Act, for example, requires an environmental impact assessment for new aquaculture sites, and it calls on fish farms to be located in areas with better biological recipient conditions, high bearing capacity and generally good self-cleaning properties.[56]

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[55] https://salmonbusiness.com/no-more-fish-farms-announces-danish-government/ & https://www.european-views.com/2019/08/denmark-to-halt-development-of-sea-fish-farming-sector/

[56] FAO (2017) Policy and governance in aquaculture: lessons learned and way forward, Fisheries and Aquaculture Technical Paper 577

Technical methods, management systems and practices should be incorporated into more formal "Codes of Practice" adopted voluntarily across the whole aquaculture industry (Phillips et al. 2001). Codes of "best management practices" should contain (Phillips et al., 2001):

- Decreased use of fertilizers, antibiotics and chemicals, their replacement with non- 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).
- Implementation of zonal or area management plans, as part of river basin management plans, to reduce the overall disease and parasites burden on sites (Science for Environment Policy, 2015).
- Transport of fish as fertilized eggs (not as living animals), to reduce the spread of diseases from introduced aquaculture species (Peeler et al., 2011).
- Sterilization of farmed species to control the impact of escapees and alien species (Science for Environment Policy, 2015).
- Treatment of wastewater from closed systems (tanks, ponds), i.e. with techniques comparable to urban and animal farming waste treatment.

Within the EU, production from aquaculture is not expected to grow significantly in the future despite a 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 recognized as a source of significant pressures on waters, but the Water Framework and Marine Strategy Framework Directives do not contain explicit obligations for aquaculture yet. Further integration of measures on the farm site level with regulatory measures at the river basin, national and EU level is required to reduce the adverse effects of aquaculture production on European waters.

3.5 Invasive alien species

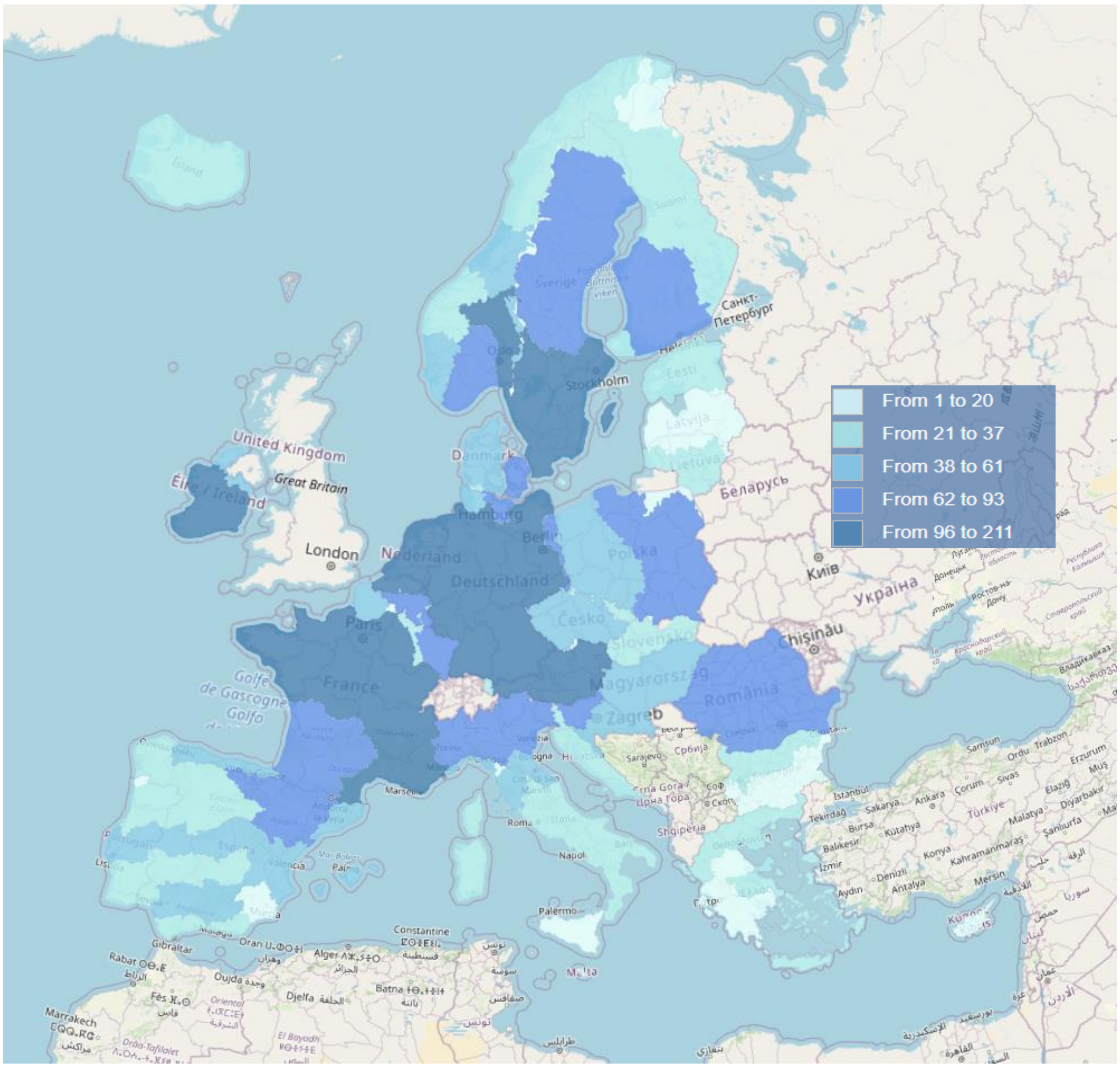
Overview

Alien species are plants and animals that have deliberately or accidentally been introduced outside their natural range. When finding 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 (IAS) are thus a significant pressure to the good ecological status of surface waters, aquatic habitats and species in general. Within the 2nd RBMPs, 15 European countries reported IAS as a significant pressure for ca. 2 700 water bodies (2 % of total) with the highest proportion being reported in Spain, the Netherlands, Norway, and Slovakia.

It is estimated that there are ca. 750 freshwater species which are established aliens 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 IAS 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 data from EASIN, the highest numbers of freshwater alien species have been registered in river basin districts in France, Germany, Netherlands, Belgium, Sweden and Ireland (**Fejl! Henvisningskilde ikke fundet.**).

Figure 15 Number of European freshwater alien species in river basin districts



Notes:

Source: European Commission - Joint Research Centre - European Alien Species Information Network (EASIN) https://easin.jrc.ec.europa.eu/; Map created on 6 November, 2020.

Alien species are mainly introduced to freshwaters via aquaculture followed by releases and escapes of pet/aquarium species. Furthermore, introductions through inland canals or shipping (e.g. with ballast water) and fisheries/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, e.g. if temperature increases, currently natural thermal barriers which normally limit the establishment of IAS will become more suitable for alien species. This will potentially lead to a geographical redistribution of species and create alien invasive 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, micro-organisms, and fish. The rate of introductions in the marine environment is continually increasing, with almost 300 new species reported since the year 2000 (EEA 2012).

Impacts

Invasive alien species (IAS) threaten native wildlife, alter communities, affect the food webs, and introduce new constraints to the recovery of the 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 natural vegetation and ecosystems impossible. Invasive plants have disrupted navigation and damaged waterworks by blocking pipes and pumps. This also included pumping intakes for cooling water of nuclear power plants resulting in safety problems (Sarat, et al., 2015). For example to control damage of floating pennywort in the Netherlands the total annual control costs have been around 1 million Euro (BirdLife International, n.d.).

Some invasive aquatic invertebrates have had major effects on the ecosystems that they invade, e.g. the red swamp crayfish and the distribution of the crayfish plague. The plague is estimated to have economic cost in Europe of over €53 million/year (EC 2019c). The zebra mussel *Dreissena polymorpha* forms dense encrustations, which provoke 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 can significantly alter ecosystems (BirdLife International, n.d.). Alien species may also act as carrier of fungus organisms or spread diseases (Strayer, 2010).

Invasive freshwater fish e.g. from stocking disrupted the food web, when predating the native smaller fish and their food, and simplified the original communities (BirdLife International, n.d.). Escapes from aquaculture (e.g. salmon) changed genetic behaviour of natural populations.

Measures and management challenges

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

Prevention measures are pathway oriented and aim at preventing the intentional or unintentional introduction. One example is ballast water management (under the Ballast Water Management Convention), where the ballast water of ships has to be treated or filtered, or exchanged in the open sea before entering the freshwater ecosystems to avoid introduction of IAS e.g. Chinese mitten crab. To avoid further spread of invasive plants between unconnected water bodies by e.g. 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.

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

Management measures aim at minimizing the harm IAS cause. Examples are the commercial use of the Chinese mitten crap for food consumption, biological control (manipulation) of the food web of an ecosystem or the use of herbicides to control massive invasive plant growth.

Besides the IAS Regulation, other policies tackle aquatic alien species as well. Under the WFD, alien species were identified and monitored as a pressure in European water bodies. But, only a low number of measures to reduce the pressure of alien species were implemented within the 2nd RBMP (EC 2019d). Other relevant policies include the Marine Strategy Framework Directive which sets specific objectives for managing alien species (non-indigenous species) in European seas to reach good environmental status, and the Regulation concerning use of alien and locally absent species in aquaculture (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 more efficient protection of naturally occurring aquatic communities, since 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 IAS and these should be more closely coordinated with the programme of measures of the WFD RBMPs as well as the programmes of measures under the MSFD. Under consideration of the significant increase of alien species in freshwaters and the marine environment in recent decades, there is risk that the number of alien species continues to rise with high impact on biodiversity, if no harmonization and efficient management strategies are implemented.

4 Cross-cutting issues for European key water management challenges

4.1 Introduction

Section 3 of this report presented selected European key water management challenges which put European water bodies most at risk of achieving the WFD environmental objectives. The drivers and pressures of these challenges have been described and their key impacts outlined on water ecosystems. Also, a summary of key measures was presented, which are available to tackle the issues and of management challenges of EU-wide relevance. A broad range of technical and management measures are already available, while details will be provided on specific measures required 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 required measures.

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

In 2021, the European Commission will provide an overview of progress on implementing measures of the second Programme of Measures. The Fitness Check Evaluation of the WFD and the Floods Directive (EC, 2019)[57] though already indicated that the main reasons, that the WFD objectives have not been fully reached yet is due to insufficient funding, slow implementation and insufficient integration of environmental objectives in sectoral policies including gaps in EU water legislation. Similarly, the evaluation of the UWWTD concluded that the UWWTD is overall fit for purpose although there is room to enhance its positive effects and to step up implementation in a number of Member States. However, the UWWTD does not adequately deal with emerging pollutants such as pharmaceuticals and microplastics (EC, 2019).[58]

It is thus expected that the measures required to tackle the European key water management challenges presented in this report can be mobilised through *better implementation of the existing legislative framework* on water (basic measures under 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 European key water management challenges indicate that the following are cross-cutting issues of EU-wide relevance to measures implementation:

- The need for more harmonization of the objectives and management responses of different directives and strategies, which set the EU policy context for taking actions and measures
- The need to coordinate sectoral developments with river basin management planning under the WFD
- The funding of measures

[57] EC, 2019, Fitness check of the Water Framework Directive and Floods Directive, https://ec.europa.eu/environment/water/fitness_check_of_the_eu_water_legislation/documents/Water%20Fitness%20Check%20-%20SWD(2019)439%20-%20web.pdf

[58] EC, 2019, Evaluation of the Urban Waste Water Treatment Directive, https://ec.europa.eu/environment/water/water-urbanwaste/pdf/UWWTD%20Evaluation%20SWD%20448-701%20web.pdf

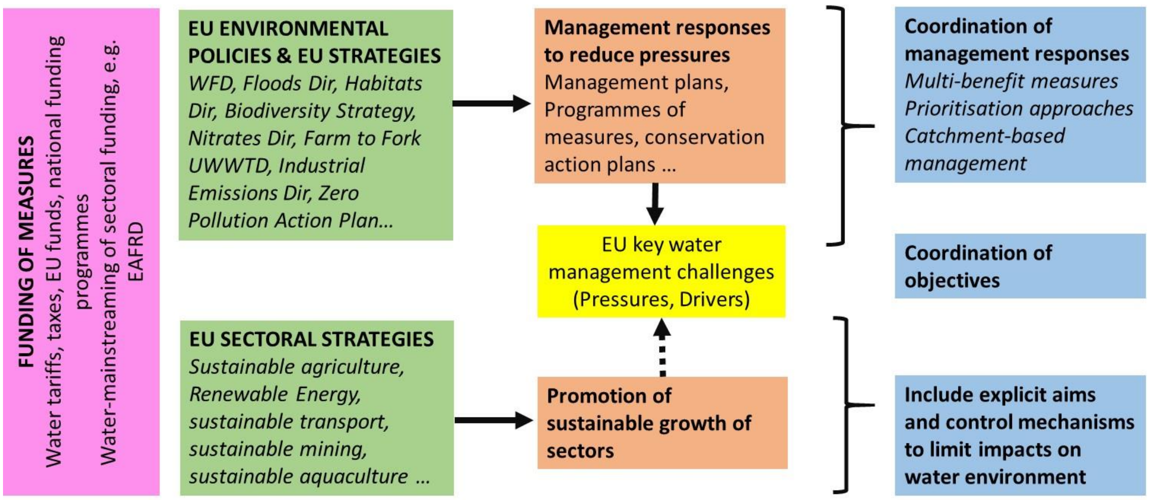
These cross-cutting issues are discussed in this chapter, with emphasis on:

- Their role in improving and accelerating the implementation of measures to achieve WFD objectives, and
- The identification of actions and coordination requirements for the EU-wide level.

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

The cross-cutting issues discussed in this chapter are outlined in Figure 16.

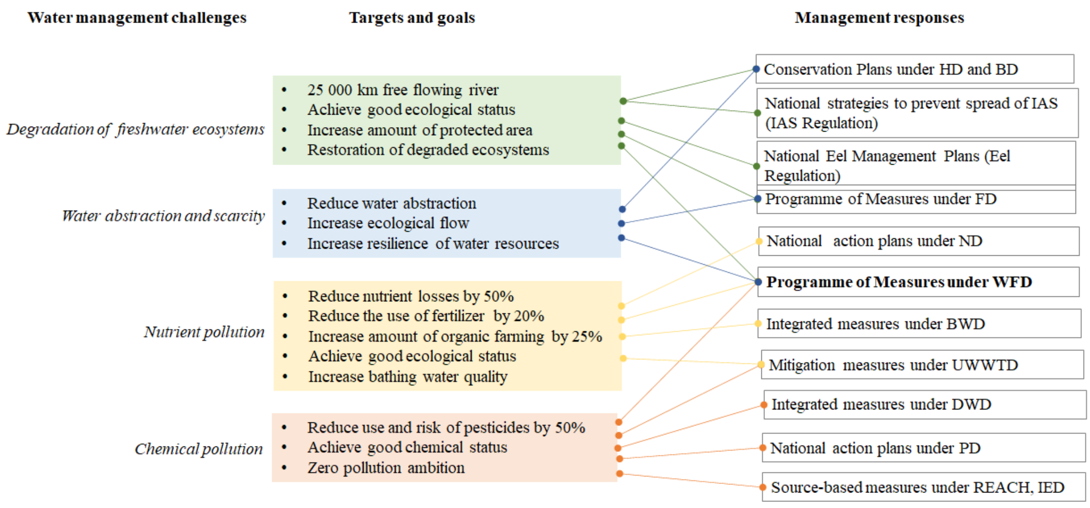
Figure 16 Cross-cutting issues for European key water management challenges



4.2 Coherence of EU policy targets and management responses

The degradation of freshwater ecosystems, water abstraction and scarcity, as well as nutrient and chemical pollution are key European water management challenges which affect a large share of European water bodies as described in section 3. To address these management challenges, targets and goals are set in European strategies as part of the Green Deal and of other major EU policies previously adopted. The set EU targets and goals are linked to a number of management responses and measures, which are required by a broad set of EU environmental directives. These linkages are illustrated in Figure 17.

Figure 17 Overview of key European water management challenges, defined EU goals and targets as well as management responses addressing the challenges



Notes: HD=Habitats Directive, BD=Birds Directive, IAS=Invasive Alien Species, FD=Floods Directive, ND=Nitrates Directive, WFD=Water Framework Directive, BWD=Bathing Water Directive, UWWTD=Urban Waste Water Treatment Directive, DWD=Drinking Water Directive, PD=sustainable use of pesticides Directive, IED=Industrial Emissions Directive.

To meet EU targets and goals on water resources and aquatic ecosystems, greater coherence is needed in the specific objectives and management responses of the relevant EU directives and policies. To implement the Green Deal, better harmonization 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 FD and other management plans and strategies with implications for pressures on water.

For better harmonization multi-benefit measures should be better used, such as nature-based solutions or natural water retention measures addressing the goals of different policies (see section 4.5). The planning of multi-benefit measures also considers different water uses and socioeconomic 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, like the provision of high-quality drinking water, the 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 of water management under the specific directives.

Catchment-based approaches, which encourage the integration of all water and land uses on catchment scale, are also in line with the goals of European strategies. This requires engagement and delivery by stakeholders at the catchment as well as local level in coordination with responsible authorities. At the same time, engagement of all stakeholders in the catchment increases the acceptance for measures implementation. 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 to 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 infiltration, through the re-establishment of wetlands and increased recharge of aquifers. Spending on 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 more adapted to dry conditions or growing different crops that require water at different times of the year.

There are several European 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, like the action plan to avoid water pollution with pesticides from agriculture, are a prerequisite to achieve European targets and goals, if their activities are adapted to the respective country conditions.

To sum up, European key water management challenges are addressed by targets of EU strategies and policy initiatives, which are further operationalised in management responses of different water and environmental directives. Management 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.

4.3 Coherence of sectoral strategies with water policy objectives

In the EU, water bodies are used for a variety of economic activities, among which navigation for trade and transportation, agricultural and industrial processes involving water abstraction, hydropower production, extraction of minerals as well as aquaculture. From the assessment of status, pressures and impacts on European waters (EEA, 2018), it is evident that the driving forces behind the achievement or non-achievement of good status are activities in economic sectors. 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, 2018).

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 pressures and impacts of the sector's activities on water resources. In the following, a number of 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, Art. 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 as well as a lower use of pesticides in areas close to surface waters and groundwater infiltration hotspots. Overall, the water environment could benefit from more integration of water aspects in agricultural production. The combination of innovative technologies such as drop 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.

Box 3 Restriction of pesticides use and other sustainable farming programmes

Belgium sets out different measures to integrate pesticides with sustainable water management (NAPAN, 2014). One measure focuses on restrictions in buffer zones, which are set at 2 to 30 meters depending on the size of the water and extent of land use. In France, economically grounded measures have been set up. The French Agency for Food, Environmental and Occupational Health & Safety (ANSES) has implemented the Ecophyto Plan which aimed to halve pesticide use by 2018. To that end, environmental taxes on sales of pesticides have been introduced. The United Kingdom implements a catchment sensitive farming programme. The scheme investigates impacts of agricultural practices, relevance of applied measures and draws out best practices in the sector (Thorén, 2017). In Ireland it is not allowed to apply organic or chemical fertiliser or dilute slurry when heavy rain is forecasted within 48 hours or when the ground slopes are steep and a risk of water pollution exists (Amery and Schoumans, 2014)

Mining can lead to groundwater and surface water chemical pollution, as well as lowering groundwater tables and disrupted flows. These pressures threaten the status of water ecosystems well beyond business operations as discharge of pollutants is longer than the mine life-cycle. Measures which 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) constitute generally the bulk of Best Available Techniques (BAT) 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 2006/21/EC, 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 different measures to counteract these is now an integrated part of a variety of mining business activities (see Box 4).

Box 4 Acknowledging water and environmental aspects in the mining sector

The European Aggregates Association acknowledges in a brochure on "Water management"[59] "that any extraction of a mineral resource will potentially generate qualitative and quantitative impacts on water resources" and describes the sectors role in relation to river basin management planning, including limiting the impacts on water quantity and quality. In other publications, the European Aggregates Association focusses on the gravel processing sites and suggests different measures focusing on reducing the impacts on water including recycling of process water.[60] In addition, Euromines, the European metals and minerals mining industry, promotes different activities in relation to sustainable development and environmental protection.[61] Euromines requires its members to perform an environmental impact assessment, as well as

[59] http://www.uepg.eu/uploads/Modules/Publications/uepg_water.pdf

[60] http://www.uepg.eu/uploads/Modules/Publications/uepg-unpg-water-management-brochure.pdf

[61] ttp://www.euromines.org/files/what-we-do/sustainable-development-issues/euromines-sustainable-development-guidelines-jan2012.pdf

a continuous update of 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).[62]

Energy production via hydropower installations also impacts aquatic ecosystems by altering flows of water bodies, disrupting river continuity and causing degradation of ecosystems. Although the largest development of hydropower in Europe has already taken place, new hydropower plants are being development especially in the Balkan region and many more (especially small ones) are in 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 **Fejl! Henvisningskilde ikke fundet.** of this report). These give strategic directions for the revision of licenses of existing hydropower plants and for the further development of new hydropower in order to mitigate or prevent hydropower impacts on the water environment.

Sustainable *navigation* strategies and guidelines are being introduced on the EU, national and even regional/river basin level (see examples of European guidelines and national or regional programmes and strategies for sustainable inland navigation in section **Fejl! Henvisningskilde ikke fundet.**). These strategies and guidelines call for sustainable navigation across inland waters through a variety of cross-cutting criteria and measures. These include preservation of river banks, stringent fuel standards, more efficient infrastructures 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 among the sustainable means of transportation in the EU by 2030 and calls for European navigable waterways to attain "good navigation status" (GNS). While the concept of GNS evolves and guidelines for its achievement (Muilerman et al., 2018)[63] are applied, further efforts are needed to ensure that the WFD objectives of good ecological status or potential and the concept of GNS are coherent (CIS WFD, 2017).[64]

Aquaculture affects water quality (through increased nutrient load and emission of cleaning agents and medicinal products) as well as 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 of 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 bear great potential. European legislation in place tries to minimize the adverse environmental effects of aquaculture, for instance planning and development of new aquaculture operations has to be in line with the Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) directives. According to these directives, environmental concerns have to be included early on in the planning process which helps to 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 the development of a protocol of best practices to ensure interoperability and clarity for aquaculture owners. Regulatory codes for monitoring as well as sustainable management practices should follow, including the use of

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[62] http://www.euromines.org/files/what-we-do/sustainable-development-issues/euromines-sustainable-development-guidelines-jan2012.pdf

[63] Muilerman, G. J. Et al. (2018), Good Navigation Status, Guidelines towards achieving a Good Navigation Status. Luxembourg: Publications Office of the European Union, 2018.

[64] CIS WFD, 2017, Workshop report, Workshop on mitigation measures and GEP for Inland Navigation water use, 29th – 30th June 2017.

latest water purification and monitoring technologies. Finally, aquaculture should be integrated into further spatial planning tools, especially in the light of river basin management plans, 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 5 Code of good practice for aquaculture in Scotland

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 committed to sustainable development practices in aquaculture, ranging from sustainable use of natural heritage to the sustainability of feed ingredients themselves. One of the main targets of the code is the minimisation of the environmental impact of aquaculture sites in the Scottish environment, including both freshwater and seawater lochs and tanks. The code is audited by independent actors, 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 for ongoing and future developments that impact European waters. Despite different priorities and investment cycles, over the past 15 years many sectors have shown attempts to acquire up-to-date knowledge and act on environmental aspects, including sustainable water resource management. This development has partly been set in motion by regulation and to a certain extent by private initiatives. Some private businesses, for instance the Scottish aquaculture industry or the European Mining Association, 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, for instance drop irrigation to reduce pressure on scarce water resources for irrigation. More initiatives of this kind are needed across all key sectors impacting water resources. In particular, a consistent combination of multiple policy tools from the Water Framework Directive, the Common Agricultural Policy and the Energy & 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 actually being implemented. Enhanced resources for enforcement, capacity-building and incentives to transition towards sustainable business models are needed, especially on the local level. Cooperation on the local, national and EU level 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 of achieving the WFD 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 as well as one of the key reasons causing delay or non-completion of basic measures at EU level (EC, 2019).

The sources of funding for WFD measures are a combination of EU, national, regional, and municipal funds, direct financing by sectors and the general 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 via the water prices charged. Box 6 presents the example of the "water cent" in Germany which is an additional charge levied on groundwater abstraction and used to fund pollution reduction measures in agriculture. Also 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. The majority of these funds initially financed piped water and sewer network expansion and rehabilitation, as well as investments in wastewater 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 the Danish fishing license fees and among others covers activities such as the improvement of the living conditions and habitats for fish (Danish Fisheries Agency, 2020). Similar schemes are found in other European countries.

Box 6 "Water cent" in Germany

13 of the 16 German federal states have introduced the so-called "water cent" as a charge for water abstraction from surface and groundwater[65]. The first federal state which introduced the "water-cent" did so already in the late 1980s, while several other states followed after the adoption of the WFD in 2000.[66] The objective of this instrument is, on the one hand, to encourage the conservation of precious water resources.[67] On the other hand, the collected surcharges have been mainly used to compensate farmers for reducing the use of nitrogen and pesticides in order to reduce the pollution levels of key drinking water sources. In at least one federal state, however, plans have been announced to use the revenue from the "water cent" (whose amount has recently been increased) also for flood protection measures.[68]

For several decades now, a large part of funding available for water resource management is being invested to improve water quality via investments in sewers and wastewater treatment. In a recent study, the 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 Urban Waste Water Treatment Directive and the Drinking Water Directive. Total cumulative additional expenditures by 2030 for water supply and sanitation amount to EUR 289 billion for the EU Member States including UK. The main sources of finance for water supply and sanitation expenditures 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, for some it will be difficult to increase levels of public budgets allocated to water supply and sanitation. While affordability constraints are mentioned to justify tariffs below cost recovery levels, data shows that in most EU Member States, more than 95 % of the population could pay more without facing an affordability issue (OECD, 2020).

[65] https://www.umweltbundesamt.de/themen/wasser/wasser-bewirtschaften/oekonomische-fragen#nationale-abgaben-und-entgelte
[66] https://recht-energisch.de/2018/12/10/wie-viel-cent-kostet-der-wasserpfennig/
[67] https://www.bmu.de/en/topics/water-waste-soil/water-management/policy-goals-and-instruments/water-protection-policy-in-germany/
[68] https://www.swp.de/suedwesten/staedte/sachsenheim/langer-atem-gegen-nitratbelastung-26790436.html

Concerning EU funding sources targeting the WFD, it is worth noting that the *WFD does not have its own specific EU funding for implementation*, but it is integrated into the budget of the EU LIFE financing instrument for environment and climate (Carvalho et al., 2019). LIFE funding amounts to €3.4 billion for the period 2014–2020. As a result of this vast difference in EU funds, the implementation success 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. Industrial Emissions Directive). 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 highly important to understand *synergies of water policy with other policy areas*. In the CAP (reform 2014-2020), there are for example various instruments to improve sustainability also in term of EU water policy objectives: cross-compliance (linking certain CAP payments with specific environmental requirements), the Green Direct Payment 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 via the European Fisheries Fund (EFF). The EFF 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 which 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 fish farmers must change their entire water circulating system and at a cost (from flow-through to recirculated systems). To support fish farm weir removal on Danish streams and rivers, a governmental finance support scheme was set up (AMBER, undated).

Also, the new Biodiversity Strategy for 2030 foresees that at least €20 billion a year should be unlocked for spending on nature (EC, 2020). As the new Biodiversity Strategy 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 of degraded ecosystems), part of the forthcoming funding sources should be invested in water-related measures.

Overall, there is need to explore in-depth and effectively communicate further policy synergies which 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 (link to land use and planning issues) and the Green Infrastructure Strategy (link to the development of infrastructure in urban or rural settings). Especially, urban rivers and lakes are often target of combined aquatic ecosystem restoration and green infrastructure for reducing flood risk, thereby also securing funding from multiple sources (EEA, 2016).

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

- In Scotland, a 'Water Environment Fund' was set up to improve the physical condition of water bodies to meet WFD objectives (Box 7).

- In Finland, a National Fish Pass Strategy was adopted in 2012 to steer the construction of fish passages during the first three periods of water management planning until the end of the 2020 (Vehanen et al, 2015).
- In Ireland, an Environmental River Enhancement Programme was developed between 2008-2012 dealing in part with river morphology enhancement (O Grady et al., 2013).
- In Germany, a connectivity programme for barriers at federal waterways, several federal states programmes and the Blue Ribbon Programme were adopted. The latter (see 4.3), started in 2017, shall run until 2050 with a budget of 50 million €/a for the restoration of rivers and their embankments and another 12-15 million €/a for the restoration of floodplains.[69]

Overall, however, public funds alone will not be sufficient to support the large number of measures needed for the achievement of WFD 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 licenses in the next 20 years (SWAM, 2019). The fund consists of contributions from all the main hydropower producers of the country and will support mitigation measures at hydropower plants which cannot otherwise afford this type of interventions.

In addition, the EU has been developing standards to further link financial investment with environmental protection (see Action Plan for financing sustainable growth (EC, 2018)), which could pose restrictions to investments in sectors that cause impacts on water bodies (e.g. transport, energy production). Building on the 2018 Action Plan, the renewed sustainable finance strategy to be presented later in 2020 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, 2020b).

Box 7 The Water Environment Fund in Scotland

The aim of the Scottish Government 'Water Environment Fund'[70] is to improve the physical condition of water bodies to meet the objectives of the WFD. The program also aims to bring wider benefits to designated nature conservation sites, local fisheries and angling opportunities, community amenity and urban green space creation.

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

The program has led to river channel restoration (including re-meandering), 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: https://www.sepa.org.uk/environment/water/water-environment-fund/

69 https://www.blaues-band.bund.de/Projektseiten/Blaues_Band/DE/00_Home/home_node.html, https://www.gewaesser-bewertung.de/files/wrrl_englische_version_dez_2016.pdf

70 https://www.sepa.org.uk/environment/water/water-environment-fund/

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, implementation success depends on identifying synergies and financing opportunities with other policy areas including sectoral ones (e.g. agricultural policy, fisheries policy, biodiversity policy). Also, public funds (EU and national) need to be complemented with other innovative financing mechanisms, especially those that involve industrial and other private sector partners.

4.5 Measures with multiple benefits

Measures with multiple benefits can be understood as actions which are beneficial to the achievement of 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 ecosystems for example self-purification, water storage or nutrient sequestration, recreation, and other ecosystem services.

Several water management measures can deliver multiple benefits such as river and floodplain restoration, integrated freshwater and coastal zone management, or projects like 'making room for the river'. 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 impacts of droughts and makes the landscape nicer 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, like the 7th EAP, the Biodiversity Strategy or Farm to Fork Strategy, goals are sustainable resource efficiency and the use of an 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 Green Deal on circular economy actions.

Management measures that work with nature and not against it, often result into a win-win situation. Multi-benefit measures serving nature conservation and water policy objectives (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 with high protection status. Prerequisite for such migratory fish species is the longitudinal continuity of the rivers and the connection to the sea. In addition, this is in line with targets of the Eel Regulation (EC, 2007) and the target of the new Biodiversity Strategy 2030 for 25 000 km free flowing rivers. Multi-benefit measures to recover longitudinal continuity 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 e.g. sediment improvement to restore spawning grounds.

Natural Water Retention Measures (NWRM) can be used as measures to meet 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 …*"([71]). Within a recent EU project, about 45 NWRM with multi-benefits for urban areas, forests,

[71] Source: http://nwrm.eu/concept/3857

rivers, and agricultural areas were identified and linked to ecosystem service benefits as well as illustrated in a number of European case studies ([72]).

A multi-benefit measure increasingly being acknowledge for its importance is the restoration of floodplains that 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 (NBS) aim for e.g. multi-functional nature-based catchment management and ecosystem restoration, or enhancing the insurance value of ecosystems. A list of some 300 different nature-based solution measures and their linkage to ecosystem services shows, how diverse the use and their applicability in several sectors, like flood protection, climate change adaptation, sustainable urban development or water management, can be (Sutherland, et al., 2014).

There are many national activities in Europe aimed at NBS, such as the Dutch Room for the River (see Box 8).

Box 8 Room for the river in the Netherlands

One example of implementation of nature-based solutions in the context of improving risk management and resilience of aquatic ecosystems is the 'Room for the River' Programme in the Netherlands. The developed strategy focusses on making more space for water to better prevent floods by lowering the level of high water and to offer spatial quality to the area reconnecting people and rivers. Several projects have been carried out at 30 locations in the Netherlands, where dykes were relocated, high-water channels constructed, and floodplains lowered ([73]). For example, in the area of the city of Nijmegen a 350 meters long dyke was relocated, and an ancillary channel was built. This project offers multiple benefits: The reduction of the water level by 35 cm, and brings also new potential for the development of the city by the creation of an urban river park with possibilities for recreation and nature (EC 2015). The total costs are 360 million Euro.

Besides establishing linkages between the WFD, the Floods Directive and nature conservation policy, measures with multiple benefits can also contribute to linking up to the Marine Strategy Framework Directive (EU 2008) is required. This is mainly due to 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. Within the 2nd RBMPs, some 70 % of all RBDs reported a link between the WFD and the MSFD; they also indicate a high number of measures listed under the WFD as relevant to also reach the objectives of the MSFD, in particular measures to reduce nutrient pollution from both diffuse and point sources as well as reduction of hazardous substances (EC 2019d).

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

[72] Source: http://eu-nwrm.eu

([73]) Source: https://www.rijkswaterstaat.nl/english/about-us/gems-of-rijkswaterstaat/room-for-the-river/index.aspx

List of abbreviations

Abbreviation	Name	Reference
BAT	Best available techniques	
BOD	Biological Oxygen Demand	
CAP	Common Agricultural Policy	
DOC	Dissolved organic carbon	
EEA	European Environment Agency	www.eea.europa.eu
EFF	European Fisheries Fund	
EWD	Extractive Waste Directive	
EWMP	Extractive waste management plan	
E-PRTR	European Pollutant Release and Transfer Register	
FRMP	Flood Risk Management Plan	
IAS	Invasive Alien Species	
IED	Industrial Emissions Directive	
PAH	Polycyclic aromatic hydrocarbons	
RBMP	River Basin Management Plan	
MSFD	Marine Strategy Framework Directive	
MW	Megawatt	
NBS	Nature-based solutions	
NWRM	Natural Water Retention Measures	
TEN-T	Trans-European Transport Network	
UWWTD	Urban Waste Water Treatment Directive	
WEI	Water Exploitation Index	
WFD	Water Framework Directive	

References

For print references use the following format:

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Author's surname, author's initial(s)., year of publication, *Title of reference work (where appropriate include edition number)*, publisher, (URL) accessed ../../....

To be updated in Zotero for final version (need access to EEA Zotero Reference List):

References in zotero (JV):

BirdLife International, 'How do Invasive Alien Species impact on biodiversity in the EU? A BirdLife Europe fact sheet BACKGROUND', (https://www.birdlife.org/sites/default/files/attachments/Fact-sheet-on-Invasive-Alien-Species-in-Europe.pdf).

BirdLife International, 'Invasive Alien Species - 10 Horror Stories', (https://www.birdlife.org/europe-and-central-asia/invasive-alien-species-10-horror-stories).

BMU/UBA, 2016, *Water Framework Directive. The status of German waters 2015.*, Bonn, Dessau.

Canova, M., Pinasseau, A., Roth, J., Roudier, S., Zerger, B., European Commission and Joint Research Centre, 2018, *Best available techniques (BAT) reference document for waste treatment: Industrial Emissions Directive 2010/75/EU (integrated pollution prevention and control)*, Publications Office of the European Union, Luxembourg.

Cid, N. and Cardoso, A. C., 2013, 'European Freshwater Alien Species', (atlas.freshwaterbiodiversity.eu) accessed March 3, 2020.

DEFRA, 2013, *Catchment Based Approach: Improving the quality of our water environment. A policy framework to encourage the wider doption of an integrated Catchment Based Approach to improving the quality of our water environment*,

EC, n.d., 'Factsheet. Water is too precious to waste.', (https://ec.europa.eu/environment/water/pdf/water_reuse_factsheet_en.pdf).

EC, 2007, Council Regulation (EC) No 1100/2007 of 18 September 2007 establishing measures for the recovery of the stock of European eel

EC, 2013, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the

Regions — An EU Strategy on adaptation to climate change, COM(2013) 216 final, Brussels, 16.4.2013.

EC, 2014, *EU policy document on natural water retention measures by the drafting team of the WFD CIS Working Group Programme of Measures (WG PoM)*, European Commission Directorate-General for Environment, Brussels.

EC, 2015, *Towards an EU research and innovation policy agenda for nature-based solutions and re-naturing cities*, European Commission, Brussels.

EC, 2016, Commission Staff Working Document — key European action supporting the 2030 agenda and the Sustainable Development Goals — accompanying the document: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: next steps for a sustainable European future: European Union action for sustainability {COM(2016) 739 final}, SWD(2016) 390 final.

EC, 2017a, *Assessment of Member States' performance regarding the implementation of the Extractive Waste Directive; appraisal of implementation gaps and their root causes; identification of proposals to improve the implementation of the Directive,*

EC, 2017b, *Commission Staff Working Document. Agriculture and Sustainable Water Management in the EU*,

EC, 2019, Annex to Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — the European Green Deal

EC, 2019a, Commission staff working document — Evaluation of the Council Directive 91/271/EEC of 21 May 1991, concerning urban waste-water treatment, SEC(2019) 448 final; SWD(2019) 701 final., {SEC(2019) 448 final}-{SWD(2019) 701 final}

EC, 2019b, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — the European Green Deal, COM(2019) 640 final.

EC, 2019c, 'Invasive alien species', *European Commission* (https://ec.europa.eu/environment/nature/invasivealien/index_en.htm) accessed October 21, 2019.

EC, 2019d, Report from the Commission to the European Parliament and Council on the implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC) — Second river basin management plans — First flood risk management plans, COM(2019) 95 final.

EC, 2019e, Report from the Commission to the European Parliament and the Council. Implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC) Second River Basin Management Plans First Flood Risk Management Plans, SWD(2019) 54 final.

EC, 2019f, *Study supporting the elaboration of guidance on best practices in the extractive waste management plans: final report.*, EC, 2020a, Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions - Chemicals Strategy for Sustainability Towards a Toxic-Free Environment, COM(2020) 667 final

EC, 2020b, Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions - EU Biodiversity Strategy for 2030. Bringing nature back into our lives., COM(2020)380 final

EC, 2020c, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system, COM/2020/381 final.

EC, 2020, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — A new circular economy action plan for a cleaner and more competitive Europe, COM(2020) 98 final.

EC, 2020d, 'From Farm to Fork: Our food, our health, our planet, our future. The Green Deal.', (https://ec.europa.eu/commission/presscorner/detail/en/FS_20_908).

EC, 2020e, Proposal for a Decision of the European Parliament and of the Council on a General Union Environment Action Programme to 2030 (8th EAP)

EC and Directorate-General for Health and Food Safety, 2017, *Sustainable use of pesticides: overview report*, Publication Office of the European Union, Luxembourg.

EEA, 2010, *The European environment — state and outlook 2010*, Synthesis Report, European Environment Agency.

EEA, 2012, *European waters — assessment of status and pressures*, EEA Report, 8/2012, European Environment Agency.

EEA, 2018a, *European waters - assessment of status and pressures 2018*, EEA Report, 7/2018, European Environment Agency.

EEA, 2018b, 'Pesticide sales — environmental indicator report 2018 briefing', *European Environment Agency* (https://www.eea.europa.eu/airs/2018/environment-and-health/pesticides-sales) accessed March 26, 2019.

EEA, 2019a, *Industrial waste water treatment — pressures on Europe's environment*, EEA Report, 23/2018, European Environment Agency.

EEA, 2019b, *The European environment — state and outlook 2020: knowledge for transition to a sustainable Europe*, European Environment Agency.

EEA, 2019, 'Urban waste water treatment for 21st century challenges', (https://www.eea.europa.eu/publications/urban-waste-water-treatment-for).

EEC, 1979, Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds, OJ L 103, 25.4.1979, p. 1-18., 79/409/EEC

EEC, 1992, 'Habitat Directive - Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora', (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0043:EN:html) accessed August 29, 2012.

Endl, A. and Berger, G., 2016, *Minerals Policy Guidance for Europe. Taking stock on EU and EU MS mineral policy and legislation*, Deliverable 2.1, Version 1., Austria.

ERMITE-Consortium, Younger, P. L. and Wolkersdorfer, C., 2004, 'Mining Impacts on the Fresh Water Environment: Technical and Managerial Guidelines for Catchment Scale Management', *Mine Water and the Environment* 23(S1), pp. s2–s80 (http://link.springer.com/10.1007/s10230-004-0028-0) accessed March 26, 2020.

EU, 1991a, Council Directive 91/271/EEC of 21 May 1991 concerning urban waste water treatment, OJ L 135, 30.5.1991, p. 40-52.

EU, 1991b, Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources, OJ L 375, 31.12.1991, p. 1-8.

EU, 1998, Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption, OJ L 330, 5.12.98, p. 32-54.

EU, 2000, Directive (EC) 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy

EU, 2004, Regulation (EC) No 648/2004 of the European Parliament and of the Council of 31 March 2004 on detergents

EU, 2006a, Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC, OJ L 64, 4.3.2006, p. 37-51.

EU, 2006b, Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC, OJ L 396, 30.12.2006, p. 1-849.

EU, 2007, Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, OJ L 288, 6.11.2007, p. 27-34.

EU, 2008, Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive), OJ L 164, 25.6.2008, p. 19-40.

EU, 2009, Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides

EU, 2018, *Best Available Techniques (BAT) Reference Document for the Management of Waste from Extractive Industries, in accordance with Directive 2006/21/EC*,

FAO, ed., 2002, *International code of conduct on the distribution and use of pesticides: adopted by the hundred and twenty-third session of the FAO Council in November 2002*, Rev. version., Food and Agriculture Organization of the United Nations, Rome.

Grebot, B., Illes, A., Madzharova, G., Scarlat, A., Anderson, N. and Fribourg-Blanc, B., 2019, *Urban Waste Water – Non-Connected Dwellings. Final report-*, Ricardo Energy & Environment, OIEAU.

Grizzetti, B., Lanzanova, D., Liquete, C., Reynaud, A. and Cardoso, A. C., 2016, 'Assessing water ecosystem services for water resource management', *Environmental Science & Policy* 61, pp. 194–203 (https://linkinghub.elsevier.com/retrieve/pii/S1462901116300892) accessed May 22, 2020.

Hasenbein, S., Lawler, S. P., Geist, J. and Connon, R. E., 2016, 'A long-term assessment of pesticide mixture effects on aquatic invertebrate communities: A long-term assessment of pesticide mixture effects', *Environmental Toxicology and Chemistry* 35(1), pp. 218–232 (http://doi.wiley.com/10.1002/etc.3187) accessed August 11, 2020.

Hornung, L. K., Podschun, S. A. and Pusch, M., 2019, 'Linking ecosystem services and measures in river and floodplain management', *Ecosystems and People* 15(1), pp. 214–231 (https://www.tandfonline.com/doi/full/10.1080/26395916.2019.1656287) accessed November 27, 2019.

Ibisch et al., R., 2016, *European assessment of eutrophication abatement measures across land-based sources*, 2/2016, ETC/ICM.

International Commission for water protection of Lake Constance (IGKB), 2014, 'Map of the sewage plants in the catchment area of Lake Constance',

IUCN, 2017, 'Invasive alien species and climate change', (https://www.iucn.org/sites/dev/files/ias_and_climate_change_issues_brief_final.pdf).

Lundin, L., Nilsson, T., Jordan, S., Lode, E. and Strömgren, M., 2017, 'Impacts of rewetting on peat, hydrology and water chemical composition over 15 years in two finished peat extraction areas in Sweden', *Wetlands Ecology and Management* 25(4), pp. 405–419 (https://doi.org/10.1007/s11273-016-9524-9).

Maksymiv, I., 2015, 'PESTICIDES: BENEFITS AND HAZARDS', *Journal of Vasyl Stefanyk Precarpathian National University* 2(1), pp. 70–76 (http://journals.pnu.edu.ua/index.php/jpnu/article/view/507) accessed October 17, 2019.

Mavrommatis, E. and Menegaki, M., 2017, 'Setting rehabilitation priorities for abandoned mines of similar characteristics according to their visual impact: The case of Milos Island, Greece', *Journal of Sustainable Mining* 16(3), pp. 104–113 (https://linkinghub.elsevier.com/retrieve/pii/S2300396017300782) accessed August 18, 2020.

Misselbrook et al., T., 2019, *Field application of organic and inorganic fertilizers and manure. Draft section for a Guidance Document.*, For discussion at the workshop on integrated sustainable nitrogen management, Brussels 30 September – 1 October 2019, UNECE.

Mohaupt, V., Völker, J., Altenburger, R., Birk, S., Kirst, I., Kühnel, D., Küster, E., Semeradova, S., Šubelj, G. and Whalley, C., 2020, *Pesticides in European rivers, lakes and groundwaters – Data assessment*,

Nunes, A., Tricarico, E., Panov, V., Cardoso, A. and Katsanevakis, S., 2015, 'Pathways and gateways of freshwater invasions in Europe', *Aquatic Invasions* 10(4), pp. 359–370 (http://www.aquaticinvasions.net/2015/issue4.html) accessed October 29, 2019.

Ramchunder, S. J., Brown, L. E. and Holden, J., 2012, 'Catchment-scale peatland restoration benefits stream ecosystem biodiversity: *Peatland stream ecosystems*', *Journal of Applied Ecology* 49(1), pp. 182–191 (http://doi.wiley.com/10.1111/j.1365-2664.2011.02075.x) accessed March 26, 2020.

Sarat, E., Mazaubert, E., Dutartre, A., Poulet, N. and Soubeyran, Y., 2015, *Invasive alien species in aquatic environments. Practical information and management insights*, Volume 1.,

Strayer, D. L., 2010, 'Alien species in fresh waters: ecological effects, interactions with other stressors, and prospects for the future', *Freshwater Biology* 55(s1), pp. 152–174 (https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2427.2009.02380.x) accessed October 29, 2019.

Sutherland, W. J., Gardner, T., Bogich, T. L., Bradbury, R. B., Clothier, B., Jonsson, M., Kapos, V., Lane, S. N., Möller, I., Schroeder, M., Spalding, M., Spencer, T., White, P. C. L. and Dicks, L. V., 2014, 'Solution Scanning as a Key Policy Tool: Identifying Management Interventions to Help Maintain and Enhance Regulating Ecosystem Services', *Ecology and Society* 19(2), pp. art3 (http://www.ecologyandsociety.org/vol19/iss2/art3/) accessed May 20, 2020.

Umweltbundesamt, 2012, *Environmental Impacts of Hydraulic Fracturing Related to Exploration and Exploitation of Unconventional Natural Gas Deposits – Short Version*,

UNCCD, 2000, *Land Degradation in Central and Eastern Europe: Proceedings of the Workshop on Land Degradation/Desertification in Central and Eastern Europe in the context of the UNCCD*,

UNEP/OCHA, 2000, *Cyanide spill at Baia Mara, Romania*,

Van den Roovaart, J., van Duijnhoven, N., Fribourg-Blanc, B., Siauve, S. and Prchalova, H., 2017, *Emissions of pollutants to Europe's waters - sources, pathways and trends*, ETC/ICM Technical Report, 3/2017, European Topic Centre on inland, coastal and marine waters, Magdeburg.

Vorne, Virpi, Silvenius, Frans, Česonienė, Laima, Eymontt, Andrzej, Hamunen, Katri, Pachel, K., Räsänen, K., Sinkko, T., Urtāne, L., Vieraankivi, Marja-Liisa and Virtanen, Yrjö, 2019, *A survey of available wastewater treatment technologies for sparsely populated areas, User's manual – Version 2.1*, Natural Resources Institute Finland (Luke).

WRc, 2012, *Task3e – Mining. Final/15761-0*,

Zupo, V., Graber, G., Kamel, S., Plichta, V., Granitzer, S., Gundacker, C. and Wittmann, K. J., 2019, 'Mercury accumulation in freshwater and marine fish from the wild and from aquaculture ponds', *Environmental Pollution* 255, pp. 112975 (https://linkinghub.elsevier.com/retrieve/pii/S0269749119313302) accessed June 16, 2020.

Additional references (not in zotero yet)

Chapter 2

EC, 2010, Europe 2020 — A strategy for smart, sustainable and inclusive growth. Communication from the Commission COM(2010) 2020. (http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-20Europe%202020%20-%20EN%20version.pdf) accessed 7 June 2018.

EC, 2012 , 'EU Biodiversity strategy to 2020 — Towards implementation' http://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm) accessed 30 March 2018.

EC, 2014, 'Environment Action Programme to 2020' (http://ec.europa.eu/environment/action-programme/) accessed 12 February 2018.

EC, 2015, Ecological flows in the implementation of the Water Framework Directive. Common Implementation Strategy for the Water Framework Directive (2000/60/EC), Guidance Document No 31 — Ecological flows in the implementation of the Water Framework Directive. Technical Report, WFD Common Implementation Strategy (http://ec.europa.eu/environment/water/water-framework/facts_figures/guidance_docs_en.htm) accessed 12 February 2018.

EC, 2019a, Report from the Commission to the European Parliament and the Council on the implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC) Second River Basin Management Plans First Flood Risk Management Plans. COM(2019) 95 final. https://eur-lex.europa.eu/resource.html?uri=cellar:bee2c9d9-39d2-11e9-8d04-01aa75ed71a1.0005.02/DOC_1&format=PDF

EC, 2019b, Commission Staff Working Document European Overview - River Basin Management Plans. Accompanying the document the Report from the Commission to the European Parliament and the Council on the implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC) Second River Basin Management Plans First Flood Risk Management Plans. SWD(2019) 30 final. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=SWD:2019:30:FIN&qid=1551267381862&from=EN

EEA, 2018, European waters – assessment of status and pressures 2018. EEA report No 7/2018 https://www.eea.europa.eu/publications/state-of-water

EEA, 2019 'Nutrients in freshwater (CSI 020)', European Environment Agency (https://www.eea.europa.eu/data-and-maps/indicators/nutrients-in-freshwater/nutrients-in-freshwater-assessment-published-9) accessed 12 June 2020.

Hymo Introduction

Brils, J., 2008, Sediment monitoring and the European Water Framework Directive, Annali dell' Istituto superiore di sanitá 2008 | Vol. 44, no. 3: 218-223.

Dworak, T. & Kampa, E. (2019). Workshop on hydro-morphological measures under the Floods and Water Framework Directives "Finding synergies and addressing challenges" Background paper with conclusions from the workshop 4-5 December 2018, Budapest, Hungary.

EC, 2019, CSWD European Overview - River Basin Management Plans.

EEA, 2018, European waters, Assessment of status and pressures 2018, EEA Report No 7/2018.

EEA, 2019, Floodplains: a natural system to preserve and restore, EEA Report No 24/20191994.

England, J. & Burgess-Gamble, L, 2013, Evidence: Impacts of dredging, Environment Agency, accessed online 9/6/2020: http://www.ecrr.org/Portals/27/Evidence%20-%20impacts%20of%20dredging%20-%20August%2013.pdf

Kondolf et al, 2014, Sustainable Sediment Management in Reservoirs and Regulated Rivers: Experiences from Five Continents, Earth's Future, May 2014.

SedNet, 2014, https://sednet.org/download/Moving-Sediment-Management-Forward.pdf

SedNet, 2017, https://sednet.org/work/policy-brief/

Barriers

Birnie-Gauvin, K. et al., (2017), 'Adaptive management in the context of barriers in European freshwater ecosystems', Journal of Environmental Management, 204, Part 1, Pages 436-441.

BMLFUW, 2017, Nationaler Gewässerbewirtschaftungsplan 2015, BMLFUW.

Brink, K., P. Gough, J. Royte, P.P. Schollema & H. Wanningen, 2018, From Sea to Source 2.0. Protection and restoration of fish migration in rivers worldwide. World Fish Migration Foundation.

EEA, 2018, European waters – assessment of status and pressures 2018, EEA Report, No 7/2018.

EC, 2020, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, EU Biodiversity Strategy for 2030, Bringing nature back into our lives, COM(2020) 380 final.

Freshwater Information System, 2019, 'Dams, barriers and locks' (http://fis.freshwatertools.eu/index.php/infolib/pressures/dams-barriers.html) accessed 25 July 2019.

Garcia de Leaniz, C. et al., 2019, Beware small dams as well as large, Nature, vol. 570.

Garrido, P.F., 2018b, Dam removal and dam management in Europe, Policy and cases examples, barrier database AMBER and background of Dam Removal Europe.

Gough, P., Fernández Garrido, P., Van Herk, J., 2018, Dam Removal. A viable solution for the future of our European rivers. Dam Removal Europe.

Jones, J. et al., 2019, A comprehensive assessment of stream fragmentation in Great Britain, Science of the Total Environment 673 (2019) 756–762.

Kampa, E., Tarpey, J., Rouillard, J., Bakken, T.H., Stein, U., Godinho, F.N., Leitão, A.E., Portela, M.M., Courret, D., Sanz-Ronda, F.J., Boes, R., Odelberg, A., 2017, Review of policy requirements and financing instruments, Deliverable 5.1 FIThydro project.

Ollikainen, H. & Vilhunen, S., 2019, The largest dam removal in Finland, River Hiitolanjoki, paving the way for new era in river restoration, International congress on ecological continuity, 24-26 September 2019, Rennes, Avranches.

Shepherd, K, 2012, One river: finding continuity for habitats, Danube Watch, 3/2012.

Loss of lateral connectivity

Amoros C. & Roux A.L. (1988) Interaction between water bodies within the floodplain of large rivers: function and development of connectivity. Münstersche Geographische Arbeiten 29: 125–130.

EEA, 2012, Cause of loss of wetlands, accessed on 9/6/2020: https://www.eea.europa.eu/data-and-maps/figures/cause-of-loss-of-wetlands

EEA, 2018. European waters – assessment of status and pressures 2018. EEA Report No 7/2018.

EEA, 2019. Floodplains: a natural system to preserve and restore. EEA Report No 24/20191994.

EEA, 2016, Flood risks and environmental vulnerability - Exploring the synergies between floodplain restoration, water policies and thematic policies. In EEA Report No 1/2016. https://doi.org/10.2800/039463

Franzén, F., Dinnétz, P. & Hammer, M. (2016) Factors affecting farmers' willingness to participate in eutrophication mitigation — A case study of preferences for wetland creation in Sweden. Ecological Economics. 130: 8–15 DOI:10.1016/j. landusepol.2015.02.007
Cited in: Science for Environment Policy (2017) Agri-environmental schemes: how to enhance the agriculture-environment relationship. Thematic Issue 57. Issue produced for the European Commission DG Environment by the Science Communication Unit, UWE, Bristol. Available at: http://ec.europa.eu/science-environment-policy.

Junk, W.J., P.B. Bayley, R.E. Sparks, 1989. The flood pulse concept in river-floodplain systems. Canadian Journal of Fisheries and Aquatic Sciences 106: 110–127.

Junk, W.J., Wantzen, K.M., 2004. The flood pulse concept: new aspects, approaches and applications–an update, in: Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries. pp. 117–140.

ICPR, 2015, The international river basin district Rhine (IRBD Rhine), 2nd RBMP from International Commission for the Protection of the Rhine (https://www.iksr.org/fileadmin/user_upload/Dokumente_en/Brochures/CMP_2015_-_en.pdf).

Rinaldi M, Surian N, Comiti F, Bussettini M (2016). IDRAIM - Sistema di valutazione idromorfologica, analisi e monitoraggio dei corsi d'acqua. ISPRA, Manuali e Linee Guida 131/2016, gennaio 2016, p 262. ISBN: 978-88-448-0756 -6. Available online: http://www.isprambiente.gov.it/en/publications/handbooks-and-guidelines/idraimsystem-for-stream-hydromorphological-assessment-analysis-and-monitoring-editionupdated-to-2016?set_language=en

Swedish Board for Agriculture & Swedish Agency for Marine and Water Management, 2015, Nationell strategi för prioritering av vatten-åtgärder inom jordbruket, Dialogprojekt Havs- och vattenmyndigheten – Jordbruksverket, Havs- och vattenmyndighetens rapport 2015:10, https://www.havochvatten.se/hav/uppdrag--kontakt/publikationer/publikationer/2015-05-25-nationell-strategi-for-prioritering-av-vattenatgarder-inom-jordbruket.html

Vartia K, Beekman J, Alves M, van de Bund W, Bussettini M, Döbbelt-Grüne S, Halleraker J H, Karottki I, Kling J, Wallentin J, Rouillard, J & Kampa, E, 2018. WG ECOSTAT report on common understanding of using mitigation measures for reaching Good Ecological Potential for Heavily Modified Water Bodies – Part 3: Impacted by drainage schemes, EUR 29132 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-80305-5, doi:10.2760/444293, JRC110959. Available at: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC110959/jrc110959_jrc110959_final_online.pdf

Hydropower

Bussettini, M. 2019, Essentials for planning successful improvement of environmental values while securing the benefits of hydropower production, Presentation at Sustainable hydropower strategic planning, measures and governance meeting, Storforsen, Vidsel, June 12-14, 2019.

Devoldere, K., Adriaensens, V., Redeker, M., Dumont, U., Anderer, P., 2011 Hydropower Generation in the context of the EU WFD, Report to EC DG Environment, Contract no 070307/2010/574390.

Eurelectric & VGB Powertech, 2018, Facts of Hydropower in the EU.

Eurostat, 2019, Energy, transport and environment statistics 2019 edition, Statistical Books.

Fyfe, R., 2019. Hydropower in Scotland - A Regulator's Perspective, Presentation at Sustainable hydropower strategic planning, measures and governance meeting, Storforsen, Vidsel, June 12-14, 2019.

ICPDR, 2013, *Sustainable Hydropower Development in the Danube Basin: Guiding Principles*, Vienna.

Kampa, E., von der Weppen, J., Dworak, T., 2011, Water management, Water Framework Directive & Hydropower, Issue Paper, Common Implementation Strategy Workshop 2011, Brussels.

Kampa et al, 2017, FIThydro Deliverable 5.1 Review of policy requirements and financing instruments

Kampa , E., Berg, L. (edit.), 2020: Fish-friendly Innovative Technologies for Hydropower. Key outputs from the FIThydro project. Policy Brief.

SWAM (Swedish Agency for Marine and Water Management), 2019, Towards sustainable hydropower in Sweden, accessed 18 August 2020, https://www.havochvatten.se/en/swam/eu--international/towards-sustainable-hydropower-in-sweden.html

WWF, 2019. Hydropower pressure on European. The story in numbers.

Navigation

BMUB/UBA, 2016, Water Framework Directive – The status of German waters 2015. Bonn, Dessau.

DG Mobility and Transport, 2019, 'Inland waterways. What do we want to achieve ?' (https://ec.europa.eu/transport/modes/inland_en) accessed 8 August 2019.

EC, 2011, White Paper "European Transport Policy for 2010: Time to Decide, COM(2001) 370 final.

EC, 2018, Guidance on Inland waterway transport and Natura 2000. Sustainable inland waterway development and management in the context of the EU Birds and Habitats Directives.

ECMT (European Conference of Ministers of Transport), 2006, Inland waterways & environmental protection, OECD publications.

EPRS (European Parliamentary Research Service), 2014, Inland waterways in the EU, Briefing 29/01/2014.

Eurostat, 2019, Freight transport statistics, accessed 1st November 2019: https://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics

Graf, W. et al., 2016, Deliverable 5-C: Report on legacy and tipping points in large rivers, MARS Project.

ICPDR, 2007, Development of Inland Navigation and Environmental Protection in the Danube River Basin, Joint Statement on Guiding Principles.

ICPDR, 2019, 'Navigation' , (https://www.icpdr.org/main/issues/navigation) accessed 2 August 2018.

ICPR, 2015, Internationally Coordinated Management Plan 2015 for the International River Basin District of the Rhine, (Part A = Overriding Part), December 2015.

ICPR, 2019. Internationaler Warn- und Alarmplan Rhein: Meldungen 2018, ICPR.

PIANC, ESPO, EFIP, CEDA, INE and IADC, 2004, Implications of the EU Water Framework Directive for Ports, Harbours, Commercial and Leisure Navigation, and Dredging, Position Paper – April 2004.

Abstractions and water scarcity

Deloitte (2015). Optimising water reuse in the EU—final report prepared for the European Commission (DG ENV), part I. In collaboration with ICF and Cranfield University

EC (European Commission) (2019) COMMISSION STAFF WORKING DOCUMENT European Overview - River Basin Management Plans, 26.02.2019

EC (European Commission) (2007) Drought Management Plan Report. Including Agricultural, Drought Indicators and Climate Change Aspects. Technical Report 2008 – 23.

EEA (European Environment Agency) (2009): Current water stress in European river basins (year 2000) and under the LREM-E scenario by 2030. https://www.eea.europa.eu/data-and-maps/figures/water-stress-in-europe-2000-and-2030.

EEA (European Environment Agency) forthcoming: Water Resources across Europe Confronting Water Scarcity and Drought-II. Annotated Contents for the 2021 report.

Dige, G. et al. (2017): Pricing and non-pricing measures for managing water demand in Europe. Service Contract No 3415/B2015/EEA.56130 for the European
Environment Agency.

European Environment Agency (2019a) Water use and environmental pressures. https://www.eea.europa.eu/themes/water/european-waters/water-use-and-environmental-pressures/water-use-and-environmental-pressures#toc-0

European Environment Agency (2019b) Freshwater abstraction in Europe by source, 2017. https://www.eea.europa.eu/data-and-maps/daviz/annual-and-seasonal-water-abstraction-6#tab-dashboard-02

European Environment Agency (2018a) European waters. Assessment of status and pressures 2018. EEA Report No 7/2018

European Environment Agency (2018b) 2018 Water Assessment. Pressures and impacts Database.
https://www.eea.europa.eu/themes/water/european-waters/water-quality-and-water assessment/water-assessments/pressures-and-impacts-of-water-bodies

European Environment Agency (2018c) Impacts due to over-abstraction. https://www.eea.europa.eu/archived/archived-content-water-topic/water-resources/impacts-due-to-over-abstraction

Franklin, P. et al. (2008) Flow controls on lowland river macrophytes: A review. Science of the Total Environment. doi:10.1016/j.scitotenv.2008.06.018

Kampragou, E. at al. (2011) Towards the harmonization of water-related policies for managing drought risks across EU, Environmental Science & Policy 14, 815-824

Old, G.H. and Acreman, M.C. (2006) Guidance on Compensation Flows and Freshets Task 3: Literature Review. SNIFFER Project WFD82 report.

Ross, A. (2016) Groundwater Governance in Australia, the European Union and the Western USA. In: Jakeman A.J., Barreteau O., Hunt R.J., Rinau- do JD., Ross A. (eds) Integrated Groundwater Management.

Sanchez, A. et al. (2016) Effects of water scarcity and chemical pollution in aquatic ecosystems State of the art, Science of the Total Environment 572, 390-403

Stein, U. et al. (2016) European Drought and Water Scarcity Policies. In: Governance for Drought Resilience. Springer International Publishing: 17-43.

Stein, U. et al. (2020) Actors in the European Union related to WS&D policy. In: Facing Hydrometeorological Extreme Events: A Governance Issue, First Edition. John Wiley & Sons Ltd. Published: 161-170.

Trémolet S. et al. (2019). Investing in Nature for Europe Water Security. The Nature Conservancy, Ecologic Institute and ICLEI. London, United Kingdom.

Vanham, D. (2018) The water footprint of the EU: quantification, sustainability and relevance, Water International, 43:6, 731-745

Aquaculture

European Commission, 2016, *Commission Staff Working Document. On the Application of the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) in Relation to Aquaculture.*

Eurostat, 2019, *Agriculture, forestry and fishery statistics — 2019 edition*.

European Commission, 2012, Aquaculture Techniques, https://ec.europa.eu/fisheries/sites/fisheries/files/docs/body/2012-aquaculture-techniques_en.pdf , Accessed: 9 March 2020.

EC, European Commission, 2015, Facts and figures on EU aquaculture production and consumption in an EU and global context, available: https://ec.europa.eu/fisheries/sites/fisheries/files/docs/body/2015-aquaculture-facts_en.pdf

EC, European Commission (2015b) Science For Environment Policy – FUTURE BRIEF: Sustainable aquaculture, May 2015 Issue 11

European Commission, n.d., Aquaculture Methods. https://ec.europa.eu/fisheries/cfp/aquaculture/aquaculture_methods_en , Accessed: 9 March 2020.

European Environment Agency, 2018, *Aquaculture Production*, https://www.eea.europa.eu/data-and-maps/indicators/aquaculture-production-4/assessment , Accessed: 22 January 2020.

Guillen, J., Asche, F., Carvalho, N., Fernández Polanco, J. M., Llorenze, I., Nielsen, R., Nielsen, M., Villasante, S., 2019, Aquaculture subsidies in the European Union: Evolution, impact and future potential for growth, *Marine Policy 104*, 19-28.

Jeffery, K.R., Vivian, C.M.G., Painting, S.J., Hyder, K., Verner-Jeffreys, D.W., Walker, R.J., Ellis, T., Rae, L.J., Judd, A.D., Collingridge, K.A., Arkell, S., Kershaw, S.R., Kirby, D.R., Watts, S., Kershaw, P.J., and Auchterlonie, N.A., 2014, *Background information for sustainable aquaculture development, addressing environmental protection in particular. Part 1 Main Report & References*. Cefas Contract Report <C6078>.

Peeler, E. J., Oidtmann, B. C., Midtlyng, P. J., Miossec, L., & Gozlan, R. E.. 2011, Non-native aquatic animals introductions have driven disease emergence in Europe. *Biological Invasions*, *13*(6), 1291-1303.

Phillips, M.J., Boyd, C. & Edwards, P. 2001, *Systems approach to aquaculture management.* In: R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery, Arthur, J. R. eds. Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. 239-247. NACA, Bangkok and FAO, Rome.

Science for Environment Policy, 2015, *Sustainable Aquaculture.* Future Brief 11. Brief produced for the European Commission DG Environment by the Science Communication Unit, UWE, Bristol.

<u>Integrated solutions – Introduction</u>

EC, 2019. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=SWD:2019:30:FIN&qid=1551267381862&from=EN

<u>Integrated solutions – 4.3 sectoral strategies</u>

EEA State of Water Report 2018

EU (2018) Best Available Techniques (BAT) Reference Document for the Management of Waste from Extractive Industries, in accordance with Directive 2006/21/EC,

NAPAN (NAPAN Task Force), 2014, Belgian action plan to reduce the risks and impacts linked to Pesticides, 2013-2017.

Rouillard et al., 2016

Scottish Salmon Producers' Organisation (2020): Code of Good Practice. Available online at: https://www.scottishsalmon.co.uk/code-of-good-practice accessed 30th April 2020.

Thorén, A.-K. (2017) Reducing pesticide residues in ground- and surface waters. A comparison of measures and instruments used in Belgium Flandern, England, Ireland, Netherlands, Scotland and Sweden, 2016/13, European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL).

UNEP (2012) Aquaculture and sustainable management in Mediterranean coastal wetlands: case study of Doñana marshes (Andalucia, Spain), available at https://www.rac-spa.org/sites/default/files/doc_fish/guidelines_wetland_2012.pdf

Willaarts, B.A. et al. (2020) Cross-sectoral implications of the implementation of irrigation water use efficiency policies in Spain: A nexus footprint approach, Ecological Indicators 109

Amery, F. and Schoumans, O. F. ,2014, Agricultural phosphorus legislation in Europe, ILVO, Merelbeke (http://pure.ilvo.vlaanderen.be/portal/files/2640562/Phosphorus_legislation_Europe.pdf) accessed 24th July 2020.

Integrated solutions – 4.4 Funding

AMBER, undated, Small barriers in Denmark and the UK, accessed 20 June 2020, https://amber.international/portfolio-item/removal-of-small-in-river-barriers-in-denmark-and-northern-england/

Carvalho et al., 2019, https://www.sciencedirect.com/science/article/pii/S004896971835126X

Danish Fisheries Agency, 2020, Welcome to the Fishing Licence System, accessed on 6 August 2020, link: https://www.fisketegn.dk/fisketegn/common/setLocale.do?language=en

EC, 2013, Overview of CAP Reform 2014-2020, Agricultural Policy Perspectives Brief N°5* / December 2013.

EC, 2018, European Commission Communication from the Commission: action plan: financing sustainable growth. COM/2018/097 final https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0097 (2018), Accessed 5th Aug 2018

EC, 2019, A European Overview – Commission Staff Working Documents on the WFD Programmes of Measures

EC, 2020, EU Biodiversity Strategy for 2030, Bringing nature back into our lives.

EC, 2020, Consultation on the renewed sustainable finance strategy, accessed 20 June 2020, https://ec.europa.eu/info/consultations/finance-2020-sustainable-finance-strategy_en

EEA, 2016, Rivers and lakes in European cities: Past and future challenges. EEA report, No 26/2016.
OECD (2020), Financing Water Supply, Sanitation and Flood Protection: Challenges in EU Member States and Policy Options, OECD Studies on Water, OECD Publishing, Paris.

O Grady et al, 2013, Environmental River Enhancement Programme 2008 – 2012 Final Report, June 2013, online: https://www.researchgate.net/publication/304673951_Environmental_River_Enhancement_Programme_2008_-_2012_Final_Report

SWAM (Swedish Agency for Marine and Water Management), 2019, Towards sustainable hydropower in Sweden, accessed 20 June 2020, https://www.havochvatten.se/en/swam/eu--international/towards-sustainable-hydropower-in-sweden.html

Trémolet S. et al. (2019). Investing in Nature for Europe Water Security. The Nature Conservancy, Ecologic Institute and ICLEI. London, United Kingdom.

Vehanen et al., 2015, Finland's National Fish Passage Strategy: From Fish Stocking to Fishways, accessed 20 June 2020, https://scholarworks.umass.edu/fishpassage_conference/2015/June22/74/

Annex 1 (repeat sequentially for subsequent annexes)

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